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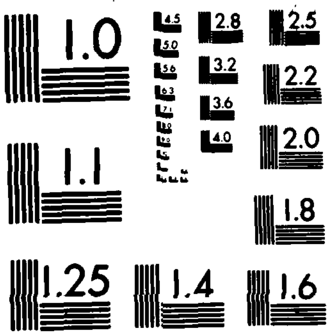

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Final Report

MULTI-TEMPORAL ANALYSIS OF LANDSAT IMAGERY FOR BATHYMETRY

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Applications Division

MAY 1983

Naval Research Laboratory
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16. Abstract

A multi-temporal processing procedure has been developed for the Defense Mapping Agency/HTC Digital Image Processing System (DIPS). The purpose of this procedure is to extract hydrographic information from multi-date Landsat and other types of remote sensing data. Water depth variations from multiple remote sensing observations can be analyzed to identify the sources of variations. When such variations can be removed from the data the multi-temporal data set can yield an improved estimate of water depth. Six available Landsat scene dates had been previously processed to provide an independent set of predicted water depths for the Bahamas Photobathymetric Calibration Area. Geographical locations of ship survey soundings were used to extract pixel locations from the six registered scene dates. Relationships between these predicted water depths and the measured depths were analyzed using standard statistical methods. Results aided the development of processing procedures and a best estimator of water depth for Landsat multi-temporal data. Multi-temporal processing (MTP) software was written to perform similar operations on the DIPS. Preprocessing steps are suggested to remove unwanted spatial noise from multi-date Landsat data.

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PREFACE

This final report, prepared by the Applications Division of the Environmental Research Institute of Michigan (ERIM) under Naval Research Laboratory (NRL) Contract N00014-81-C-2334, covers the work performed from June 6, 1981 through September 30, 1982. The technical representative for the contracting officer was Mr. Peter A. Mitchell of NRL. The principal investigator was Fred J. Tanis, with important contributions to the technical program made by Fred J. Thomson and Ross Hieber. This technical work was conducted by the Applications Division under the direction of Mr. Donald S. Lowe.

This contract involves the development of techniques to process multi-temporal remote sensing data for purposes of extraction of hydrographic information. The techniques and processing software developed under this contract were based on multi-date analysis of a set of previously processed Landsat scenes covering the Bahamas study region.

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1.0

SUMMARY

In order to enhance its Digital Image Processing System (DIPS) capability the Defense Mapping Agency (DMA) has supported the development of a multi-temporal procedure (MTP). This procedure has been designed with maximum flexibility to allow the operator to apply the software to a variety of hydrographic applications and remote sensing data sources. A goal at DMA is to develop processing technology for passive remote sensors which minimizes the need for ship supported surface truth measurements. With the present capability the DIPS cannot be used to remove unwanted noise and effects which can influence the depths predicted from satellite sensor data. Multi-temporal processing provides a means to diminish noise and separate the effects due to temporal phenomenon such as turbidity, haze, and surface slicks. The multi-temporal software developed for the DIPS allows the operator to perform basically nine separate operations. These include display functions for loading, viewing, and combining multi-date subscenes which have been previously co-registered. Options are also provided for image smoothing and polygon subarea selection. The polygons can be examined to determine depth statistics and depth differences for selected dates. Further a SCATTERPLOT and REGRESSION option allows the operator to investigate the relationships between predicted depths for several dates and adjust, if necessary, the water depth equation parameters. With the parameters adjusted between scene dates the operator can recalculate the water depths for each date and weight average the results to eliminate unwanted noise. The resulting predicted depths can then be used as a basis for additional parameter adjustments in an effort to further resolve date-to-date differences in predicted depth. Once the operator is satisfied with the result, a relationship can be established between the original depth prediction for each scene date and the final best predicted depth for the calibration polygon(s). The APPLY function can then be used to modify each of the scene dates and obtain a best estimated depth for the entire subarea. The flexibility in the options of the MTP software allows the definition of many separate procedures to extract a best estimated water depth from temporal data.

A multi-temporal data set was constructed from six previously processed Landsat scenes covering portions of the Bahamas Photobathymetric Calibration Area. The six scenes were brought into registration using common ground control positions and a series of affine transformations. Once these images had been satisfactorily registered, a semi-rigid Landsat imaging model was used to locate pixels corresponding to SAI ship transect depths in the scene [1]. Errors in the registration process were found to be on the order of two pixels in each direction, while the errors associated in the location of ship data were within two pixels. Four data sets were assembled for calibration areas 3A, 3B, 3C, and 3D (see Figure 1, page 10). Each of these data sets consisted of the average ship-measured depth over each Landsat pixel along with the six individual predicted depths as derived from the Landsat signal levels. These data were analyzed to gain insight into the characteristics of multi-temporal data and as test cases for calibration and evaluation of suggested procedures.

Large offsets (0.5-5.0m) in mean water depth were observed between the Landsat predicted depths and those provided from ship measurements. Of data from the six available dates, data from three were found to be sufficiently noisy to caution their use in any multi-temporal analysis. The multi-date algorithm showed improvement over the best single date results for the case where ship survey data were utilized and also for the case where a best depth estimate was formulated based only on the Landsat signal values. Observed improvements were found to be comparable to that predicted from rms noise reduction. It was concluded that the algorithm effectiveness may be improved by implementing pre-water depth processing procedures design to remove systematic noise components.

2.0

INTRODUCTION

The Defense Mapping Agency has responsibility for issuing bathymetric charts for all areas of the world outside the United States. Costs of revising charts using conventional ship survey methods have increased sharply in recent years. As a result DMA is no longer able to meet the demands for accurate charts and has been increasing its effort to develop a Satellite/Airborne remote sensing survey capability which would allow charts to be updated in a more efficient manner. ERIM has participated in numerous studies supported by both DMA and NASA to develop and refine techniques that predict water depth based upon Landsat radiometric parameters [2,3]. In each of these previous studies water depth algorithm development was accomplished by relating measured depths to Landsat radiometric parameters. Altogether these studies provide a significant data base for the evaluation of remote sensing techniques. Since many of these studies were conducted in the Bahamas, DMA designated this region as the Bahamas Photobathymetric Calibration Area. The waters in this region are exceptionally clear and exhibit a wide variety of flora and bottom types [4].

Based on the algorithms developed in the above studies, DMA has supported the development of software to be run on its Digital Image Processing System (DIPS). With the present capability, however, DMA has no way to remove unwanted noise and effects which can easily influence predicted depth calculations derived from Landsat data. Processing of bathymetric/hydrographic data images can require detailed analysis in each of two or three spectral bands. When it is necessary to separate time-varying phenomenon as turbidity, surface slicks, clouds and haze from bathymetric features, multi-date imagery is required. Given that multi-date imagery is frequently available for purposes of image selection and to identify temporal features it is reasonable to consider developing algorithms which can exploit co-registered multi-date imagery.

Work under this contract consists of development of a multi-temporal processing procedure for application on the DIPS. The present DIPS system is still in the development stages and, therefore, processing algorithms developed for the DIPS must be flexible and sufficiently generalized so as to alter application for use with a variety of data sources and applications. Once procedures have been proven through repeated use, then processing software on the DIPS can be modified to reduce present time consuming constraints. In this effort, work was directed toward utilizing multi-date Landsat coverage to develop a procedure which will minimize the influence of noise and other effects such as varying bottom reflectance and water clarity in order to provide a best estimate of water depth.

2.1 BACKGROUND

The Defense Mapping Agency at its Hydrographic/Topographic Center (HTC) has the capability to process Landsat MSS data to produce water depth maps. The algorithms used are a single channel algorithm based on digital values in band MSS4 (green) and a two channel algorithm based on the ratio of digital values in bands MSS4 and MSS5 (red) [5]. The Landsat estimates of water depth contain errors caused by changes in water clarity, tidal state, bottom reflectance, surface reflected energy, atmospheric effects, and sensor noise. The algorithms require estimates of water clarity (K, the irradiance attenuation coefficient) and bottom reflectance. These parameters are entered as constants in the program. If they are estimated incorrectly, depth errors will result in the processed data.

Random noise effects can be reduced if more than one Landsat data set can be analyzed. Before the beneficial effects of noise reduction (through averaging the depth estimates made on two or more scenes) can be realized, the systematic errors between scenes must be reduced to low levels. This reduction can be accomplished by adjusting the parameters used to process the various MSS data sets to minimize, in a least squares sense, the differences in water depths computed from the scenes being analyzed.

The parameter adjustment process requires precisely registered scenes of Landsat data, so that pixel-by-pixel comparisons can be made. The technology exists to accurately correct scenes if a few (5-10 per scene) ground control points are available and the spacecraft attitude is known. The latter information has been available in the X-format tapes provided by EROS Data Center.

Two cases of parameter adjustment can be distinguished; a case where a few known depth points are available, and a case where no ancillary depth information is available. In the first case, water depth estimates from a reference scene are first corrected to the known data by adjustment of the algorithm parameters to minimize the difference between the estimates of depth (from the Landsat data) and the actual depths. After the reference scene has been adjusted, each of the additional scenes can be brought into correspondence with the reference scene by a similar parameter adjustment procedure. At each step of the parameter adjustment procedure, the resulting revised parameters should be checked to assure that the adjustments are reasonable. If unreasonable adjustments arise from the least squares procedure it is an indication that something may be wrong with the data set being analyzed. In the case where no ancillary bathymetric data are available, the estimates of water depth from the various Landsat scenes can be brought into correspondence by adjusting algorithm parameters to minimize the mean square depth difference between the scenes. But because of uncertain tidal state and solar irradiance and bottom reflectance effects, the average computed depths may be biased with respect to true depths.

2.2 OBJECTIVES OF THE PRESENT STUDY

The present study had four objectives. First, the mathematical details of the parameter adjustment procedure were developed. Second, a multi-temporal data set was assembled from six previously processed Landsat scenes covering the Bahamas Photobathymetric Calibration Area. Third, the procedure was applied to the composite Bahamas data set and the results analyzed. Fourth, software was written to perform the required analyses within the context of the DIPS at DMA/HTC. In the remainder of this report the results of the four efforts are discussed.

