

# CERES Visualization SSF Plot Generator

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## **Abstract**

The first Clouds and the Earth's Radiant Energy System (CERES) instrument will be launched in 1997 to collect data on the Earth's radiation budget. The data retrieved from the satellite will be processed through twelve subsystems. The SSF (Single Satellite Footprint) Plot Generator software was written to assist scientists in the early stages of CERES data analysis, producing two-dimensional plots of the footprint radiation and cloud data generated by one of the subsystems. Until the satellite is launched, however, software developers need verification tools to check their code. This plot generator will aid programmers by geolocating algorithm results on a global map.

## **Introduction**

Interest in the radiation levels of the Earth's atmosphere goes back to the 1960's when the first instruments aboard satellites measured Earth's radiation budget. Recently, the greenhouse effect and global warming has brought much attention to the way the atmosphere absorbs and reflects visible and invisible wavelengths. In the 1980's, the Earth Radiation Budget Experiment (ERBE) was launched to better understand the radiation budget. In 1997, the first Clouds and the Earth's Radiant Energy System (CERES) will be launched to continue the ERBE data collecting, but also expand to increase our knowledge of our atmosphere.

The purpose of this paper is to give the background behind the development of the SSF Plot Generator, software created for CERES software developers and scientists.

## **The Earth Radiation Budget Experiment**

The Earth Radiation Budget Experiment (ERBE) began observing the Earth in 1984. The three satellites in the experiment each had aboard them two instruments, a scanner and a nonscanner, to measure the monthly average radiation budget for regional, zonal and global scales; equator-to-pole transport gradient; and the monthly average diurnal variation in radiation budget on a regional scale.

The scanner instrument has three detectors to measure different wavelengths: shortwave (0.2 to 5 $\mu$ m), longwave (5 to 200 $\mu$ m) and total waveband (0.2 to 200 $\mu$ m). The scanner has a sweeping motion, swinging side to side, recording data for the field of view at which the detectors are pointed. The nonscanner produces one channel of solar data, and four channels of earth-viewing data. It has no moving parts, collecting data only in the field of view underneath it and continues to send back data today.

The ERBE data has been archived on magnetic tapes. The Processed Archival Tape S-8 consists of four files: the header, the test record, the scale factor and offset record, and the data record. The header serves as an identifier, storing information regarding date, time, satellite, and orbit number. The test record is included as a check for those using the data. S-8 data is stored in a packed format of integer values which are unpacked using the scale factors and offsets. The unpacked test record values are printed in ERBE S-8 User's Guides to verify the unpacking algorithm. For every S-8 variable, there is a unique scaling factor and offset. The data record contains the actual integer values recorded by the instrument on the satellite.

## **The Clouds and the Earth's Radiant Energy System**

Planned for launch aboard the Tropical Rainfall Measuring Mission (TRMM) in August 1997 and the EOS-AM and EOS-PM in the following years, CERES plans to continue ERBE's mission of tracking the earth radiation budget. CERES will also provide estimates for surface radiation, radiative fluxes within the atmosphere, and cloud properties. As of now, the role of clouds within the atmosphere is unknown. CERES will be able to identify cloud amount, height, optical depth and cloud particle size and phase. Learning more about clouds will help scientists in determining how clouds affect earth's radiation budget.

CERES is a scanner similar to the instrument on ERBE. Modifications were made to improve the data, including smaller field of views, better electronics to reduce the offsets, and the replacement of the longwave channel with a window channel (8 to 12 $\mu$ m). CERES also has the capability of operating in a rotating azimuth plane scan (RAPS); instead of collecting all parallel scans, the scanner rotates, collecting data in an asterisk pattern, viewing a more diverse region of the hemisphere.

Since the instrument has not been launched, no CERES data products exist yet. Eventually, the data will be stored in a number of different data products, each having its own use and method of derivation. Subsystem 4, the subsystem of concern in this paper, produces a Single Satellite Footprint (SSF) data product. One SSF footprint contains an array of surface fluxes, top of the atmosphere fluxes and clouds property data. An SSF file stores one hour's worth of footprints, approximately 245,000 footprints, depending on the operational mode and the number of earth viewing footprints with associated imager data.

