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AIRCRAFT SENSOR ANALYSIS  
PACKAGE SYSTEM DESCRIPTION

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Greenbelt, Maryland

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## ABSTRACT

This document presents an overview of the capabilities of the Aircraft Sensor Analysis Package (ASAP). ASAP is a menu driven software package which executes on the Atmospheric and Oceanographic Information Processing System (AOIPS).

The approach of this document is non technical, and several output products are illustrated. Its sole purpose is to present the major features of the system in more detail than is found in the User's Guide to a potential user, or to a user looking for a specific capability to be incorporated in another system.

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AIRCRAFT SENSOR ANALYSIS PACKAGE  
AN INTERACTIVE DATA PROCESSING SYSTEM

\*\*\* DEMONSTRATION TAPE \*\*\*

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CODE 933



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## INTRODUCTION

The Aircraft Sensor Analysis Package (ASAP) is an interactive software system designed to operate on digital data acquired by multichannel scanning radiometers which are flown on a variety of NASA aircraft. The software system requires the hardware associated with the Atmospheric and Oceanographic Processing System (AOIPS) GE Image 100 terminal.

ASAP operates on scanner data which has been calibrated on an IBM 360 computer system and presents an image on the AOIPS display monitors. Provisions are made for rapidly acquiring segments of interest, enhancing them, obtaining relevant parameters for further processing on other systems, and recording results in a permanent form. Data manipulations unique to aircraft scanner data are also included in the software.

ASAP is currently being used to analyze data obtained from radiometers flown on U2 aircraft which are forerunners of instruments to be flown on satellites. These consist of the Ocean Color Scanner which corresponds to the Coastal Zone Color Scanner to be flown on Nimbus-G, and the Heat Capacity Mapper which relates to the Heat Capacity Mapping Mission which will be flown as the first Applications Satellite Mission (AEM-A). Data obtained from aircraft flights prior to the launch of the satellite instrument simulates expected satellite data, and is used to develop appropriate analysis algorithms. After the satellites are launched, aircraft scanner data will be obtained during concurrent aircraft underflights and will be used to verify calibration and other parameters pertaining to the satellite instrument. The ASAP package is designed to operate with data obtained from future aircraft instruments, provided calibrated output is in the form described in Section 2.1.

ASAP is a menu type system. Within each menu, however, the user is required to answer prompts which relate to the selected menu item. Operations performed on data are confined to that image data which is displayed on the AOIPS display monitors; thus, the 8 most significant bits are used.

The purpose of this document is to provide a potential user with a feel for what the ASAP system requires, and what it does - not how it does it except from a mathematical standpoint. The user is referred to the ASAP users guide (see Reference 1) for details of operation. This document is located in the AOIPS facility library.

The remainder of this document consists of seven additional sections. Section 2 describes input data forms acceptable to ASAP. Overviews and general data displays are discussed in Section 3. Data operations which are uniquely related to the fact that data is obtained from an airborne platform are covered in Section 4.,



Enhancement techniques which form a part of the ASAP package are described briefly in Section 5. Output products, line plots, and dialogue recording are covered in Sections 6, 7 and 8 respectively.

## 2.0 SYSTEM INPUTS

ASAP accepts data from 9-track Computer Compatible Tapes (CCTs) at densities of 800 or 1600 bits per inch (bpi). The primary restriction is that there be one scan line per physical tape record.

Data may be in any of three forms:

### 2.1 CALIBRATED INPUT DATA

The aircraft data acquisition system digitizes the scanning radiometer data in flight, and records the data as a serial bit stream on one direct record track of an instrumentation tape recorder located in the aircraft. After the flight, this tape is processed by a formatting system which produces raw data CCTs. These tapes are then processed on an IBM 360/91 computer system by existing aircraft scanner calibration routines which have been developed over the past few years. The calibrated output CCTs are the input for ASAP. Appendix 1 discusses the calibrated tape format for the Ocean Color Scanner in detail.

Each data point in the data scan record corresponds to a 16-bit index which refers to a calibrated data table having up to  $12^{16}$  points in scientific notation. Typically, the table length is 1024 which corresponds to a digitizing accuracy of 10 bits. In cases where calibrated values are linear with respect to sensor output, only the necessary constants for conversion to radiance are given. The data for each scan line is band interleaved, that is, for a N channel scanner with 200 elements per channel, band 1 is located in bytes 1-400 (2 bytes/element), band 2 in 401 to 800, etc. In practice, the data within each record is offset by 28 bytes to allow timing and other information to be included in the record. The reader is referred to the ASAP user and programmer guides for details regarding the use of this data (see References 1 and 2).

### 2.2 ASAP GENERATED DATA

Data of this type is in a byte format and consists of a TV or film recorder image with one line/record and one spectral band per file. This mode is used for reading intermediate images or results generated by ASAP (see Section 4), or to read data generated by other sources with a similar format.

## 2.3 SMIPS/VICAR INPUTS

ASAP can read both labeled and unlabeled data tapes generated by the SMIPS/VICAR system (see References 3 and 4). The SMIPS/VICAR system is operational on Goddard IBM 360 computers, and is often used to perform operations not available on AOIPS such as resampling and geometric correction.