2.3 EXISTING DIPS CAPABILITY

The DIPS provides a basic operating capability to process Landsat MSS data and other sources of remote sensing imagery to detect and position unknown navigational hazards or update charts which poorly describe hazard features. The DIPS provides real time interactive display and manipulation capabilities that allow the operator to process one or more Landsat bands for purposes of extracting hydrographic information in the form of predicted water depths or location of specific bottom features. When fully operational DMA/HTC plans to use the DIPS to support the following hydrographic work:

(1) Evaluation of hydrographic charts for accuracy.
(2) Updating and chart revision.
(3) Provide regular inputs to Notice to Mariners reports.
(4) Confirm and position doubtful dangers.
(5) Provide planning inputs to shallow water hydrographic ship surveys.
(6) Provide a monitoring function for unstable navigational hazards.

Presently the DIPS image processing and analysis functions are limited to the spatial units of a single display image (512 x 512). Each display image (subarea) can be transformed into geographic coordinates with the aid of operator selected ground control points. The image warp function can be used to transform geographic coordinates of ship soundings to image line and point coordinates. Signal levels of these latter pixels can be used to perform a linear regression analysis yielding a relationship between water depth and signal level.

The linear equation is a logarithmic transformation of:

$$V = V_s + V_o e^{-2Kz} \qquad (1)$$

where V = Landsat signal count
z = water depth (m)
K = irradiance attenuation coefficient
V_s = Average deep water signal
V_o = Average $V\text{-}V_s$ signal for zero depth

$$V_o = \frac{E_o \rho G \tau}{\pi} \qquad (2)$$

where: E_O = solar irradiance at ocean surface
ρ = bottom reflectance
G = scanner sensitivity constant
τ = atmospheric transmittance

The logarithmic equation has the linear form:

$$Y = A + BZ \qquad (3)$$

where $Y = \ln(V - V_s)$
$A = \ln(V_o)$
$B = -2K$

Equation 3 above can also be used to express water depth in terms of a two band ratio (MSS4 and MSS5).

Presently there is no capability on the DIPS to extend depth predictions derived on one subarea to an adjacent one or to mosaic processed subareas.

3.0

MULTI-TEMPORAL PROCEDURE DEVELOPMENT

The multi-temporal processing procedure developed for the DIPS is one which utilizes multi-date Landsat data to remove uncertainty in the depth calculation input parameters which are either assumed or measured at selected point locations in the scene. In this regard the calculation of water depths from Landsat data depends on knowledge of three basic parameters for each scene date. These are the deep water signal V_s, the irradiance attenuation coefficient K, and the bottom reflectivity ρ. In the water depth algorithm presently on the DIPS it is assumed that the deep water signal is constant throughout the scene. However, spatially varying surface and atmospheric effects can lead to significant errors in this term. The extinction coefficient could be highly variable both spatially and temporally. The bottom reflectivity could also display large spatial variance, but temporal changes can be expected to be isolated if they exist at all. In addition, Landsat image characteristics including striping and angular distortions will affect predicted depths. Thus there exist substantial spatial and temporal complexities in the determination of water depths. Under these circumstances of parameter uncertainty, the multi-temporal technique becomes an attractive approach. The multitemporal procedures as described below were developed using a six date scene set covering a portion of the Bahamas Calibration Area. More specifically, Landsat derived water depths from study areas 3A, 3B, 3C, and 3D were combined with 1980 ship transect depths to form a test set (See Figure 1). The specifics of the test set development are discussed in section 4.0.

3.1 BACKGROUND ANALYSIS

In the simplest form of the problem, given perfect knowledge of V_s, K, and ρ and with noise effects spatially uniform and comparable for each of the individual scenes, we would be able to determine the average depth or "best" estimate at each pixel. However, under more realistic

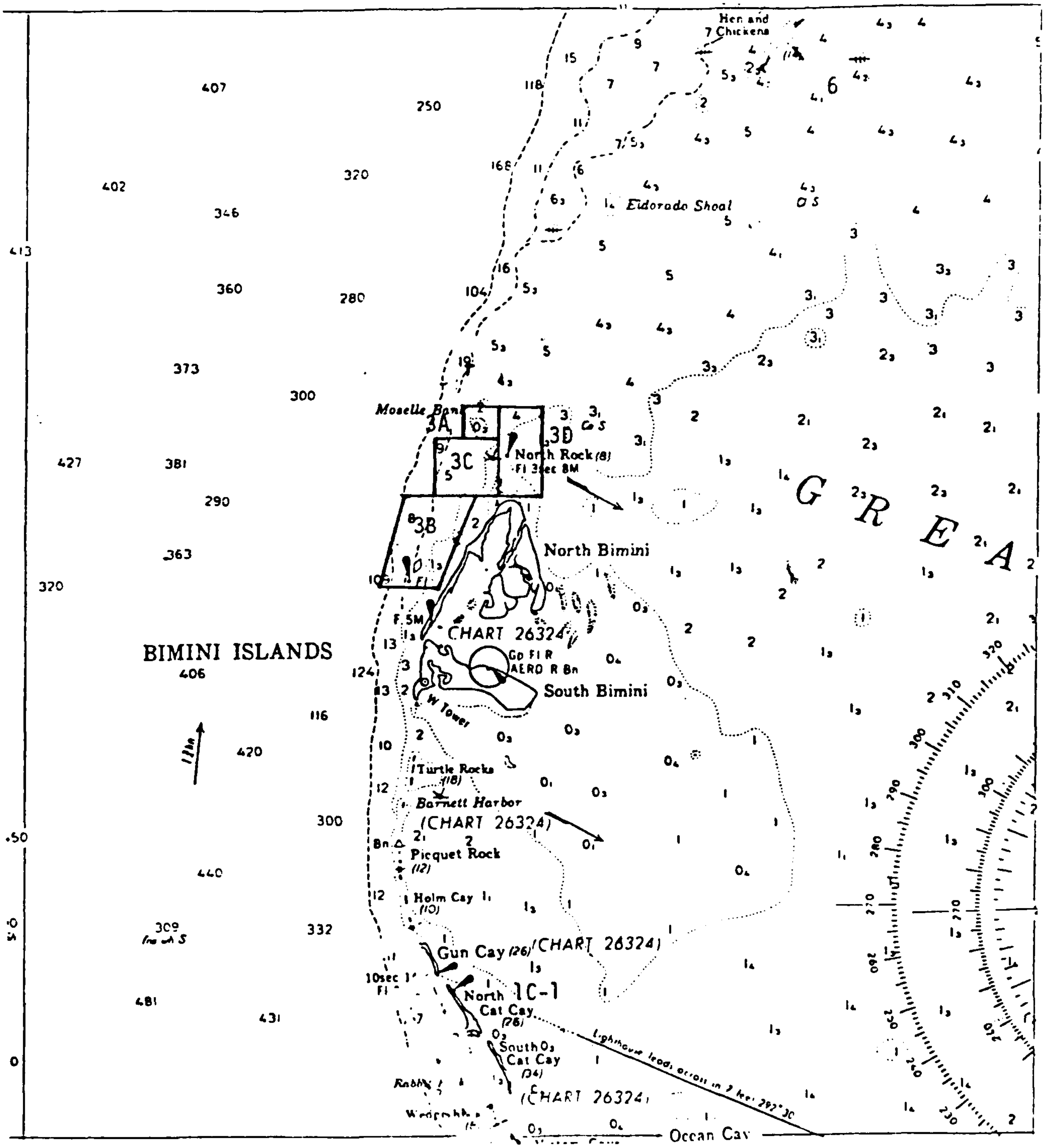

Figure 1. Portion of the Bahamas Photobathymetric Calibration Survey Areas

conditions we have imperfect parameter information and possibly spatially varying noise. Under such conditions we desire to utilize the multi-temporal data in a methodology which will produce a "best" estimate of water depth. There are essentially two types of uncertainty which in turn suggest very different approaches for obtaining a best estimate. First, with V_s there is uncertainty in the measurement accuracy and applicability to the depth determinations at other points in the scene. If the variation in the V_s term is random, then the errors may average out to some extent when the multi-temporal results are combined. If on the other hand the variations are due to patterns in atmospheric haze, then it seems essential that such haze be first normalized throughout the scene. It is recommended that such a haze algorithm should be added to the DIPS processing software.

A measured difference in V_s from scene date to scene date cannot be used to improve the determination of K or ρ. The bottom reflectance is not expected to change temporally. But because it is difficult to estimate algorithms which minimize the effects of changing bottom reflectance on water depth calculations are being developed. The zero depth signal V_0 contains the bottom reflectance coefficient and can be either estimated from the data or calculated using solar irradiance, sensor responsivity, atmospheric transmission and bottom reflectance as in equation (2). The values of V_s and V_0 must be tied to a subscene area. In fact the V_0 term varies from pixel-to-pixel in the scene but cannot be directly calculated at each point without knowledge of ρ. Because V_0 is the product of a series of parameters, variation in V_0 from scene date to scene date is not directly related to variations in bottom reflectance. Knowledge of the water attenuation coefficient, K, could on the other hand, be useful if certain assumptions are permissible. First, if the K value does not change from date to date and there is a significant and known change in the tidal state, then it is possible to calculate the value of K at each pixel given a value of V_s and V_0. Second, if the K value has changed temporally by a known quantity then it is possible to estimate the water depth independently of the bottom reflectance.

It is questionable whether either of these approaches is applicable to the Bahamas region since the tidal changes are small and on the order of the water depth errors. In addition there is no data to support any uniformity in the reported tidal state. Variations in tidal state can be expected as a function of bottom slope and depth patterns. There is little reported data on spatial variations of K values. It is likely that spatial variations in K exceed those due to temporal changes with the possible exception of those caused by passage of large storms.