## **The ERBE Plot Generator**

In 1992, Joseph Henderson, a LARSS student, created software to plot the ERBE S-8 data on a cylindrical world map. Used to visualize the data, it could plot various types of radiometric data, particular orbits, and data from various times of the day. The plots served as a verification tool for the scientists. Henderson's Fortran 77 code used NCAR Graphics, plotting software developed by the National Center for Atmospheric Research.

The original code, however, could only read ERBE data with separate header and data files, one called 'header', the other named 'erbe'. This program was modified so it would read any S-8 file without separating the header and data.

## **The SSF Data File Generator**

In developing software to plot an SSF data file, an SSF data file was necessary to test the algorithm. Since both the ERBE and CERES missions have basic similarities, their data products include much of the same information, merely in different formats. S-8 data could be used to simulate the SSF. Sandy Nolan, a NASA contractor at IESC, had written a program to stuff the test record of a headerless S-8 into an SSF format. (Software is available to remove the header.) However, the test record contains no scientific data and would not be useful to those wanting to test code.

Modifications were made to Nolan's algorithm so a useful product could be created. The program converts a user specified headerless S-8 file into files of SSF format. One S-8 file can produce a maximum of 24 SSF files; the user specifies how many hours to create.

## The Obstacles

Fortran 90 is the preferred language on the CERES project; many commonly used routines had already been written with F90, running on the machines *nimbus*, *asdsun*, and *bobill*. However, it still is a young language and the compiler had not been thoroughly tested. Linking a Fortran 90 main program with NCAR functions written in Fortran 77 was a task nobody had attempted before. Theoretically, there should not have been a problem; F90 should have been able to handle the F77 code and calls. However, the loader failed because it could not link to the appropriate libraries. Other flaws found were: the current compiler is not capable of making system calls and it does not find standard libraries during compilation. The system administrators are still working on a solution.

While Fortran 90 was being investigated, it was decided to work with C instead. Small test programs were written to test parameter passing from C programs to Fortran 77 subroutines. However, a sample program making two NCAR calls had linking problems also. After the linking problem was solved, there was still a problem with the versions of C and Fortran. It was discovered that the same versions of the compilers need to be running for the languages to be compatible. Once *bobill* was upgraded to the newer C compiler, the Fortran and C could communicate.

Reverting back to Fortran 77 because of the linking problems, it was discovered that the original S-8 Plot Generator would no longer compile. No changes had been made to this file; the problem was unexpected. After searching through the original files, another NCAR directory was found.

On *nimbus*, NCAR exists in three locations:

- /opt/optional/ncar3.2/bin - The scripts in this directory, supposedly the latest version of NCAR, do not call the appropriate libraries. Compiling Fortran 77 results in an undefined symbol warning.
- /opt/optional/ncar/bin - These scripts result in another list of undefined symbols, although not as long. This is assumed to be NCAR 2.0 because it doesn't support some of the newly documented calls.
- /opt/optional/nbin - The working version of NCAR. It is evidently version 3.2 because of the calls it supports. Fortran 77 files compile and run.

On *asdsun*, NCAR is located in two places:

- /opt/optional/ncar - The scripts call libraries in /usr/local/ncar/lib. The programs compile and execute but crash because it is an old version of NCAR.
- /opt/optional/nbin - The libraries it calls are in /usr/local/lib. Code will compile and execute, but again, the NCAR is an old version.

Using the /opt/optional/nbin/ncargf77 script on *nimbus* or any machine mounted to *nimbus*, both the S-8 Plot Generator and the modified SSF Plot Generator compiled and ran.

The C code looks as if it will run. The sample program making NCAR calls runs using /opt/optional/nbin/ncargcc but the main plotting code was never debugged enough to compile and link.

Within the working NCAR directory, no Fortran 90 script exists. It should be possible to modify the Fortran 77 script to include the necessary F90 libraries and F77 libraries.