## 3.0 DATA SCANNING

Calibrated input data may consist of from 300 to 5,000 scan lines per flight segment with each line having up to 16 spectral channels. The user can select up to 5 spectral channels for display at any one time and assign them to any of the 5 available refresh memories associated with the AOIPS Image 100. Since 493 lines are visible on the AOIPS display monitor, two modes of examining the data are used:

### 3.1 OVERVIEW DISPLAY

Up to 2,000 scan lines are read in from the calibrated CCT, but only every  $n^{\text{th}}$  line and  $j^{\text{th}}$  element are displayed on the monitor.  $n$  and  $j$  are selected so as to maintain an approximately correct visual aspect ratio. The limit of 2,000 lines is chosen so that the displayed image width is a minimum of  $1/4$  the screen width.

At this juncture, the user may continue scanning in the overview mode using any displayed line as a starting point (specified by use of a box cursor), or switch to the incremental scan mode.

### 3.2 INCREMENTAL SCAN DISPLAY

Data is displayed on the AOIPS monitor at full resolution for 493 successive lines. The starting line may be defined from the overview display by use of the box cursor or a manual keyboard entry. The full resolution data display may then be moved up or down the screen with following or preceding data being added to the display with respect to the defined starting point.

In both these modes of operation, basic enhancements may be applied for clarification purposes by responding to menu prompts. If the enhancement option (see Section 5) is taken, the specified enhancement may be modified, bypassed or applied to further displays of the data set.

## 4.0 AIRCRAFT DEPENDENT MANIPULATIONS

Due to the nature of the aircraft data system and the actual scanner, certain data manipulations are required and are discussed below.

### 4.1 DATA RECTIFICATION

Two types of scanner rectification are available and are as follows:

#### A. Pixel Replication

Due to the fact that the aircraft data system samples along a scan line at approximately one half of the Nyquist frequency, displays will appear elongated when compared to maps. A simple single pixel replication corrects this effect. Normally this causes more than 512 elements to be available for display. In this case, the center 512 elements will be displayed unless otherwise directed by the user.

#### B. Scanner Distortion

Foreshortening effects due to looking at the earth off nadir are corrected by a variable pixel replication technique. The size of a resolution element viewed by the radiometer varies as the  $\sec^2$  of the nadir angle. Since the display device assigns a fixed area to a pixel regardless of location, noticeable foreshortening occurs at the outer boundaries of the display especially when the off nadir angle is greater than  $30^\circ$ .

The technique used to correct for foreshortening effects assigns a fixed number of display points (e.g., 5) to a nadir element. When the  $\sec^2$  increases by 10-30%, 6 pixels per scanner data point are output; 30-50%, 7 pixels per scanner data point are output, etc. After an expanded line is generated, 500 equally spaced points are selected and displayed.

An example utilizing this technique and a pixel replicated version is shown in Figure 1a and 1b. The data was taken by the OCS while flying off of Tampa Bay, Florida.

The differences between Figures 1a and 1b though not great, are significant. The width of small cloud formations in the upper center portion of the figures is narrower for the scanner corrected version than for the pixel replicated version. However, the curvature of the bridge on the right side of these figures is greater