3.2 MULTI-TEMPORAL PROCESSING METHODOLOGY

With this background let us now explore possible methodologies for obtaining a best depth estimator. First consider a case where one has only very limited water depth soundings as may be available from a crude chart. It is further assumed that these depths are suitable for purposes of checking or validating the results obtained by processing remote sensing data but insufficient by numerous parameter estimation. Initial values of water depths are obtained by making reasonable assumptions for K and deriving V_s and V_o from each of two to four individual data sets. Under such circumstances an approach is sought which will utilize the multi-date information to obtain results which are superior to those from a single date. If one attempts to apply an iteration and/or relaxation process over the parameters of interest it is soon discovered that there is no criterion available for testing convergence. A plot of depths calculated on one date versus those calculated on a second, for a set of registered pixels and a range of depths, can suggest two types of parameter changes (Figure 2). A regression slope not equal to one suggests a change in K while an offset indicates a change in V_o. If this latter term is calculated rather than estimated from the data, then the offset may be due to changes in irradiance or tidal state. Once the slope deviation has been removed by adjustment of

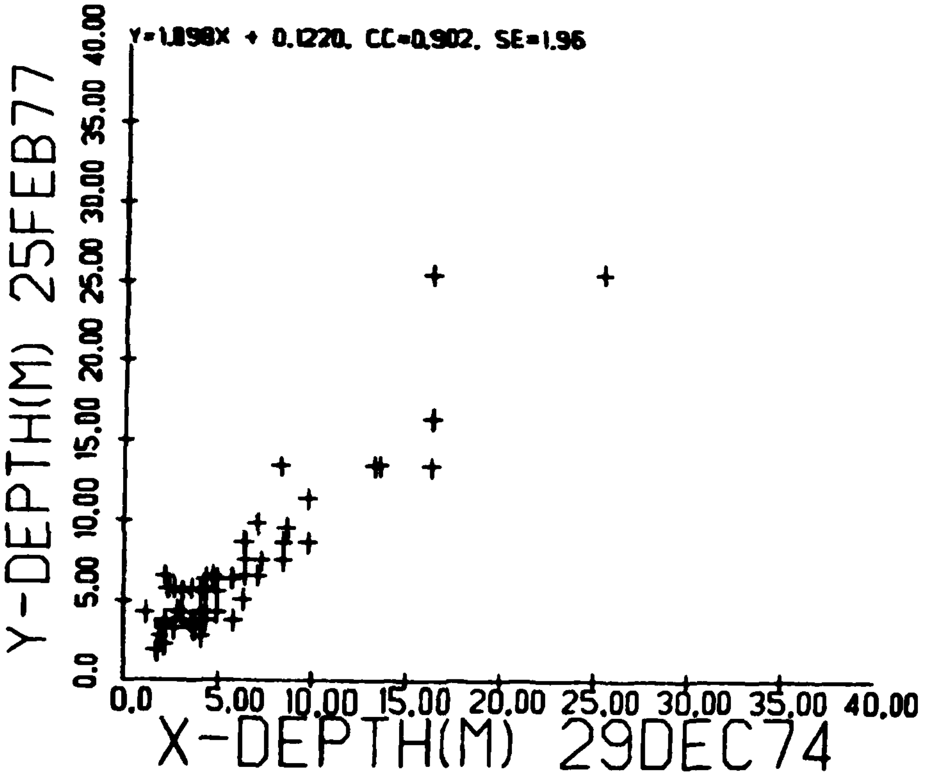

Figure 2. Scatter Plot of Landsat Predicted Depths for 25 Feb 77 and 29 Dec 74.

one date's K value and the tidal change is used to remove the offset, the two data sets are in agreement outside of the possibility of systematic scattering (spatial variations) about the regression line or as residual differences related to spatial location or water depth. If the bottom reflectance parameter is perturbed in an effort to obtain better agreement, one realizes that all such perturbations merely move the position of the point along a line parallel to the slope (note that such perturbations are taken to be the same for each date). In this case the information necessary to reconcile the bottom reflectance on a pixel-by-pixel basis is not present. If the slope in the original plot were greatly different than one, implying a large change in K, then one could, in principle increase or decrease the bottom reflectance value of the individual pixels to bring them into closer agreement. However, unless the atmospheric spatial variations are first removed from the data such results are meaningless and such variations due to path radiance must be removed from the data before beginning the depth processing.

Presently there is no atmospheric correction capability with the DIPS software. Further our experience with the Bahamas data set demonstrates only very slight changes in K value from date to date and insufficient ones from which to make any attempt to analyze possible spatial variations in bottom reflectance. Any number of scene dates can be reconciled into agreement by adjustment of K and the offset, and the residuals can be used to indicate any systematic differences. Once these are removed, the date-to-date residuals will have a random character and no further parameter adjustment to improve agreement is possible. In this circumstance the average depth computed for each pixel becomes the "best estimator". If the spatial noise properties of data sets are greatly different, then weights related to the noise amount can be derived for each data set, and the average computed as a weighted average.

Under a separate set of circumstances the multi-date data would be accompanied with a large number of ship survey soundings which are suitable to both calibrate and check the predicted depths. If these depths are evenly distributed over the scene, then parameter adjustments derived from these water depth measurements would in principle be valid over the entire scene. If on the other hand these depths are derived from transect data, then, of course, the validity of extrapolating water depth remote sensing parameter results to other portions of the scene is in doubt. Given the ship depths, our objective is to not only adjust the predicted depths from date-to-date but to make further parameter adjustments to minimize the differences between measured and predicted depths with a least squares criteria. In this approach K and ρ parameters can be estimated initially and fed into a system of equations, such as shown below, which adjust each parameter by some small change so as to minimize the difference in the mean squared error over a given series of N available scenes and M pixel locations.

$$z_{ij} = \hat{z}_{ij} + \left(\frac{\partial z}{\partial K}\right)_{ij} \Delta K_j + \left(\frac{\partial z}{\partial \rho}\right)_{ij} \Delta \rho_j \qquad \begin{array}{l} j = 1,\ldots,N \\ i = 1,\ldots,M \end{array} \tag{4}$$

where $\hat{z}_{ij}$ are measured water depths,
z_{ij} are Landsat estimated depths.

The resulting adjusted parameters are then fed back into the same set of equations in an iterative process so as to converge to a best estimated water depth. In formulating the equations one must be careful to make the number of independent equations substantially greater than the number of parameter unknowns so that the system can produce a stable solution. For example suppose there are M ship depth locations and N scene dates. Then one can write up to N x M equations in N x M unknowns but would need to have substantially fewer unknowns to obtain a stable solution. If one allows K and tidal state (T) to vary temporally but not spatially then K and T produce 2M unknowns. If the bottom reflectance is assumed to vary spatially but not temporally then we have an additional N unknowns. The variations in solar downward irradiance, which can also be thought of as a variation in the V_s term, are perhaps equally variable in both space and time. However, this latter parameter variation leads to N x M unknowns making it unsuitable to this iteration procedure. Thus, it is again seen that a procedure is needed to first remove the spatial atmospheric variations prior to water depth processing. The extendability of the bottom reflectance parameters to other portions of the scene is certainly a dubious procedure. However, one could, in the event that there exist large K changes from date to date, use the bottom reflectances as determined from the iterative solution using measured depths to define and validate a bottom reflectance adjustment procedure as discussed above which could be applied to all water pixels of the scene.

Without the atmospheric and spatial noise normalization procedure, ship survey soundings can be used to adjust the K irradiance attenuation parameter and remove depth offsets due to changes in tidal state or other parameters affecting the V_o term. In this case the parameter adjustments can be expressed as shown in equation (4) above, then use an iterative process of first determining a set of parameter adjustments, then substituting the adjusted parameters back into the same equation to converge to a least squares parameter fit. When the terms in the iteration equation are linear in water depth, the described iteration process is equivalent to linear regression analysis and the parameters defined by regression must necessarily be the same least squares solution as that obtained with the iteration process. Thus linear regression can be used to adjust assumed K values in order to bring them into line with the measured depths. Once K and ρ parameter adjustments have been completed for two or more scenes, residual differences can be examined for any systematic patterns with depth and those can possibly be removed from the data with some further parameter adjustment. At this point the predicted water depths for different dates are essentially equivalent except for random differences. The best depth estimator becomes, as in the previous case, the weighted average of predicted depths from each scene date.

Based upon the analysis of the available Landsat multi-date water depth maps in the Bahamas calibration study area, a general processing procedure is described below. The analyses of these data are described in section 5.0.

3.3 DESCRIPTION OF PROCESSING PROCEDURES

Preparation procedure: Using existing DIPS software and procedures to:

(1) View Landsat band 4 and select desired subscenes for multi-temporal processing (i.e., 512 x 512 blocks).

(2) Locate geometric control points.

(3) Register by warping subscenes from different Landsat dates.

(4) Outline deep water and zero water depth areas and calculate the deep water signal, V_s, and zero depth signal, V_0-V_s, respectively.

(5) Use available supporting data to make best guesses of K, ρ, and tidal state for each subscene date. At this point assume that K and ρ are constant for each date. Use these parameters to estimate water depths for each pixel and date within the subscene.

3.4 MULTI-TEMPORAL PROCESSING ELEMENTS

Use new MTP DIPS software to resolve date-to-date depth differences and obtain a "best" estimator. Operator selects appropriate command process from the following menu. There are four basic commands within the menu: LOAD, POLYGON, SCATTERPLOT, and APPLY. Each command will have several operator selected menu options as described below.

(1) LOAD - Screen subscene for selected dates. Operator selects dates and the program loads one date depth file into each of the 3 Comtal image planes. Operator has option to load two depth files and their difference map which is calculated with this routine with an offset value of 128. Once image planes are loaded, operator can proceed with selection of polygon test areas.

(2) POLYGON - Define study areas for multi-date analysis using a cursor driven polygon selection routine. These areas may have uniform bottom or K value. Areas selected should contain locations of available measured or otherwise known depths. Operator can select multiple polygons within the subscene as a single study area set using this command. The program stores data for all of the study sets selected for each of the available dates, including estimated water depth and the Landsat counts in bands 4 and 5. All of these data are stored in a single file with appropriate name and type designators. Operator may optionally exclude one or more dates or selected portions of the study area from further processing. Operator can use this command to combine one or more study sets from the same subscene. Operator may terminate the command by requesting the statistics of the study set (pixel count, mean values, range, and standard deviation about the mean). Operator can also use this command to estimate the uncertainty in the depth predictor for an individual date by selecting a study area with uniform water depths.

(3) SCATTERPLOT - Adjust K and ρ parameters between dates to minimize date-to-date differences in a least squares sense and subsequently obtain the "best" estimate of water depth for each pixel of the study area. This command has several operator controlled options.

(a) Input measured or estimated reference control water depths as polygon areas, transects, or points. These depths have latitude/longitude coordinates which must first be converted into line and point coordinates. Merge measured depth information with study area file.

(b) Scatter plot the predicted depths for two dates or with the measured depths.

(c) Use the previously calculated study set statistics to select a reference date. Input the reference date.

(d) Set maximum K and ρ parameter values and delta changes which are acceptable in the least squares parameter analysis.