## The SSF Plot Generator

The current SSF Plot Generator prompts the user for:

- plot type - which SSF variable to plot
- cloud level - cloud data will have a level associated with it
- hours of data - the number of filenames the user will be inputting
- filenames of the SSF files - maximum of 24 since they come in hourly blocks and more would result in overlapping data
- day/night preference - when the time of day is of concern
- output destination - write to screen, printer, or file.

After opening the one hour SSF file, the SSF Plot Generator reads the user-specified data for one footprint, assigns a color to the pixel at that particular latitude and longitude, and repeats the procedure for each footprint in the hour. The procedure repeats for any other hours given, and places the final array on a cylindrical world map. The software was tested with SSFs created with two different methods and with two hours at a time. Because an S-8 was used to produce the SSF, the plots look identical using the S-8 plot generator and the SSF plot generator. Verification is possible by merely comparing the S-8 and SSF plots.

A comparison of Figures 1 and 2 show the SSF is created correctly. The SSF and S-8 plots are identical except for the amount of data shown. The S-8 Plot Generator plots orbits which are about ninety minutes long; Figure 1 is three orbits. SSFs are developed in hourly products; Figure 2 is two hours long.

The SSF Plot Generator has the capability of plotting up to 24 SSFs as requested by the user. The hours need not be consecutive but the data products must be entered sequentially for the begin and end times on the plot header to be correct. Figure 2 illustrates two hours of data; Figures 3 and 4 are each one hour long.

The plot generator distinguishes between night and day by the solar zenith angle, the location of the sun with respect to the satellite. The amount of sunlight affects the readings for shortwave and longwave radiation; shortwave only occurs during the day. Figure 5 has noticeable radiation data; Figure 6 has no radiation because of night wavelengths. By distinguishing between night and day, scientists have a simple check on the data.

The S-8 contains no cloud data, an important aspect of the CERES project. Chuck McKinley of SAIC created another SSF with only 140 footprints but containing cloud data. Three Imager Radiation options were added to the plot generator and tested with this SSF. Figure 7 is the whole plot from the short SSF; Figure 8 shows the details of Figure 7. The 140 footprints are located over the North Pacific.

## The Applications

Currently, the software is being used as a verification tool. The other programmers on the project need to be sure their code is working. The ability to view the plotted data helps them analyze what their programs may or may not be doing.

When the first CERES data products are produced from CERES, scientists will quickly need to verify the data looks similar to the expected results. This plotting software will allow them to immediately view the product.

The modified original program which reads any S-8 file is saved on *bobill* in *jbarsi/ceres\_ssf/plot\_s8/read\_any\_s8*. The recompile command is 'recompile\_mod' and the execute command is 's8erbep1'.

The software to remove the header of the S-8 is located on *bobill* in *jbarsi/ceres\_ssf/make\_ssf/removeheader*. To compile, execute 'write\_s8.exe' and supply the program with the filename of an S-8 file. The headerless S-8 will be stored as the same filename, with the 'new\_' prefix added to the name.

The code to convert S-8s to SSFs is available on *bobill* in *jbarsi/ceres\_ssf/make\_ssf*. To compile, execute the Makefile. The executable, 'fill\_ssf.exe', will ask for the headerless S-8 filename and a filename for the initial SSF. The SSF filenames will each be appended with its hour number.

The SSF Plot Generator software, on *bobill*, is in the directory *jbarsi/ceres\_ssf/plot\_ssf*. There are two versions of the *ssf\_user* file - 'ssf\_user.f' and 'ssf\_user2.f'. The file 'ssf\_user.f' has the data ranges for true SSF data, as specified by the SSF definition, while 'ssf\_user2.f' contains the data ranges for the S-8 file. The compile line, 'ssf\_compile', will need to be edited when using a real SSF file. To execute, run 'ssf\_plot'.

## Acknowledgments

I would like to thank my mentor Chris Currey and Erika Geier for supporting all my questions and Jim Kibler and Marsha Sherland for attempting to solve the impossible.