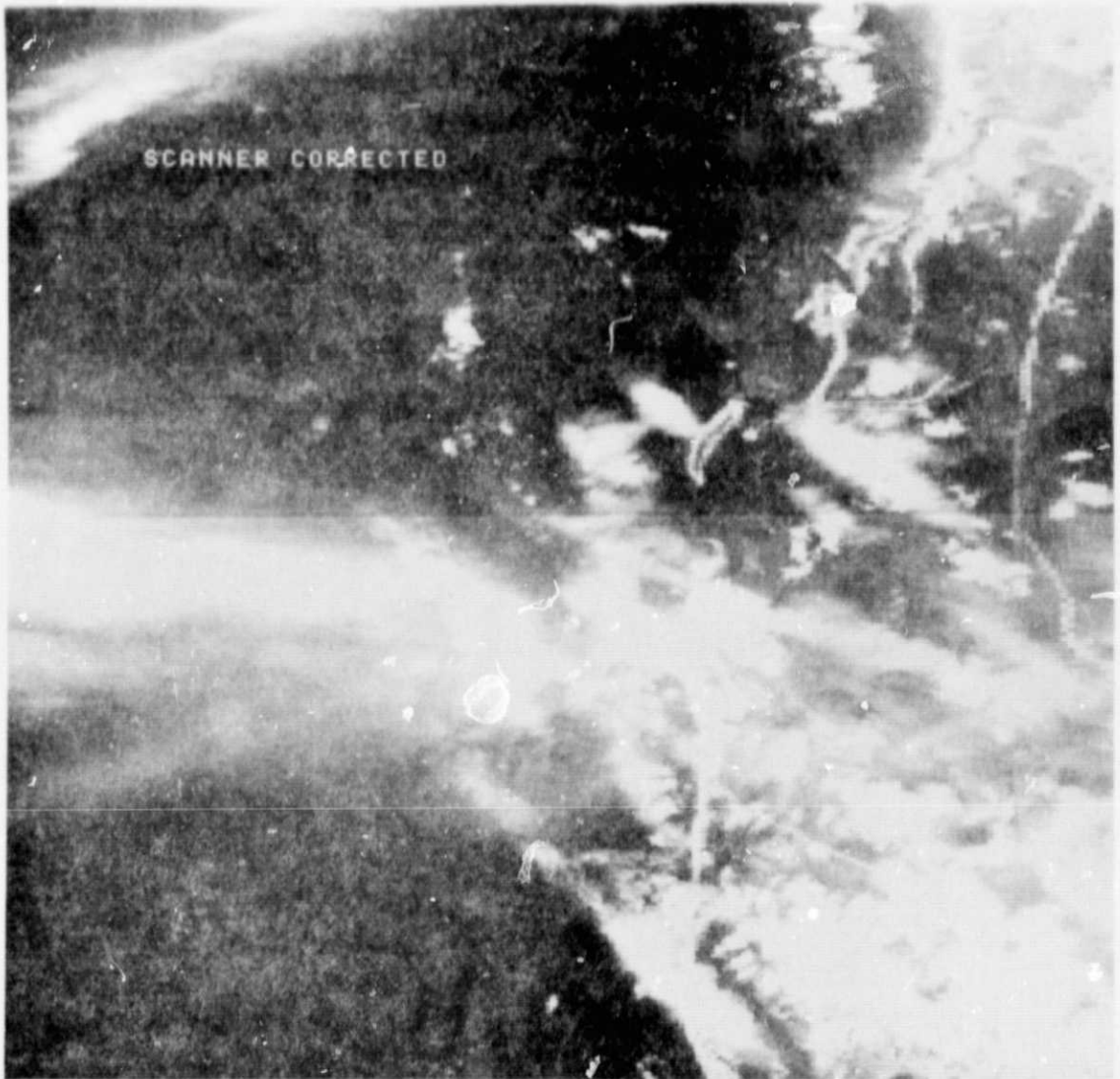


Figure 1a. Data Corrected for Scanner Distortion

for the scanner corrected version than for the pixel replicated version. Measured distances between features in the center to features on the right side are significantly less for the scanner corrected version than for the pixel replicated version.

The scanner corrected version effectively produces a truer horizontal mapping of points relative to each other than the pixel replicated version.

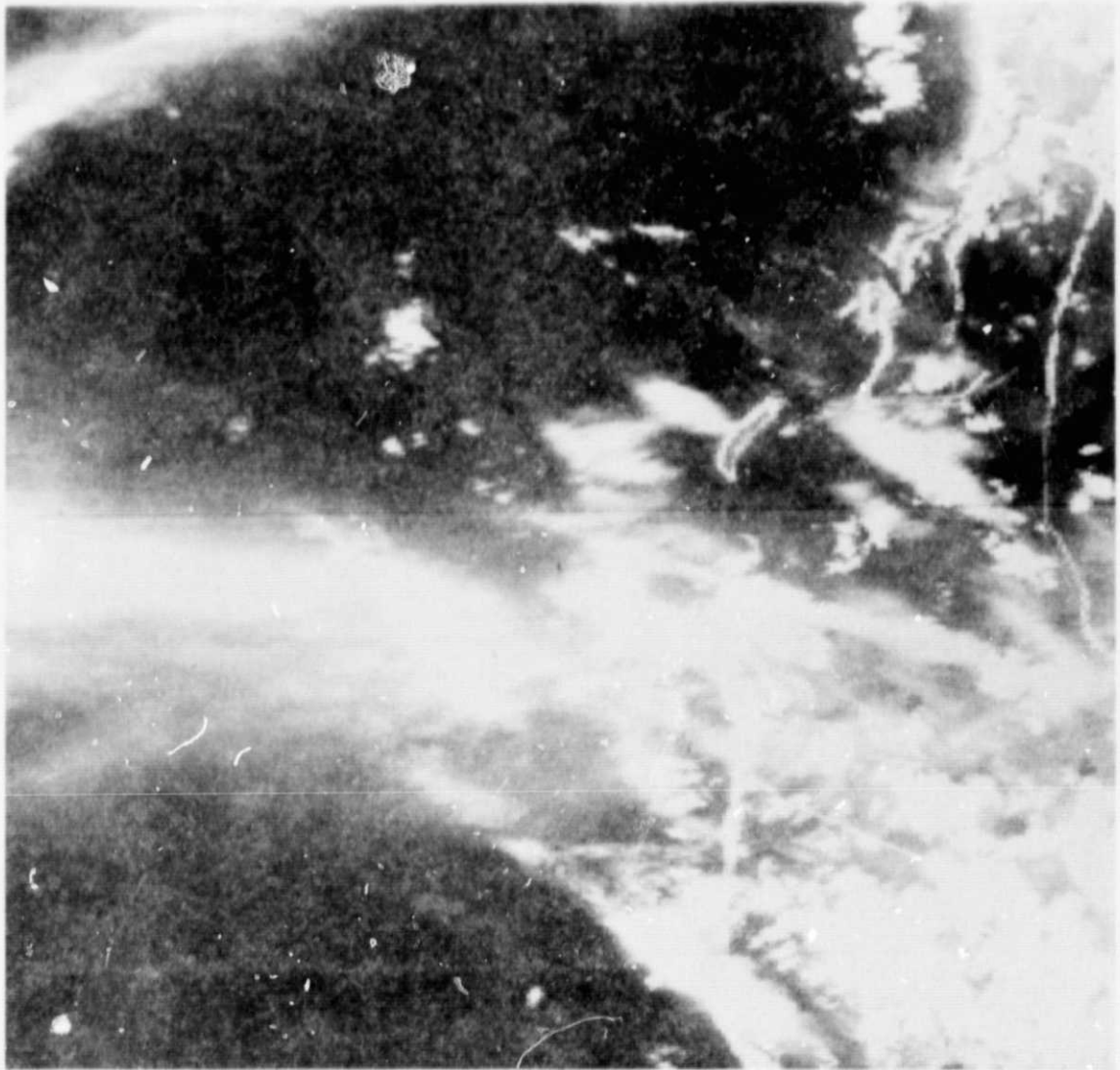


Figure 1b. Data Corrected by Pixel Replication

#### 4.2 IMAGE REVERSAL

In many cases, the aircraft will be flying in a northerly direction, hence when the image is displayed, southern data is displayed at the top of the screen since it is acquired first. Provision for reflecting data about a centered horizontal or vertical axis is made in order to orient the data in a way which a user prefers to see it. Rotations of the images are not included.