(e) Operator selects dates from the study set whose water depths are to be regressed against those for the reference date. The slope and intercept are used to modify K and ρ parameters for the individual dates. If adjusted parameters exceed operator designated limits, the operator may eliminate that data set from the analysis or <u>reset</u> the parameters. Adjusted parameters are then used to predict water depths for each pixel in the study area. Residuals from the reference date are computed for each of the date sets utilized in the analysis. The newly predicted depths (by least squares parameter adjustment) are then averaged for each pixel to obtain a "best" estimate. Residuals and "best" estimated water depths are stored in the study set file. The adjusted K and ρ parameters and regression statistics are stored in a parameter file for the study set. The operator can obtain a printout of the study area file and/or the parameter file.

(f) Same analysis as in (e) with the reference date data replaced by the measured water depths. The subsequent analysis would be performed only on those pixels of the study set for which there exists measured water depths.

(g) Operator selects dates for analysis but no reference date or measured data are utilized. Average depths are computed for each pixel for the dates selected. These average depths then become the reference data set as in option (e) and an identical process is completed to obtain a "best" estimator.

(h) Operator inputs uncertainties in original selection of K and ρ parameters to obtain an estimate of the corresponding depth errors in the "best" depth estimate. Errors are computed for 1.0, 2.0, 3.0, 5.0, 7.0, 10.0, 15.0, 20.0, and 30.0 meter water depths.

(4) APPLY - The "best" depth predictor as derived in (4) is applied to the Landsat data to obtain estimated depths for the entire subscene. Operator initiates APPLY command by designating the parameter file which contains subscene name, dates, and parameter values needed to compute the "best" multi-temporal estimate. Results are included in the multi-date file structure for the subscene and can be subsequently displayed and compared with previous single date predictions or other multi-date estimates using the LOAD command. Other known chart depths in the subscene can be checked against the "best" estimated depth using the analysis command options (a) and (b).

The balance of the required processing, such as obtaining hardcopy of the depth map, can be accomplished using existing DIPS software. The MTP software delivered and installed on DIPS consists of a series of modules which support the multi-temporal command operations and interface with existing routines.

Software has been developed as described in Appendices A and B which can be used to implement the above procedures on the DIPS. Section 5.0 discusses suggested applications of this software on the DIPS.

4.0

MULTI-TEMPORAL DATA SET CONSTRUCTION

Two processing steps were performed in order to prepare the six previously processed Landsat scenes and the 1980 Ship Transect Data for analysis. First, each of the six Landsat data sets was registered to geodetic coordinates using ERIM's semi-rigid Landsat model and available ground control points. Second, the 1980 ship transect data, referenced to latitude, longitude geodetic coordinates by SAI, were sampled and merged with six sets of raw Landsat data and six depth estimates. This latter step created a data base of about 400 pixels for four test areas around the Great Bahama Bank. The four test areas used for this study are designated as 3A, 3B, 3C, and 3D as shown in Figure 1. Test areas were selected which exhibit a range of water depths and/or bottom type. The rationale for this selection is more fully explained in section 5.

4.1 DATA SET DESCRIPTION

The Landsat data sets we used for analysis had been selected and previously processed. Table 1 lists the scene ID's and other relevant information. As described in [1] the data sets were processed for water depths using a combined ratio-single band algorithm and the detector parameters shown in Table 2. For all data sets a bottom reflectance of 0.22 was assumed. This value is used along with other parameters to calculate V_0. For all data sets water attenuation coefficients of $K_4 = 0.0748m^{-1}$ and $K_5 = 0.326m^{-1}$ were used, corresponding to values for Jerlov Type IB water.

Previous water depth processing results exhibited varying water penetration and depth uncertainty owing to seasonal changes in water clarity and to cloud and haze patterns. Because data quality is important for subsequent analyses, a qualitative discussion is presented in section 5.2.

TABLE 1. LIST OF LANDSAT SCENES OVER THE GRAND BAHAMA BANK

Date	Scene ID	Satellite Landsat 1 or 2	Mode	Solar Elevation
25 Feb 77	5678-14102	1	Low gain	30°
3 Feb 75	1925-15015	1	Low gain	34°
24 Dec 75	5249-14435	1	High gain	28°
29 Dec 74	1889-15033	1	Low gain	30°
11 Oct 77	2993-14385	2	High gain	36°
25 Jun 77	2885-14444	2	High gain	54°

TABLE 2. VALUES OF V_{0i} AND V_S FOR THE SIX LANDSAT SCENES

VALUES OF VO_i

Scene Date	Solar Elevation	V_{04}(MSS4)	V_{05}(MSS5)
25 Feb 77	30°	22.4	26.2
3 Feb 75	34°	25.1	29.3
24 Dec 75	28°	63.2	73.7
29 Dec 74	30°	22.4	26.2
11 Oct 77	36°	88.6	121.0
25 Jun 77	54°	122.0	166.0

VALUES OF V_S (MSS4)

	Detector Number					
Scene Date	1	2	3	4	5	6
25 Feb 77	15.2	16.0	15.2	15.2	15.8	15.2
3 Feb 75	15.3	15.1	15.0	15.1	15.6	15.3
24 Dec 75	45.5	45.8	46.0	45.8	46.0	45.5
29 Dec 74	16.4	16.1	16.7	16.6	16.4	16.3
11 Oct 77	33.4	37.4	38.5	37.4	41.5	40.6
25 Jun 77	55.7	58.0	63.7	60.4	64.9	62.7

4.2 1980 SHIP SURVEY DATA

In July and August 1980 a series of cruises were made in vessels operated by the Johns Hopkins Applied Physics Laboratory. Data collected from these vessels included echo sounding depth transects, submersible photometer measurements in Landsat MSS and TM spectral bands and high spectral resolution bottom reflectance data. Because of previous difficulties with obtaining reliable ship position, a special emphasis was made in this survey to gather accurate coordinates for survey sampling positions. A LORAC positioning receiver was used in connection with a series of geodetic positions as located with a satellite positioning system. Details of the reduction of the navigation and echo sounding fathometer data are presented in ref [1]. Bottom reflectance spectra collected with an ISCO spectral radiometer have been previously reported [4].

All depth sounding and location data were supplied to ERIM on magnetic tape. Because of the high spatial density of echo sounding locations relative to the nominal 80 meter pixel size of Landsat, the measurements for areas 3A through 3D were sampled and averaged with Landsat pixel spacing. The latitude and longitude of each derived location was then assigned to a particular pixel whose center coordinates were nearest these values. With this procedure we were able to obtain a representative water depth value for each pixel which was intersected by the ship transect.

4.3 IMAGE-TO-IMAGE REGISTRATION

Before multi-temporal analysis could be conducted, each of the six Landsat scene dates had to be co-registered to one another. We first transformed each scene to geodetic coordinates and resampled each scene by nearest neighbor resampling. The registration to geodetic coordinates was required to merge in-depth sounding information.

The registration procedure uses a semi-rigid Landsat imaging model and a few (5-10) well spaced control points per Landsat scene to compute two twenty-two term mapping polynomials. Control points are required because the satellite ephermeris and attitude information, as reported in the SIAT file of the Landsat data tapes, is not sufficiently precise to assure subpixel registration accuracy to a geodetic grid.

Difficulties were encountered in correcting the scenes because of lack of well spaced control points. Four good ground control points were located in the Bahamas. Because the western boundary of the scene covered the eastern coast of Florida, additional ground control was sought from the 1:250,000 scale Miami and West Palm Beach sheets. These control points, along with additional points obtained from chart 26320 (scale 1:300,000) were later rejected as being too imprecise. Unfortunately, this left us with only four points on the eastern edge of the scene and no points on the western edge. As a result, the model east-west errors are considerably larger (102.2m) than the north-south errors (29.7m). Table 3 shows the results of the modeling efforts. Notice that, although all control points are listed, only those with unit weight are used in the model application. Similar results were obtained with other frames. The conclusion is that the resulting corrected data set matches the ship transect data to within about two pixels. This accuracy should be adequate for most bathymetry analyses except in cases where there is an abrupt change in bottom depth or reflectance.

Nearest neighbor resampling was used to obtain the geometric corrected depth files. Use of cubic convolution or restoration is not appropriate for these data since non-linear processing has been applied to the Landsat radiometric data values.

Data were resampled into a Universal Transverse Mercator (UTM) projection with 50m pixels. From this projection it is possible to compute the latitude and longitude of each pixel, using well documented formulas. It is also easy to compute the pixel line and point number from a given latitude and longitude.

TABLE 3. LANDSAT IMAGING MODEL RESULTS

Landsat Ground Control Points REV 10.0

SCENE ID 25 FEB 77

RMS ERRORS EAST-WEST 102.2 NORTH-SOUTH 29.7 (METERS)

POINT	FILE	WEIGHT	EAST-WEST ERROR (m)	NORTH-SOUTH ERROR (m)	CONTROL SITE
1	1		[illegible]	[illegible]	[illegible] PLM BEACH
2	1	[illegible]	-15[illegible]7.[illegible] -13	[illegible]-324	[illegible] PLM BEACH
3	1	[illegible]	-1154.7 -11	-9164.[illegible]-309	[illegible] PLM BEACH
4	1		[illegible]	-7[illegible].[illegible]-259	[illegible] PLM BEACH
5	1	[illegible]	-1435.[illegible] -14	-6884.7-231	[illegible] PLM BEACH
7	1		-982.4 -10	-5142.0-173	MIAMI
8	1	[illegible]	-9[illegible].2 -9	-4[illegible]34.5-166	MIAMI
9	1	0	-558.4 -5	-4512.0-152	MIAMI
10	3	0	-360.4 -4	-2743.5 -92	26320 1:3[illegible]
11	3	0	-255.7 -3	-3073.6-103	26320 1:3[illegible]
12	3	0	136.9 1	-1268.[illegible] -43	26320 1:3[illegible]
13	3	[illegible]	60.5 1	-944.4 -32	26320 1:3[illegible]
14	3	[illegible]	-146.3 -1	-9[illegible].5 -3	26320 1:3[illegible]
15	3	[illegible]	-59.0 -1	3[illegible]3.7 13	26320 1:3[illegible]
16	3	0	20.6 0	-1[illegible]83.9 -36	26320 1:3[illegible]
17	4	0	-220.8 -2	-1645.7 -55	26320 1:3[illegible]
20	3	1	-48.8 [illegible]	[illegible].1 0	GREAT ISAAC
21	3	[illegible]	-130.0 -1	-961.2 -32	NORTH ROCK
30	3	1	36.0 0	44.6 1	S TIP GUN CA
31	3	1	-131.0 -1	-22.5 -1	N CC FUEL PI
32	3	1	144.6 1	-31.0 -1	BROWN'S HOTE

4.4 REGISTRATION OF SHIP TRANSECT AND IMAGE DATA

Smoothed ship transect depth data (see section 4.2) and Landsat estimates were merged. Data were stored in a list file for later access by the statistical analysis routines as discussed in section 5.