## References

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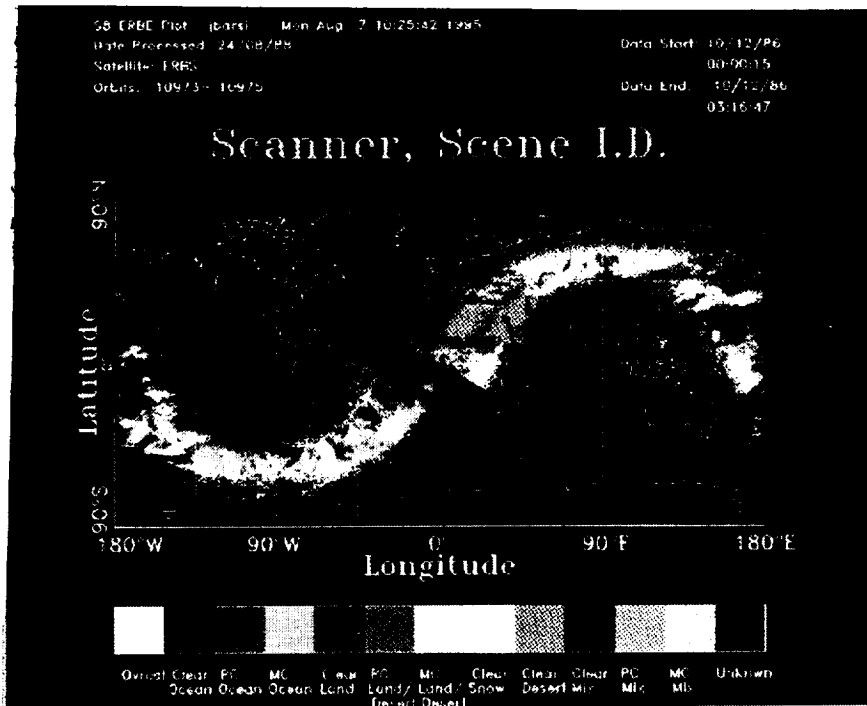