## 5.0 DATA ENHANCEMENTS

Enhancement routines are designed to operate only on displayed data in order to clarify detail. The following operations are possible:

### 5.1 HISTOGRAM COMPILATION

In the context of enhancement, histograms are used to determine the frequency of grey level occurrence as a function of grey level. This information is required as a starting point prior to applying contrast enhancements.

The histogram routine counts the number of pixels in each bin of 4 contiguous grey levels. Areas for histogramming are selected by setting the box cursor around the area of interest. An option for a full screen histogram exists, but unless all screen elements are filled with picture data this option should be avoided as zero (blank screen) counts will dominate the display.

The histogram is displayed on the Cathode Ray Tube (CRT) display unit. The abscissa is pixel value and ranges from 0 to 255. Sixty-four points are displayed hence each abscissa point corresponds to 4 contiguous grey levels. The ordinate is relative frequency, and all data is normalized to the maximum frequency obtained. Twenty-six lines are used to display this information, hence the frequency is known to approximately 4%. Values less than 4% are shown as zero. Data pertaining to screen location, tape location, normalizing value and total pixels are included in the title information. Figure 2 is an example of the histogram display.

The histogram routine can operate on up to 5 channels in serial sequence provided the image areas of the 5 channels to be histogrammed are identically defined.

### 5.2 CONTRAST ENHANCEMENT

These routines are used to contrast stretch an image. Contrast stretching is essentially a process of mapping the dynamic range of the original data values into the dynamic range of the display device. The user has two options:

#### A. Piecewise Linear Stretch

The user can define up to 10 sets of coordinates  $(x_i, y_i)$  which map  $x$  into  $y$  by linear interpolation where  $x$  refers to the original image data and  $y$  to the display



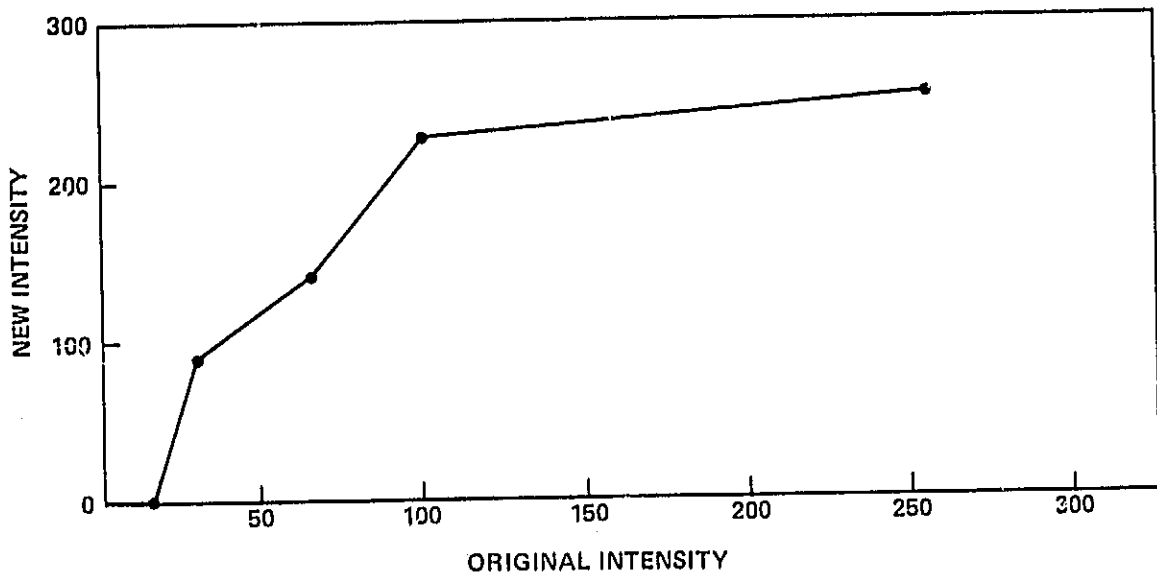


Figure 3a. Possible Piecewise Linear Stretch Function  
 $(x_i, y_i) = (0, 0), (15, 0), (30, 90), (65, 140), (100, 230), (255, 255)$