5.0

PROCEDURE ANALYSIS AND EVALUATION

As discussed in the previous sections, this contract work involved both the development of a multi-temporal processing procedures and its implementation on the DIPS. The approach taken was to develop elements of the procedure based upon the DIPS software capabilities, theoretical considerations, and anticipated quantity of multi-date imagery. Procedure evaluation was made with a single multi-temporal Landsat data set. Because the software developed for the DIPS could not be directly implemented on the ERIM PDP/11 the procedure evaluation analyses were carried out on the University of Michigan MTS computer system. The approach involved using the MTS statistical analysis package on the previously registered ship and multi-temporal data set as discussed in section 4.0. The following sections describe some of the statistical characteristics of this data set, typical results obtained when these data were used to implement proposed procedures, an interpretation of these analyses, and based upon our experience, a recommended set of initial applications of the MTP software.

5.1 DATA SET QUALITY AND NOISE CHARACTERISTICS

For purposes of this description the Landsat/ship data set assembled consisted of four separate portions, one each from calibration subareas 3A, 3B, 3C, and 3D. Each set contained the multi-date Landsat derived water depths for 25 February 77, 3 February 77, 29 December 74, 24 December 75, 25 June 77, and 11 October 77. In addition each set contained the survey ship measured soundings and TM radiometer measurements. Each of these multi-variate data sets 3A, 3B, 3C, and 3D contained respectively 105, 231, 202, and 238 pixel locations. Initially it was necessary to ascertain the relative quality and noise condition of each of the six independent water depths. Of the calibration areas selected for this multi-temporal analysis, 3D was found to contain regions with little variation in measured water depth. For this reason

3D was considered a good candidate for noise analysis of the Landsat predicted depths. A total of twenty pixels were selected from an approximately two square kilometer area within 3D. For each of these a 3 x 3 array was recovered from each of the six dates with the center pixel corresponding to that pixel selected from 3D. For each scene date a local mean and standard deviation were calculated for each array and used to estimate a standard deviation and mean for the entire twenty arrays. These calculations are summarized in Table 4.

TABLE 4. STATISTICS FOR LANDSAT EXTRACTED WATER DEPTHS SELECTED FROM AREA 3D

Scene Date	Mean Depth (m) $[\bar{x}]$	Standard Deviation (m) $[\sigma_x]$	$\sigma_x/\bar{X}$	$\sigma V_s/\bar{V}s$ (MSS4)	$\sigma V/\bar{V}$ (MSS4)	Ratio Col. 6/ Col. 5
25 Feb 77	5.2	0.82	0.158	0.034	0.049	1.44
03 Feb 77	6.6	1.18	0.179	0.047	0.069	1.46
29 Dec 74	4.2	1.11	0.264	0.042	0.070	1.67
24 Dec 75	6.3	1.57	0.249	0.036	0.083	2.31
25 Jun 77	9.8	2.50	0.255	0.033	0.121	3.67
11 Oct 77	8.4	2.74	0.326	0.050	0.167	3.34

The ship-measured depths for the twenty pixels exhibited a mean of 8.58 meters and a standard deviation of 0.227 meters. The scene dates in the table have been placed in order of quality from the best to the poorest based upon (1) visual inspection of the resulting water depth maps, (2) the standard deviation of the predicted depth, and (3) the ratio of standard deviations in MSS4 i.e., ratio of column 6 to column 5 as shown in the table above. Column 5 is the ratio of the standard deviation in MSS4 over deep water to the mean deep water signal, V_s. Column 6 is the same ratio but where the standard deviation and mean MSS4 signal are averaged over the twenty pixel arrays in 3D. The ratio of these two quantities (Col. 7) provides an indicator of how the data vary in noise properties from those determined in a deep water region. Analysis of the TM2 submersible radiometer values in the TM green band for the same twenty pixels yield a standard deviation equivalent to eight percent of the mean value. Some of that change is due to changes in water depth and subsurface downwelling irradiance. Comparisons made in the table above suggest the following. While the 11 Oct 77 predicted mean depth falls closest to that measured by the ship, it exhibits poorest reliability because of the large noise components which are far in excess of those due to changes in water depth, bottom type, or noise associated with deep water signals. The sources of this noise are likely a combination of errors from image to image registration, pixel extraction, and atmospheric conditions. In the first three dates of the table, on the other hand, variations are only about 50 percent greater than those associated with deep water variations in V_s, and are considered superior to the last three. Since there undoubtedly exist some errors due to each of the previously mentioned sources, the reported standard deviations in the Landsat predicted depth appear reasonable even though they suggest one meter accuracy at eight meters depth if the offsets are corrected. The large error in predicted depth is due to offset which suggest some difficulty in calculating representative values of V_s and V_o from the data. Further it underscores the need for multi-temporal analysis to resolve observed differences in predicted depth and provide a best estimate water depth.

5.2 EXAMPLE CALCULATIONS USING MULTI-TEMPORAL PROCEDURES

Example calculations using suggested multi-temporal procedures are presented here to show methods of operation and value when applied to the assembled Landsat/measured data sets. Basically, calculations were made with and without the aid of ship measured water depths. The large errors in mean water depth shown above for a portion of area 3D were found with each of the other areas as well. This finding confirms that unless ship surface truth is used in the depth analysis, large errors due to offsets in depth/signal relationships can be expected. Statistical and depth analysis results are summarized for areas 3A, 3B, 3C, and 3D in Tables 5 through 8 respectively. Of the four areas, 3B showed the best distribution of water depths and, therefore, potentially the greatest opportunity for resolution of differences in predicted and measured water depths. The following discussion is, therefore denoted, primarily to the results obtained from area 3B. The noise analysis conducted above indicated data from three of the six scene dates to be suitable for multi-temporal processing. As a result most calculations reported were made using these three dates. For purposes of this analysis the 231 pixels extracted from 3B were divided into two groups, 1-75 and 76-231. The first served as a calibration set and the latter as a validation or test set. In general two types of multi-temporal analyses were performed on the 3B data set -- (1) A least squares adjustment of K and ρ parameters between scene dates and between an adjusted average and the measured water depths. (2) A straight average of the independent satellite predicted depths. Initially data from the best three dates were used to resolve K and ρ parameter differences using date-to-date regression. For these cases all 231 pixels were used to produce the regression equations (6.1) and (6.2) in Table 6.

The resulting coefficients and constants indicate the amount of adjustment in K and V_0 necessary to bring the two data sets into agreement in a least squares manner. The coefficient (a_i) dictates the amount of adjustment in K necessary to bring the two data sets into agreement ($K^* = a_i^{-1} \cdot K$). The constant, b_i, in combination with the coefficient, determines the adjustment necessary in the V_0 term ($V_0^* = V_0 {*} e^{2Kb_i/a_i}$). If the ratio method is used we are referring to a K difference and a ratio of V_0 for MSS4 and MSS5. Using equations 6.1 and 6.2, data sets 2 and 3 can be transformed to estimate V_1. The remaining differences can be attributed to random noise processes. The random differences can be reduced by averaging V_1, $\hat{V}_1$ (V_2), and $\hat{V}_1$ (V_3). The

TABLE 5. SUMMARY STATISTICS AND REGRESSION RESULTS FOR CALIBRATION AREA 3A

	Pixel No. 51-100				All Pixels			
VARIABLE	MIN	MAX	MEAN	STD DEV	MIN	MAX	MEAN	STD DEV
Predicted Depth (m) February 25, 1977	2.50	25.50	6.49	3.90	1.90	25.50	7.04	5.17
Predicted Depth (m) February 3, 1977	3.80	25.50	7.08	5.03	3.70	25.50	7.26	5.30
Predicted Depth (m) December 29, 1974	0.30	25.50	6.83	3.37	0.30	25.50	7.09	3.61
Ship Meas. Depth(m)	5.34	29.54	9.15	3.59	5.34	35.93	9.57	4.10
Predicted Depth (m) from Eq. 3 below	6.20	23.23	9.15	2.89	5.75	23.23	9.56	3.83
Residual Errors (m) Eq. 3 below	-6.52	6.31	0.10	2.16	-13.00	12.70	0.00	3.02
Average Adjusted Depth (m) from Three Dates	4.18	23.93	6.58	3.33	4.10	23.93	6.90	3.98
Predicted Depths (m) from Eq. 4 below	7.42	23.04	9.32	2.63	7.36	23.04	9.57	3.15
Residual Errors (m) from Eq. 4 below	-7.75	6.93	-0.17	2.35	-7.75	12.89	0.00	2.65

Regression Equation	Correlation Coefficient	Standard Error
5.1 $\hat{V}_1(V_2) = 0.885\ V_2 + 0.611$	0.909	2.16
5.2 $\hat{V}_1(V_3) = 1.066\ V_3 - 0.510$	0.745	3.46
5.3 $\hat{z} = 0.740\ V_1 + 4.35$	0.804	2.16
5.4 $\hat{z} = 0.822$ (Adjusted Average) + 3.74	0.762	2.35

where:

V_1 = Predicted Depth (m) 25 FEB 77; V_2 = Predicted Depth (m) 3 FEB 77;
V_3 = Predicted Depth (m) 29 DEC 74; $\hat{z}$ = Actual/Measured Depth (m)

TABLE 6. SUMMARY STATISTICS AND REGRESSION RESULTS FOR CALIBRATION AREA 3B

	Pixel No. 1-75				Pixel No. 76-231			
VARIABLE	MIN	MAX	MEAN	STD DEV	MIN	MAX	MEAN	STD DEV
Predicted Depth (m) February 25, 1977	1.80	25.50	8.05	6.08	2.70	25.50	10.99	5.83
Predicted Depth (m) February 3, 1977	1.90	25.50	9.69	6.68	3.10	25.50	12.82	6.92
Predicted Depth (m) December 29, 1974	3.10	18.20	8.11	4.26	3.20	25.50	10.77	5.40
Ship Meas. Depth(m)	3.88	39.36	10.81	6.93	4.78	43.33	13.36	7.73
Predicted Depth (m) from Eq. 3 below	4.97	27.10	10.81	5.68	5.81	27.10	13.55	5.44
Residual Errors (m) from Eq. 3 below	-10.90	20.76	0.00	3.99	-12.14	16.23	-0.19	4.92
Average Adjusted Depth (m) from Three Dates	2.53	21.44	8.24	5.03	3.67	23.88	10.90	5.23
Predicted Depths (m) from Eq. 4 below	4.37	25.71	10.81	5.68	5.66	28.47	13.82	5.90
Residual Errors (m) from Eq. 4 below	-10.44	17.07	0.00	2.38	-10.08	14.91	-0.46	4.21