Figure 1. ERBE S-8 Plot of Scene Identification

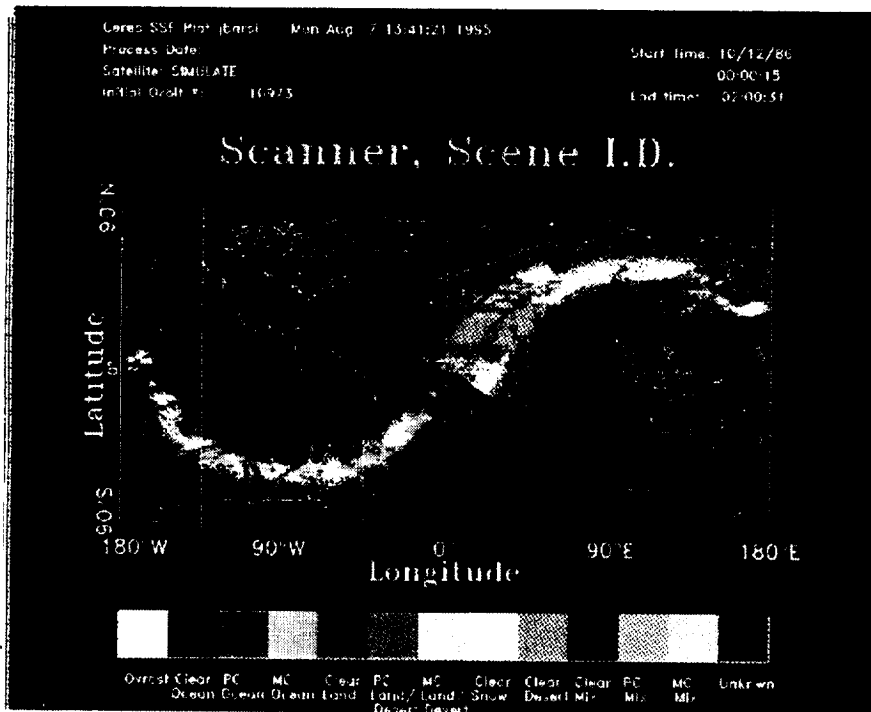


Figure 2. CERES SSF Plot of Scene Identification

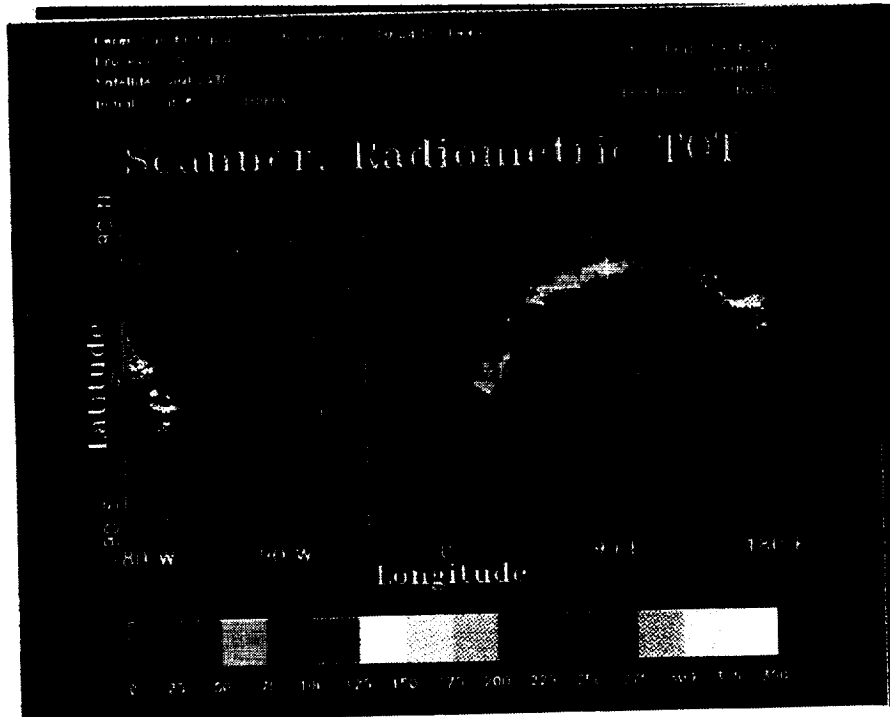


Figure 3. CERES SSF Plot of Radiometric Total Channel for the first hour of data.

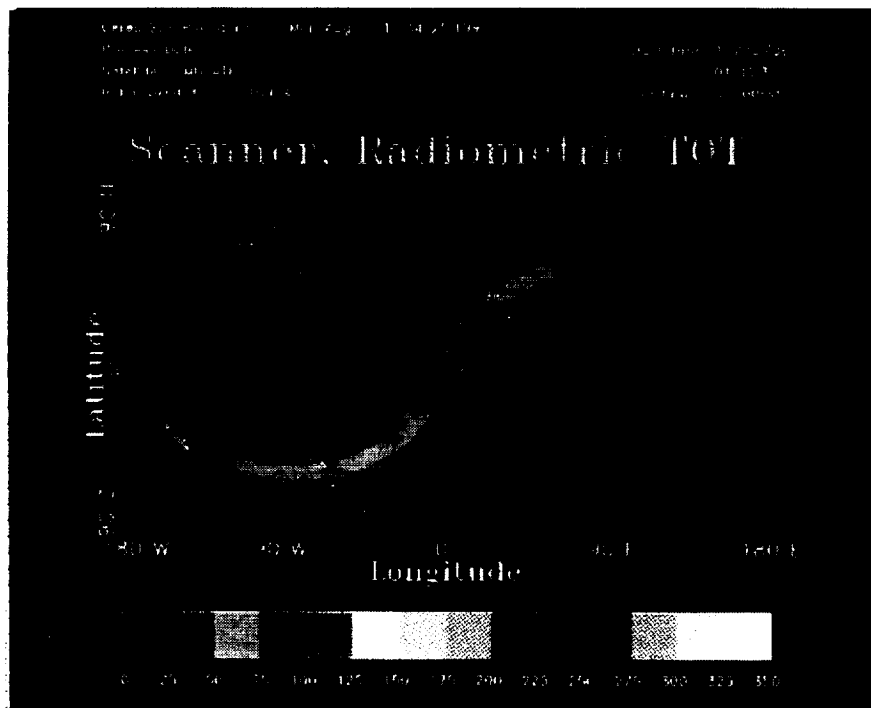


Figure 4. CERES SSF Plot of Radiometric Total Channel for the second hour of data.