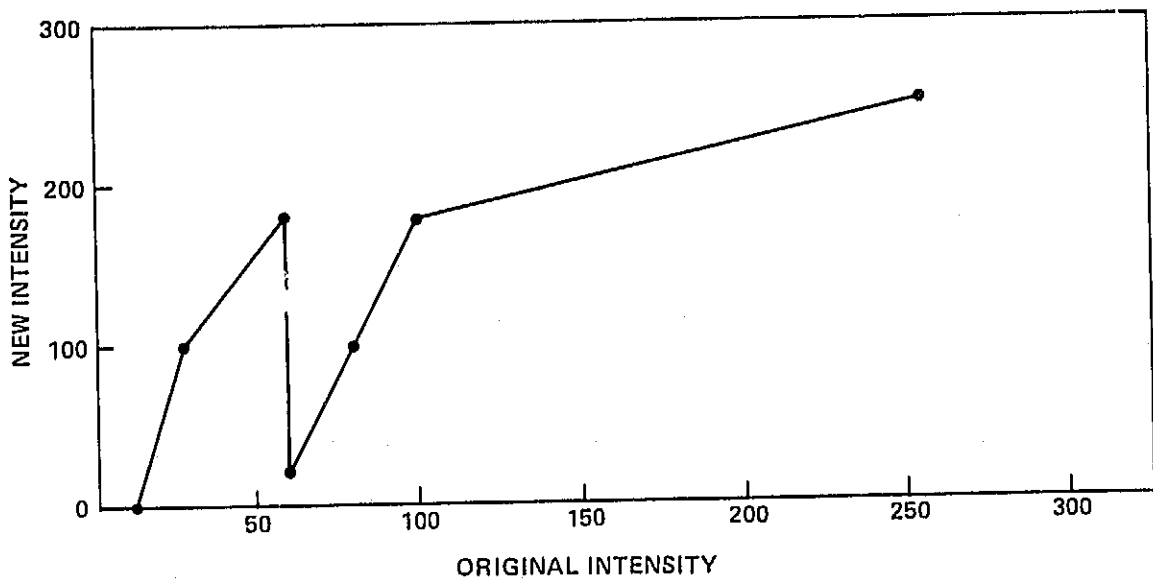


Figure 3b. Possible Bi-Modal Piecewise Linear Stretch Function  
 $(x_i, y_i) = (0, 0), (11, 0), (27, 100), (59, 180), (60, 20), (79, 100), (100, 180), (255, 255)$





### 5.3 PSEUDO COLOR ENHANCEMENT

Pseudo color enhancement is the process of assigning a color to a particular range of grey levels. The color is generated via a look up table which assigns appropriate intensities to the three color guns. The pseudo color routine generates 33 distinct colors in an approximate chromatic sequence. The user may specify both the number of colors desired and the range of grey levels in the image to be processed. The standard product is 32 colors at 8 grey levels/color over the range 0-255.

Depending on the data, a 32 color display may lead to an incomprehensible product. Thus the user may select 8 colors over an input data range of 30-150. For this case color 1 is assigned to grey levels 30-41, color 5 to grey levels 42-53, etc. up to color 29 being assigned to grey levels 139-150. The reason for skipping every  $32/N^{\text{th}}$  colors ( $N=8$  for this case) is the chromaticity of the table which has the first 8 colors as 4 shades of grey and 4 shades of blue.

### 5.4 ZOOM OPERATIONS

The user can designate a subimage area by the box cursor and obtain a pixel and line replicated version of the area. The blow up factor is shown on the typewriter CRT and is the minimum integer of  $493/NL$  or  $493/NP$  where  $NL$  and  $NP$  refer respectively to the number of lines and pixels bounded by the box cursor.

### 5.5 VISUAL CORRELATION

This routine enables the user to move one image with respect to another image of the same area by selecting a feature common to both images. It is assumed that both images have the same scale and are similarly oriented. Image translation occurs in the horizontal and vertical directions.

## 6.0 SYSTEM OUTPUTS AND ANNOTATION

The primary output of the system is a CCT which can be processed by the Dicomed film recorder into a permanent image or used to store intermediate results. Both labeled and unlabeled tapes may be generated for this purpose (see Reference 5). These tapes are usable as input to the SMIPS/VICAR system or for storage of intermediate results which require further processing by ASAP. If unlabeled tapes are desired for images, the user can specify a line-pixel repeat factor to enlarge the final image. For a standard TV image this factor is 1 if full 4" X 5" film output is desired. Output tape density 800 or 1600 bpl, is a function of intended postprocessing.

A secondary output device is the printer. The controlling routine allows the user to specify an area for printing via the box cursor and displays the grey level values. The printer output is designed for easy montaging.

All output images can be annotated by superimposing alphanumeric data on the image or in header records of a particular output file. Cursors may also be superimposed on an image for reference purposes. Additionally, cursor location information can be displayed or fed in via the keyboard. This feature is illustrated in the frontispiece.

## 7.0 ANALYSIS OPERATIONS

Two plot routines are available for analysis purposes. In both cases, an optional nearest neighbor averaging process exists.

### 7.1 LINE PLOT

Radiances or grey levels are plotted along a line of arbitrary direction within a displayed image. The line is specified by setting the crosshair cursor at any two points on a selected image. The standard deviation is plotted when averaging is selected. This is illustrated in Figure 4a for the case of a 9 point (3 X 3) average.