Regression Equation	Correlation Coefficient	Standard Error
6.1 $\hat{V}_1(V_2) = 0.763\ V_2 + 1.031$	0.879	2.89
6.2 $\hat{V}_1(V_3) = 1.001\ V_3 + 0.113$	0.859	3.11
6.3 $\hat{z} = 0.933\ V_1 + 3.29$	0.820	3.99
6.4 $\hat{z} = 1.129$ (Adjusted Average) + 1.51	0.820	2.38

where:

V_1 = Predicted Depth (m) 25 FEB 77; V_2 = Predicted Depth (m) 3 FEB 77;
V_3 = Predicted Depth (m) 29 DEC 74; $\hat{z}$ = Actual/Measured Depth (m)

TABLE 7. SUMMARY STATISTICS AND REGRESSION RESULTS FOR CALIBRATION AREA 3C

	Pixel No. 1-50				Pixel No. 51-202			
VARIABLE	MIN	MAX	MEAN	STD DEV	MIN	MAX	MEAN	STD DEV
Predicted Depth (m) February 25, 1977	1.90	25.50	6.54	5.41	2.30	25.50	6.75	4.21
Predicted Depth (m) February 3, 1977	0.60	25.50	6.56	4.99	2.70	25.50	7.78	4.60
Predicted Depth (m) December 29, 1974	1.20	25.50	5.37	4.53	2.20	25.50	6.48	3.38
Ship Meas. Depth(m)	4.86	35.05	9.81	4.97	6.39	24.90	9.53	2.55
Predicted Depth (m) from Eq. 3 below	6.07	25.08	9.81	4.36	6.40	25.08	9.98	3.39
Residual Errors (m) from Eq. 3 below	-7.63	9.97	0.00	2.42	-6.40	3.49	0.45	1.91
Average Adjusted Depth (m) from Three Dates	1.76	25.29	6.07	4.81	2.84	25.28	6.90	3.84
Predicted Depths (m) from Eq. 4 below	5.84	27.52	9.81	4.44	6.83	27.52	10.58	3.53
Residual Errors (m) from Eq. 4 below	-5.01	7.53	0.00	2.28	-6.62	2.79	-1.05	1.91

Regression Equation		Correlation Coefficient	Standard Error
7.1	$\hat{V}_1(V_2) = 0.876\ V_2 + 0.11503$	0.914	1.84
7.2	$\hat{V}_1(V_3) = 1.098\ V_3 - 0.1125$	0.902	1.96
7.3	$\hat{z} = 0.805\ V_1 + 4.55$	0.876	2.42
7.4	$\hat{z} = 0.921$ (adjusted average) $+ 4.22$	0.892	2.28

where:

V_1 = Predicted Depth (m) 25 FEB 77; V_2 = Predicted Depth (m) 3 FEB 77;
V_3 - Predicted Depth (m) 29 DEC 74; z = Actual/Measured Depth (m)

TABLE 8. SUMMARY STATISTICS AND REGRESSION RESULTS FOR CALIBRATION AREA 3D

	Pixel No. 150-224				Pixel No. 1-149, 225-238			
VARIABLE	MIN	MAX	MEAN	STD DEV	MIN	MAX	MEAN	STD DEV
Predicted Depth (m) February 25, 1977	1.90	7.50	3.76	1.20	1.90	6.60	4.63	1.08
Predicted Depth (m) February 3, 1977	2.70	9.90	4.64	1.35	2.70	8.50	5.34	1.23
Predicted Depth (m) December 29, 1974	1.60	8.50	3.82	1.23	1.20	6.50	3.98	0.94
Ship Meas. Depth(m)	2.35	9.58	5.48	2.60	2.50	9.72	7.56	1.69
Predicted Depth (m) from Eq. 3 below	3.85	8.76	5.48	1.05	3.85	7.97	6.24	0.95
Residual Errors (m) from Eq. 3 below	-3.50	4.94	0.00	2.39	-2.58	4.57	1.31	1.52
Average Adjusted Depth (m) from Three Dates	2.76	6.93	4.04	0.83	2.49	6.09	4.50	0.68
Predicted Depths (m) from Eq. 4 below	3.51	9.92	5.48	1.28	3.09	8.63	6.18	1.04
Residual Errors (m) from Eq. 4 below	-3.14	5.18	0.00	2.28	-2.83	5.12	1.38	1.57

Regression Equation	Correlation Coefficient	Standard Error
8.1 $\hat{V}_1(V_2) = 0.571 V_2 + 1.436$	0.628	0.925
8.2 $V_1(V_3) = 0.650 V_3 + 1.800$	0.566	0.980
8.3 $\hat{z} = 0.876 V_1 + 2.19$	0.404	2.39
8.4 $\hat{z} = 1.537$ (Adjusted Average) $- 0.736$	0.491	2.28

where:

V_1 = Predicted Depth (m) 25 FEB 77; V_2 = Predicted Depth (m) 3 FEB 77;
V_3 = Predicted Depth (m) 29 DEC 74; z = Actual/Measured Depth (m)

result, which we will refer to as V_1 (adjusted average), can then be related to the measured depths in an effort to make final adjustments to K and ρ parameters as shown in Figure 3. For this case the regression equation is given as equation 6.4 in Table 6.

Predicted depths are shown for both the regression pixels (1-75) and the balance of 3B (76-231). The residual errors between this model and the ship measurements are shown in Figure 4. The residual patterns appear random except for groups of points along parallel lines oriented at a sixty degree slope. These residual patterns are associated with the use of quantized signal levels used to predict discrete depths rather than continuous levels. This effect will be most pronounced in deeper waters where there are just a few Landsat raw data count changes over a large range of depths. In these cases a single depth is predicted for pixels having a range of measured depths. The residual is a simple linear function of the measured depth. Outside of these patterns, the residuals appear to be random. When this analysis process was repeated using all six dates, the standard error of the estimate increased from 2.38 to 5.27 meters. This increase is expected, given that the latter three scene dates are of relatively poorer quality as discussed in section 5.1. A further comparative analysis was made by using only the first and best scene date (25 Feb 77). The resulting regression equation is given as equation 6.3 in Table 6. Plots of this regression analysis and residual errors are shown in Figures 5 and 6 respectively. The standard error of 3.99 meters is approximately 3 times that obtained for the three date case above. This comparison suggests that the primary effect of using the multiple dates was simple reduction of random noise.

In the second type of analysis performed on these data, Landsat predicted depths were simply averaged on a pixel by pixel basis with no parameter adjustments from those originally assumed. Averages for three and six date cases are plotted against measured ship depths as well as

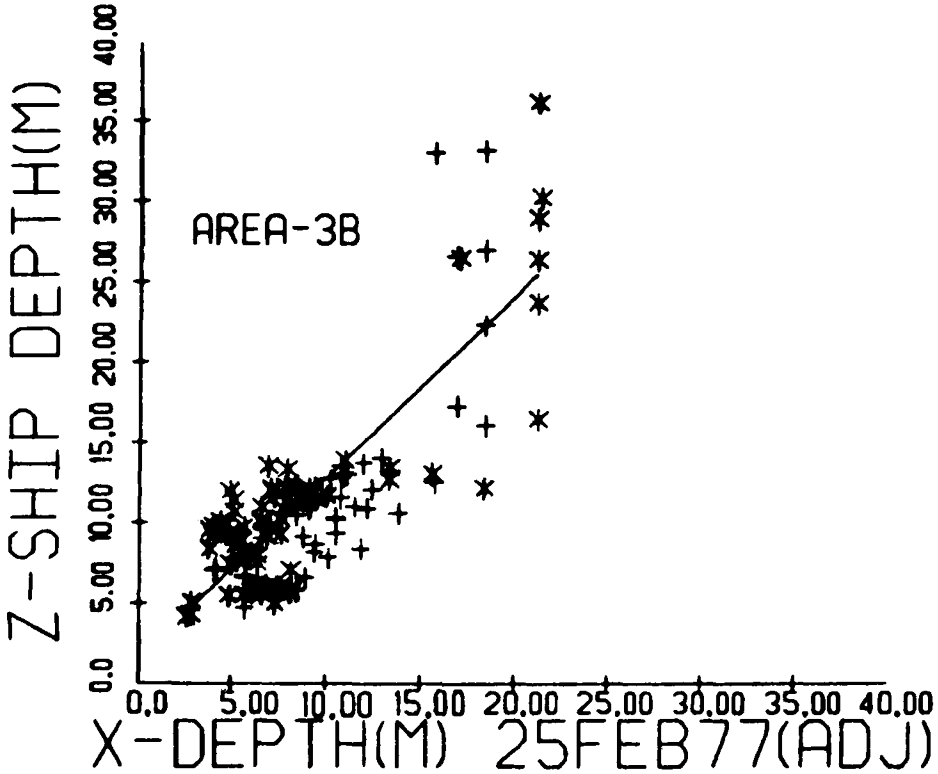

Figure 3. Scatter Plot of the Measured Ship Depths and Landsat Adjusted Average Depths. The regression line (z = 1.129 x +1.510) is based upon points (1-75) shown with the * symbol. The + symbol denotes other points in the 3B data set (76-231).