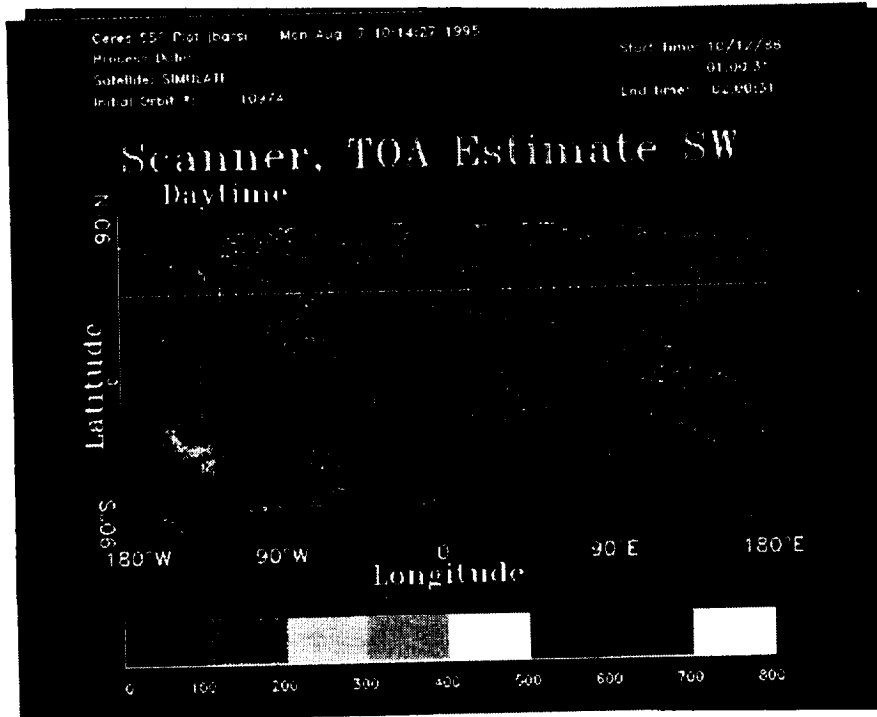


Figure 5. CERES SSF Plot of Top of the Atmosphere Flux for daytime data.

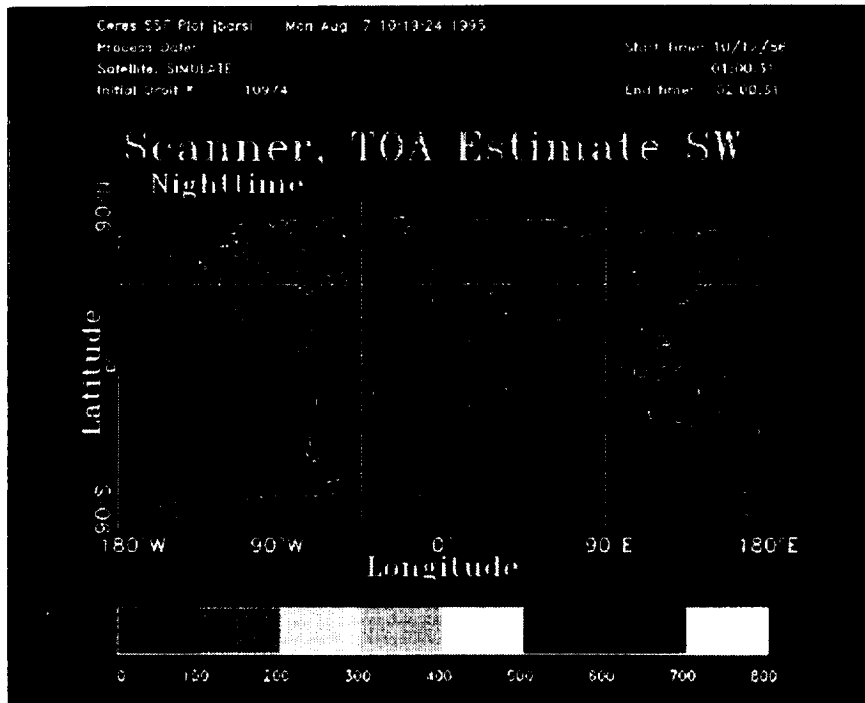


Figure 6. CERES SSF Plot of Top of Atmosphere Flux for nighttime data.