### 7.2 SPECTRAL PLOT

This produces a radiance vs. wavelength plot of the Ocean Color Scanner (OCS) data at any point designed by the crosshair cursor. Data from all channels on the calibrated input tape are used and standard deviations are optional. The

ASAP-LINE ANALYSIS PLOT

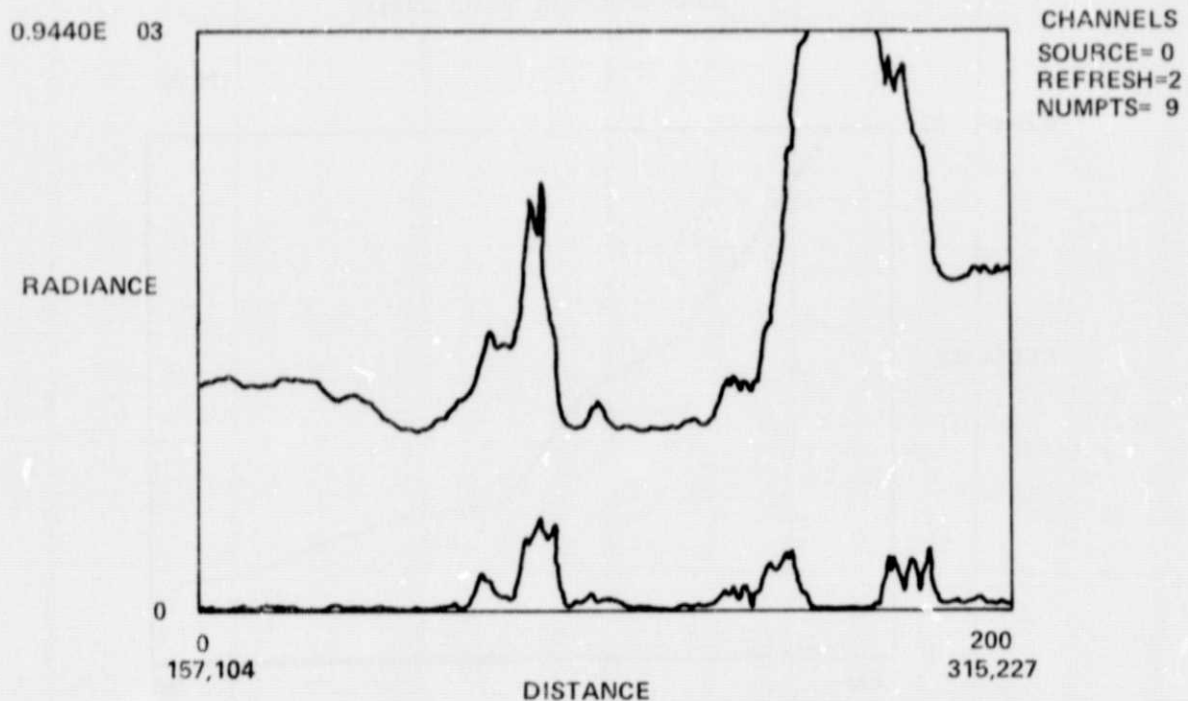


Figure 4a. Grey Level Plot and Standard Deviation from Tampa Bay Data Set

current program uses wavelengths corresponding to the OCS for the abscissa. This output is shown in Figure 4b and represents data from 10 spectral channels.

Figure 4c is a contrast stretched, unrectified version of the original data and annotated to show the locations of the plots of 4a and 4b. Note that standard deviations (lower plot) for the line plot in Figure 4a appear large only at boundaries of clouds or land with water.

### 8.0 USER SESSION HISTORIES

The system has the facility to record the user computer dialogue on the Gould printer for an entire ASAP processing session. This information can be used to trace through the processing steps executed during a data analysis session and can serve as an aid in solving a variety of problems that might arise during a user session.

# ASAP—SPECTRAL ANALYSIS PLOT

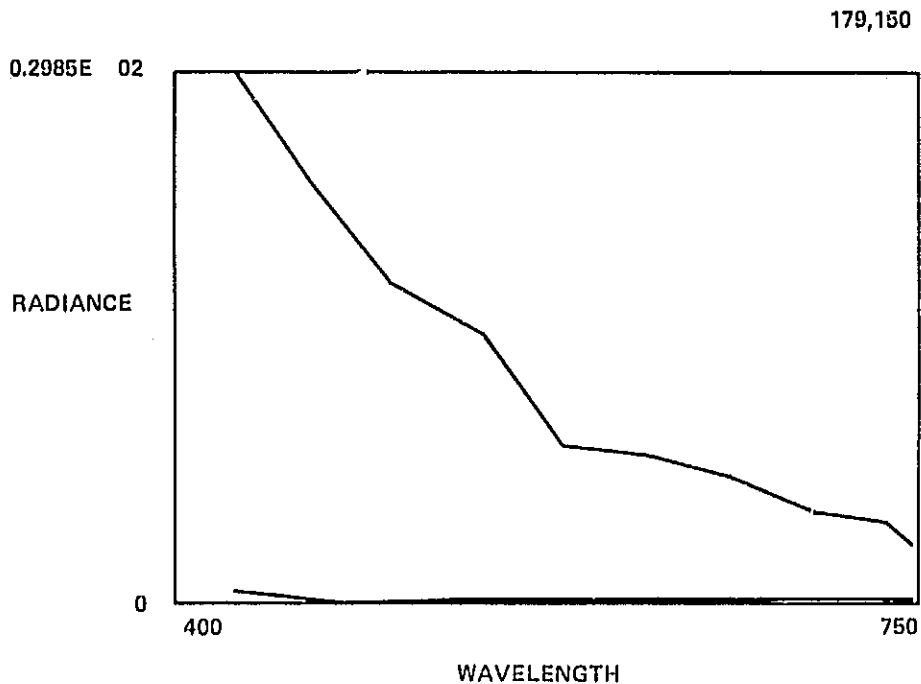


Figure 4b. Spectral Plot and Standard Deviation from Tampa Bay Data Set

## 9.0 ACKNOWLEDGEMENTS

The author wishes to thank the following for their efforts in producing a useable ASAP system. Richard Cogan whose programming talents resulted in the ASAP system as it is today. Gary Wolford, who was responsible for the development of the aircraft calibration programs and whose cooperation regarding interface problems between the IBM 360 and the DEC 11/45 was invaluable.