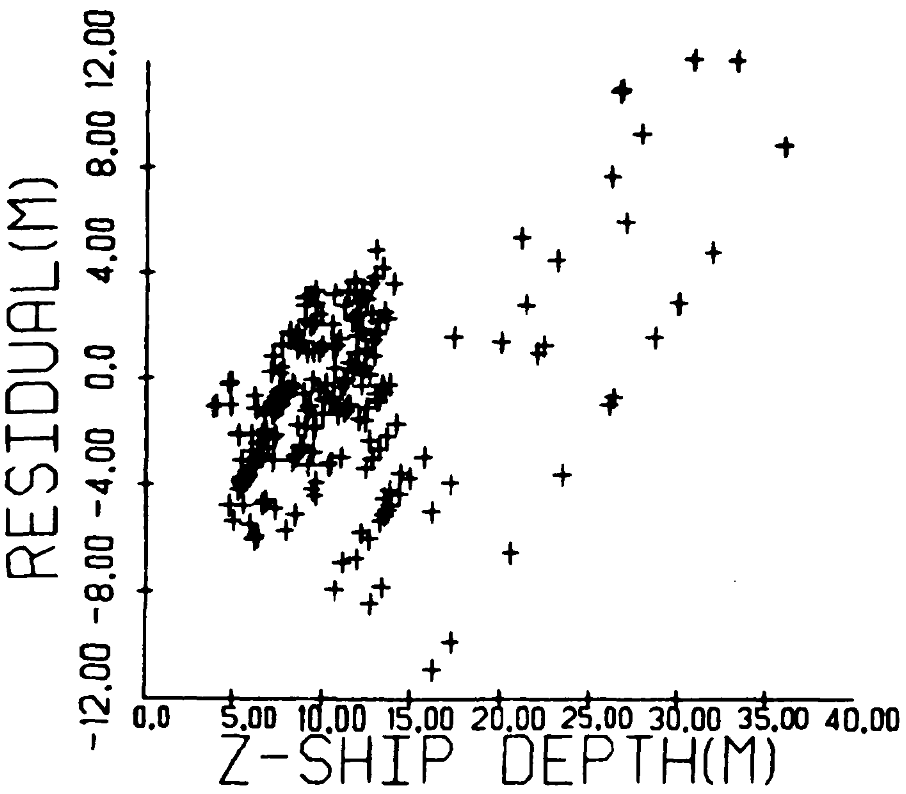

Figure 4. Scatter Plot of Residual Errors of the Regression Estimate (see Figure 3) versus the Measured Depth.

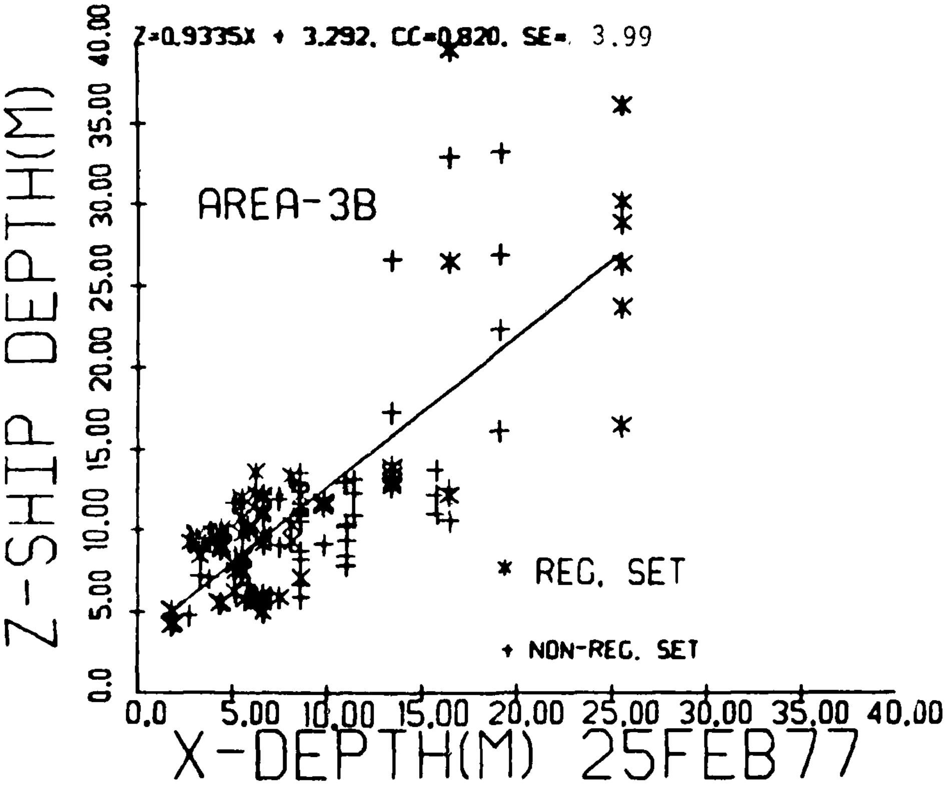

Figure 5. Scatter Plot of the Measured Depths Versus Landsat Predicted Depths from the 25 February 77 Scene. The regression line (z = 0.933 x +3.292) is based upon points (1-75) shown with * symbol. Other points (76-231) are shown with a + symbol.

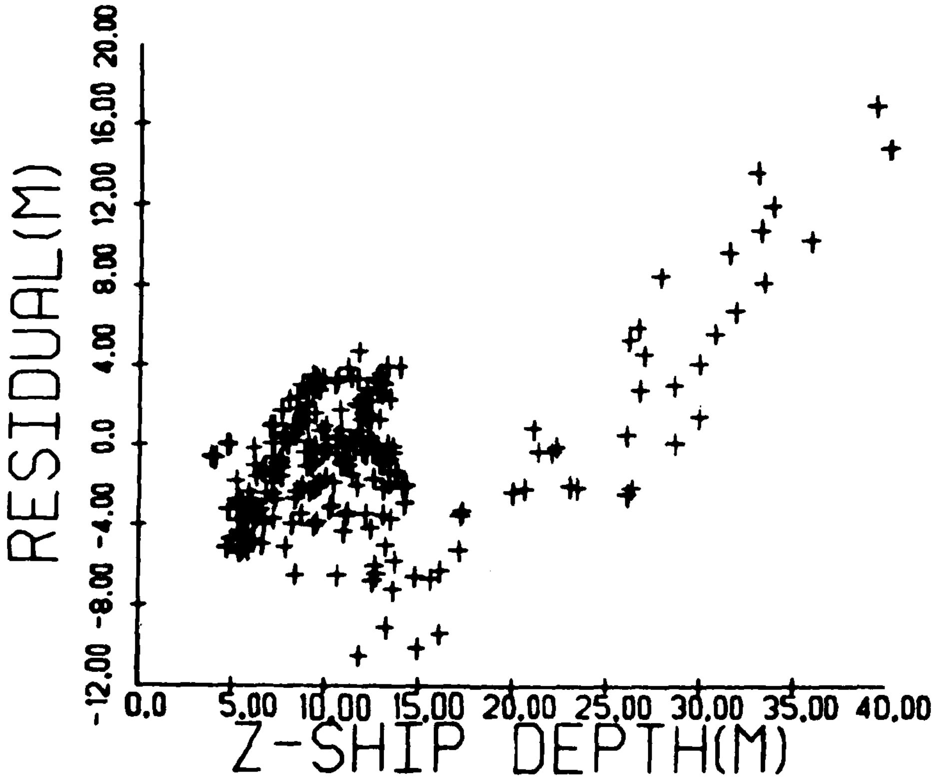

Figure 6. Scatter Plot of Residual Errors of the Regression Estimate (See Figure 5) versus the Measured Depth.

depth differences in Figures 7 through 10. Correlation coefficients of 0.840 and 0.855 were obtained between the three-date and six-date averages and the measured ship depths respectively. The six date average produced a slightly tighter grouping of plotted points in the 5 to 15 meter depth range than the three date case indicating this average was less sensitive to actual depth changes. Thus while the straight averaging process will tend to reduce absolute errors in mean depth as described above, the average as a best predicted depth will show greater absolute errors as water depths deviate from the mean. If one can effectively reduce the constant differences between predicted and measured depths then the adjusted averaging process appears to be superior to straight averaging of multidate extracted depths.

5.3 MULTI-TEMPORAL ANALYSIS PROCEDURES ON THE DIPS

The results described above should not be construed as an evaluation of the MTP software capabilities; rather they are results obtained with MTP type operations which were considered appropriate to the available data set. As previously stated, evaluation must be made on the basis of analysis of several sets of multi-temporal remote sensing data. The following descriptions are intended as representative analysis procedures which could be carried out on the DIPS with the aid of the ERIM developed software.

In each of the following examples it is assumed that necessary preparation procedures (image to image warping, etc.) have been carried out as described in section 3.4 and the DIPS operator manuals. For each date the best available parameter estimates have been used with the DIPS DEPTH routine to convert the Landsat signal levels at each pixel in a 512 x 512 subarea to an estimated water depth. At this point the operator can call up the MTP menu and have the following selection of operations:

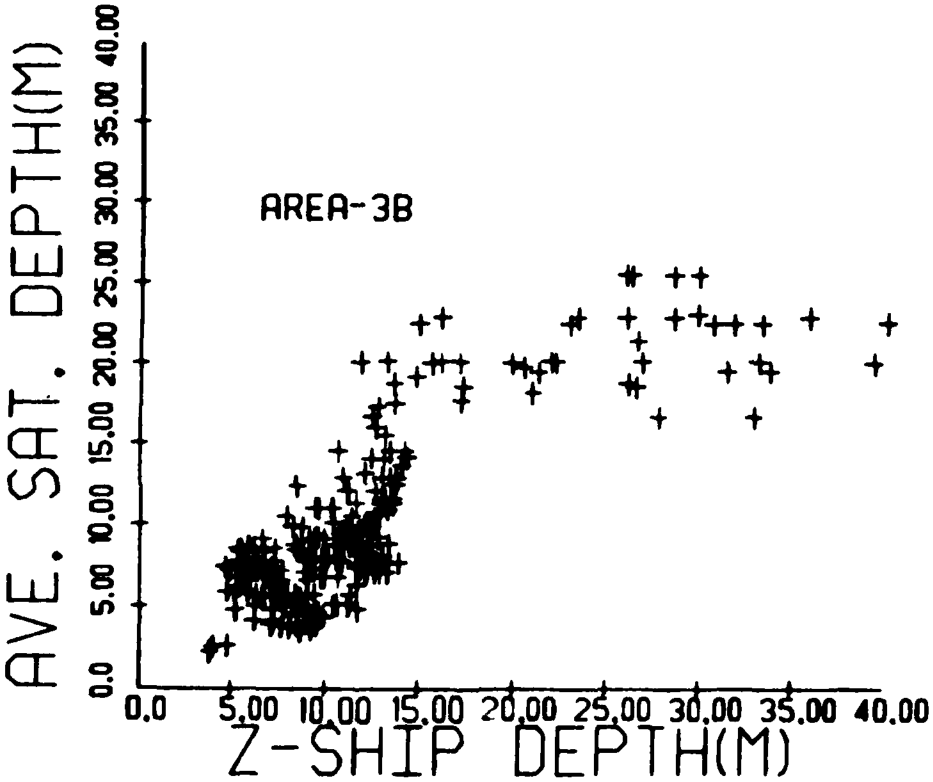

Figure 7. Scatter Plot of Unadjusted Average Landsat Predicted Water Depth for 25 Feb 77, 3 Feb 77, and 29 Dec 74 versus the Measured Depth.