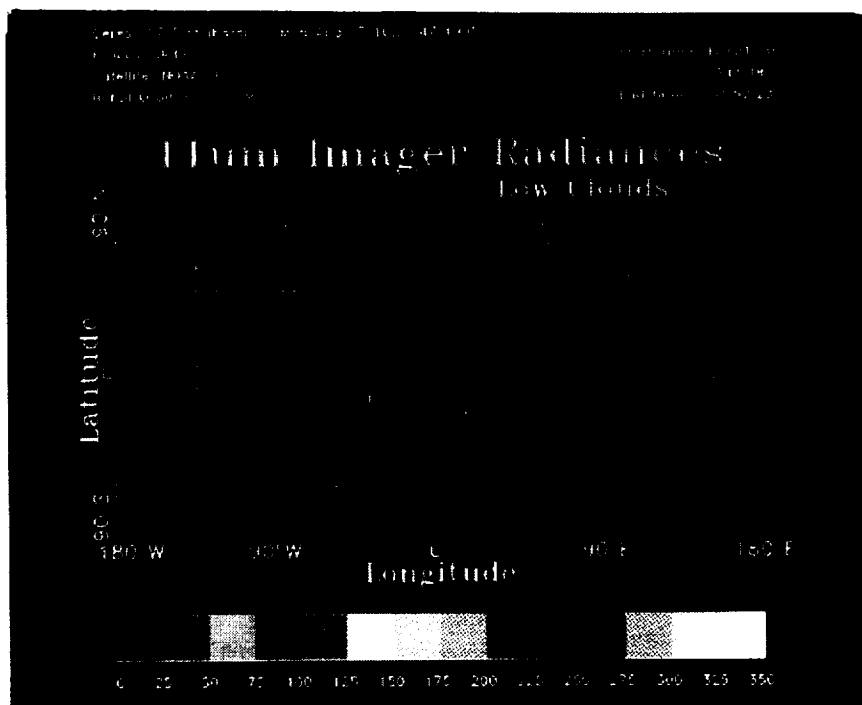


Figure 7. CERES SSF Plot of Imager Radiances at 11um.

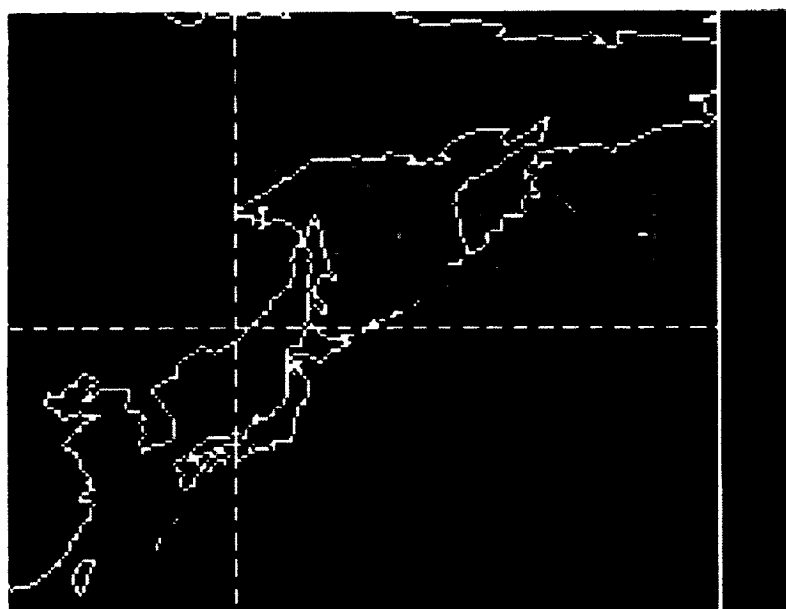


Figure 8. Detail of Figure 7. Data located over east Asia.