## 10.0 ASAP USAGE TO DATE

The ASAP system has been utilized by several users from outside government agencies in connection with the Heat Capacity Mapper and Ocean Color studies. It has also been transferred to the EROS Data Center in Sioux Falls.

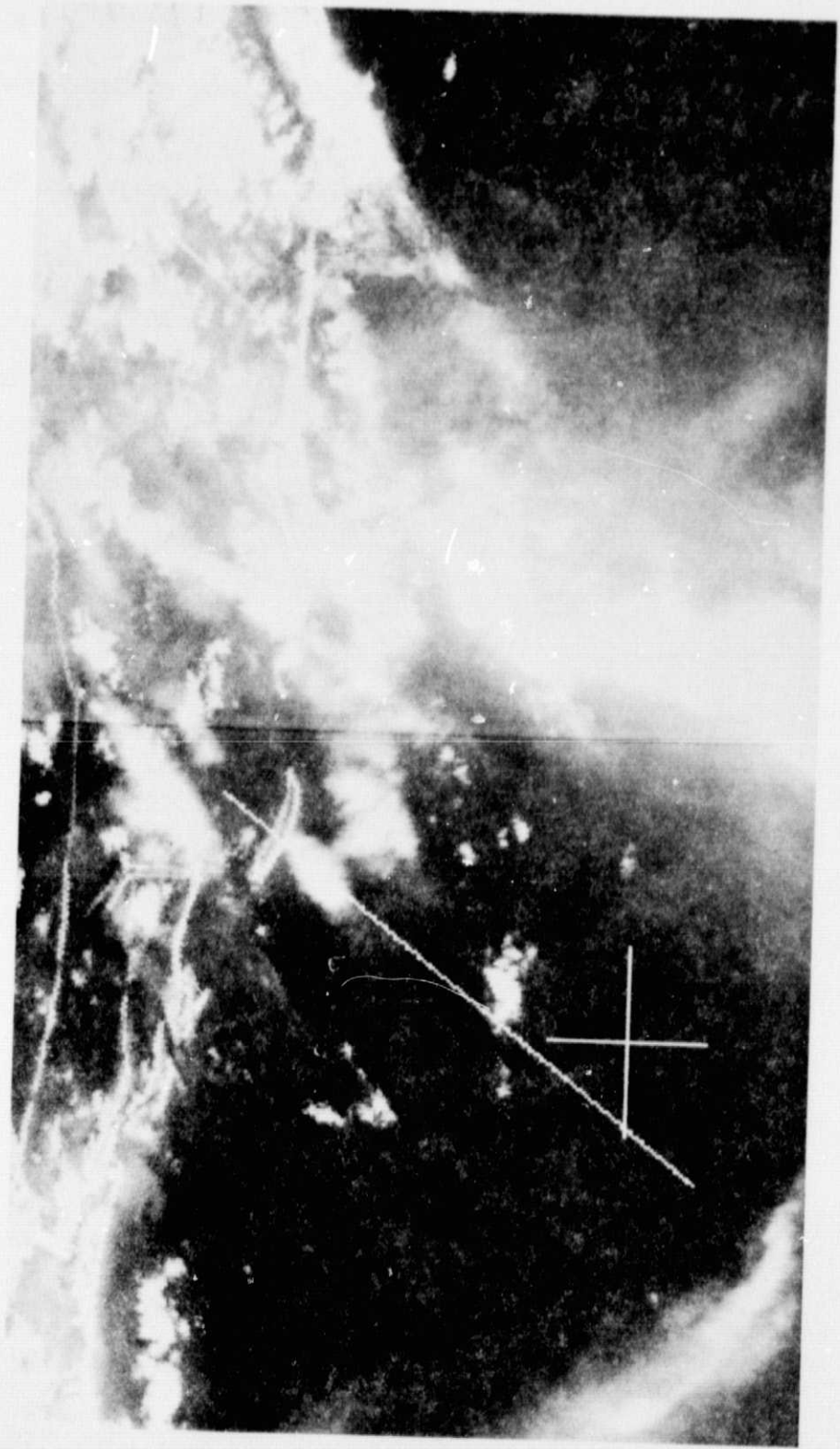


Figure 4c. Unrectified View of Tampa Bay with Annotation Showing  
Location of Spectral Plot (+) and Grey Level Plot (Straight Line)

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3. Moik, J. G., "Small Interactive Image Processing System (SMIPS) User's Manual", NAS X-650-73-273.
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# APPENDIX A

## SAMPLE INPUT DATA FORMAT

The calibrated data tape from the radiometer flown on aircraft is a 9-track 1600 BPI multifile tape. The records are written in the Variable Blocked (VB) format with a logical record length of 5432 bytes and a blocksize of 32596 bytes. The first file consists of documentation data and master conversion values to radiometric units. Each of the subsequent files will consist of a flight segment and will contain a documentation record descriptive of the flight segment and data scan records from that segment. For long flights more than one calibration tape may be required and where practical a flight segment will be wholly contained on one tape. The data scan record in the flight segment files contain values that are to be interpreted as indices for use with the master conversion values in file one. If physical units are required, then multiplication by channel conversion values are necessary, but for display purposes the indices may be used and manipulated. The format of the first or flight documentation file is as follows:

### Record 1: Flight Documentation Record

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
1-20	EBCDIC	experiment name (OCS FLT XX)
21-40	EBCDIC	platform flight number
41-60	EBCDIC	GSFC flight number
61-64	I*4	number of bands in scan data records
65-68	I*4	*channel number of first band
69-72	I*4	channel number of second band
73-76	I*4	channel number of third band
"	"	"
101-104	I*4	channel number of tenth band



## Record 1: Flight Documentation Record (Continued)

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
105-128	Not Used	
129-132	I*4	number of flight segments on this tape
133-136	I*4	file number for first segment (2)
137-156	EBCDIC	geographic area
157-160	EBCDIC	start day
161-164	EBCDIC	start hour
165-168	EBCDIC	start minute
169-172	EBCDIC	end day
173-176	EBCDIC	end hour
177-180	EBCDIC	end minute
181-184	I*4	file number for second segment
185-204	EBCDIC	geographic area
205-208	EBCDIC	start day
209-212	EBCDIC	start hour
213-216	EBCDIC	start minute
217-220	EBCDIC	end day
221-224	EBCDIC	end hour
225-228	EBCDIC	end minute
"	"	"
565-568	I*4	file number for tenth segment

Record 1: Flight Documentation Record (Continued)

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
569-588	EBCDIC	geographic area
589-592	EBCDIC	start day
593-596	EBCDIC	start hour
597-600	EBCDIC	start minute
601-604	EBCDIC	end day
605-608	EBCDIC	end hour
609-612	EBCDIC	end minute
613-636	Not Used	

\*The Scan data record contains space for 10 data channels of 270 points each. However, all 10 channels may not be available on all calibration tapes. The numbers appearing in bytes 65-104 provide identification of channel numbers and their respective location in the scan data record.

(e. g.) Bytes 65-104 = 0, 2, 0, 4, 5, 0, 7, 0, 0, 0; channels 2, 4, 5, 7 are found in band positions 2, 4, 5, 7

Bytes 65-104 = 2, 4, 5, 7, 0, 0, 0, 0, 0, 0; channels 2, 4, 5, 7 are found in band positions 1, 2, 3, 4

Record 2: Master Calibration Tables Documentation Record

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
1-68	Not Used	
69-72	R*4	index-mw conversion for channel 1 data
73-80	Not Used	

Record 2: Master Calibration Tables Documentation Record (Continued)

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
81-84	R*4	index-mw conversion for channel 2 data
"	"	"
179-180	R*4	index-mw conversion for channel 10 data
181-220	R*4	volt-mw conversion used for calibration

The format of each flight segment file is as follows:

Record 1: Flight Segment Documentation

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
1-20	EBCDIC	experiment (OCS FLT XX)
21-40	EBCDIC	platform flight number
41-60	EBCDIC	GSTC flight number
61-80	EBCDIC	geographic area
81-84	EBCDIC	starting latitude (degrees)
85-88	EBCDIC	starting latitude (minutes)
89-92	EBCDIC	starting longitude (degrees)
93-96	EBCDIC	starting longitude (minutes)
97-100	EBCDIC	end latitude (degrees)
101-104	EBCDIC	end latitude (minutes)
105-108	EBCDIC	end longitude (degrees)

Record 1: Flight Segment Documentation (Continued)

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
109-112	EBCDIC	end longitude (minutes)
113-116	EBCDIC	start time (day)
117-120	EBCDIC	start time (hour)
121-124	EBCDIC	start time (minute)
125-128	EBCDIC	end time (day)
129-132	EBCDIC	end time (hour)
133-136	EBCDIC	end time (minute)
137-156	EBCDIC	experimenters' names
157-164	EBCDIC	date of calibration
165-166	I*2	number of scan data lines
167-168	I*2	byte increment to number of data samples/channel in scan data record (26)
169-170	I*2	maximum number of data samples/channel in scan data records (270)
171-172	I*2	average number of data samples/channel

Record 2 - last: Scan Data Record

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
1-2	I*2	digital reel sequence number
3-8	EBCDIC	digitizing date
9-12	I*4	record number of scan start pulse

Record 2 - last; Scan Data Record (Continued)

<u>BYTES</u>	<u>FORMAT</u>	<u>DESCRIPTION</u>
13-14	I*2	time of start pulse (hour)
15-16	I*2	time of start pulse (minute)
17-18	I*2	time of start pulse (seconds)
19-20	I*2	time of start pulse (milliseconds)
21-24	I*4	time of start pulse (total in milliseconds)
25-26	I*2	spacing for boundary alignment
27-28	I*2	*number of data points/channel
29-30	I*2	**band 1 sample 1
31-32	I*2	band 1 sample 2
567-568*	I*2	band 1 sample 270
569-570	I*2	band 2 sample 1
571-572	I*2	band 2 sample 2
1107-1108	I*2	band 2 sample 270
"	"	"
4889-4890	I*2	band 10 sample 1
4891-4892	I*2	band 10 sample 2
5427-5428	I*2	band 10 sample 270

\*Only the number of samples specified in bytes 27-28 are valid. This is based on normal sampling rate. If other sampling rates are used the maximum number of data samples/channel is found in bytes 169-170 of the Flight Segment Documentation Record.

\*\*See footnote of flight documentation record #1 for correspondence of data bands with actual channel numbers.