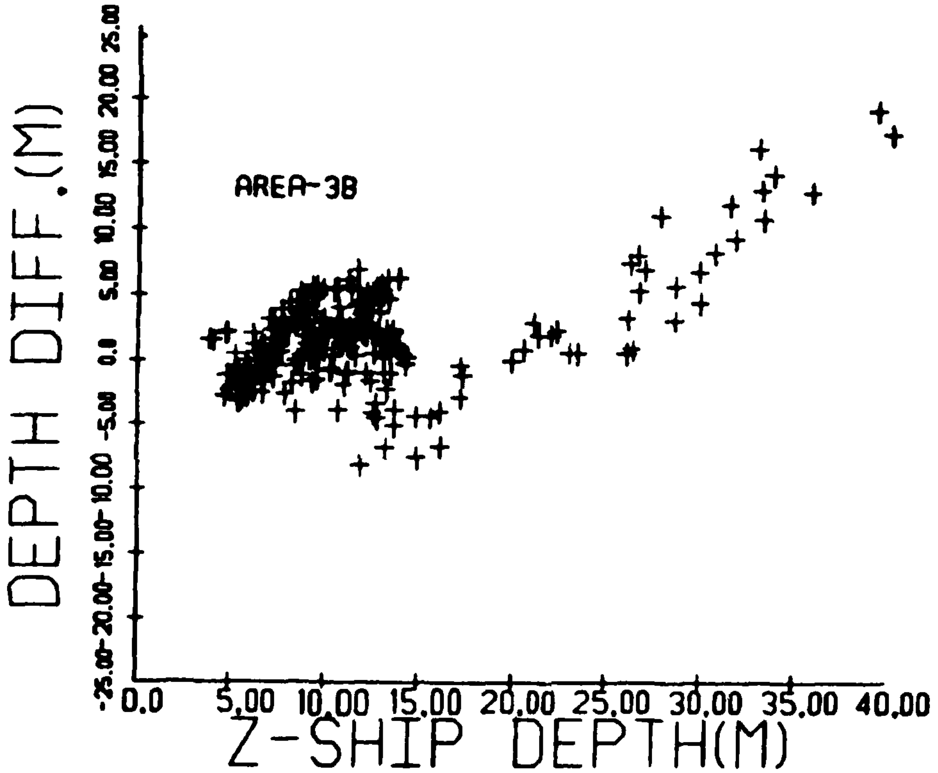

Figure 8. Scatter Plot of the Residual of the Unadjusted Average Predicted Depth versus the Measured Depth (see Figure 7).

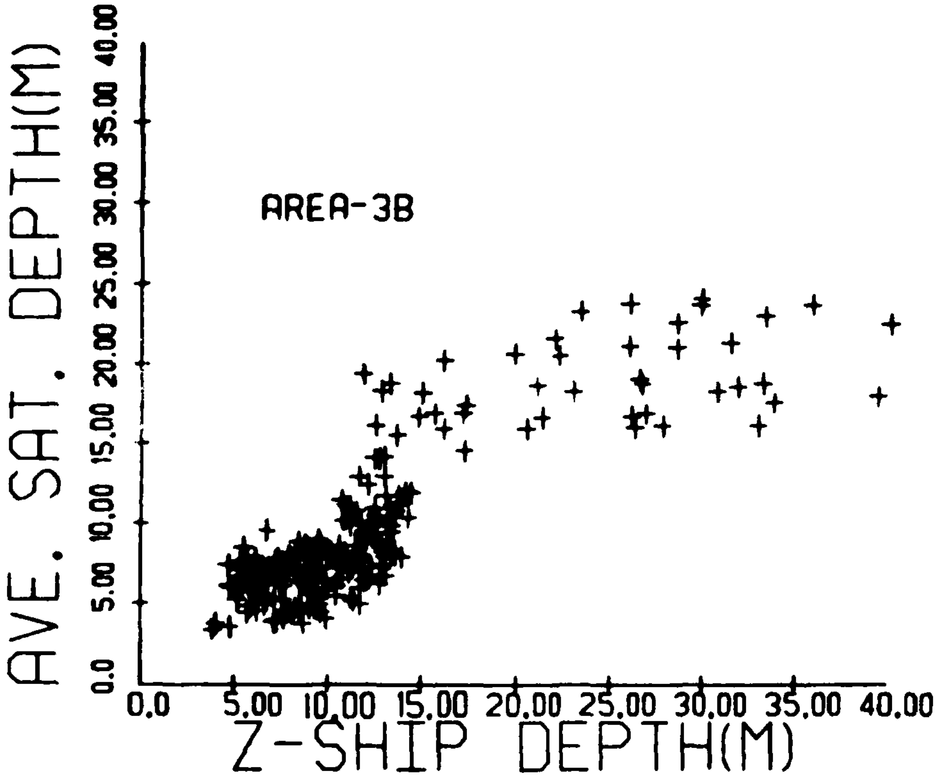

Figure 9. Scatter Plot of the Unadjusted Average Landsat Predicted Water Depth for All Six Available Dates Versus the Measured Depth.

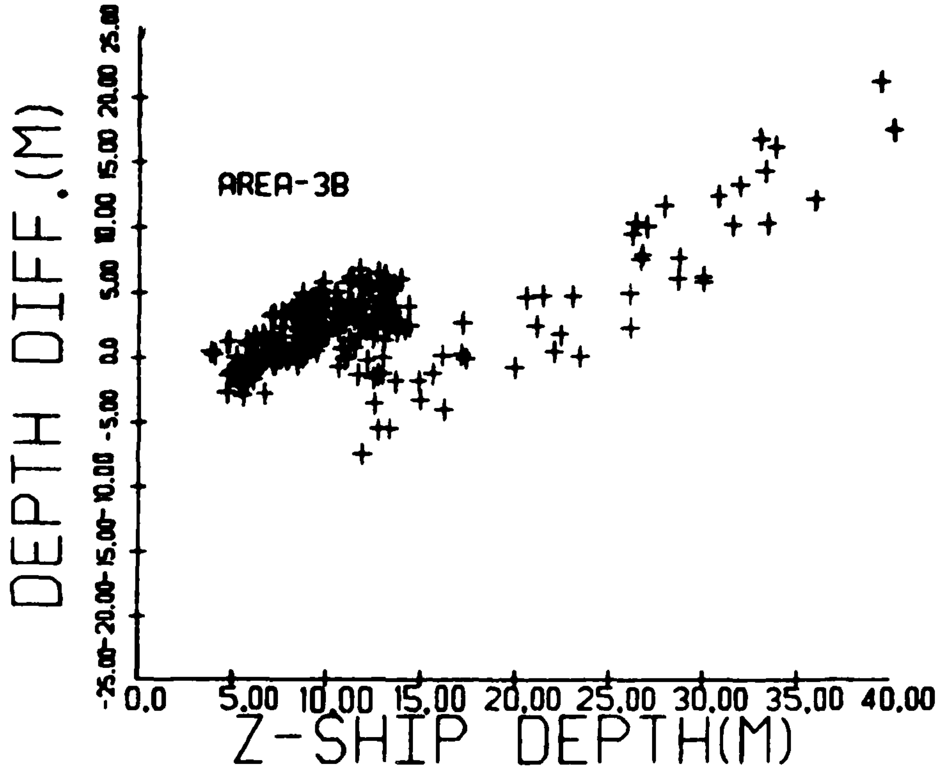

Figure 10. Scatter Plot of the Residual of the Unadjusted Average Predicted Depth versus the Measured Depth (see Figure 9).

Multi-temporal Program Depth Analysis Sub-Menu

1. Load image files to display.
2. Select image plane for viewing.
3. Conduct simple operations between image planes.
4. Select smoothing operation.
5. Select polygon areas.
6. Make scatterplots and calculate regression statistics for pixels within polygon(s).
7. Extract statistics from polygon area(s).
8. Apply regression coefficients to adjust depth algorithm parameters.
9. Estimate parameter error propagation.
10. Exit menu.

The following four examples are considered representative of the types of water depth problems for which the MTP software could help to enhance the depth estimates. In each case the objective is to extract the water depth information from remote sensor data given available surface truth measurements and water calibration depths.

(1) Assume we are examining a small area with uniform bottom type but with unknown reflectance. Suppose further there exists a large K difference between the available scene dates as ascertained with the SCATTERPLOT routine. Use regression to estimate the K difference pairwise for the scene dates. Return to the DEPTH routine and treat the pairs of dates as pairs of wavelengths in the ratio algorithm which eliminates the need for a specific bottom reflectance coefficient.

(2) Assume that the K value is constant but unknown for the available scene dates. Suppose that for at least two of the dates there exists a known tidal state change. Use the SCATTERPLOT and REGRESSION routine to confirm the offset in predicted water

depth due to tidal state. Use the regression slope information and the APPLY routine to remove any differences in K type parameters from the data. Use the APPLY routine to calculate the predicted depth difference between scenes (pairwise) and the STATISTICS EXTRACTION routine to compute the average difference. Adjust the K parameter by the ratio of this average to the known tidal state change and recalculate using the DEPTH routine. Actually we do not have to assume a constant K from scene to scene since the differences can be assessed from the REGRESSION coefficients and adjusted individually by the tidal state factor.

(3) Assume we are examining a large area with variable bottom reflectance. Use the SCATTERPLOT, REGRESSION, and APPLY routines to adjust out scene-wide K and r type parameter differences. Group the available scene dates into two groups according to known high or low tidal state. Adjust each scene date using the APPLY routine to add (or subtract) a constant from each pixel depth so as to transform the data to a state of normal high or normal low tidal state. Even though the residuals appear to be random errors about the tidal difference they may contain systematic spatial components due to bottom reflectance variations. A depth difference map(s) can be computed using the APPLY routine and subsequently loaded into the available Comtal image planes using the LOAD option. If the difference maps display patterns which correlate with bottom features as determined from aerial photos, ship surveys, or knowledge of coastal processes, then such difference maps can be used with the MTP software to essentially adjust the bottom reflectance on a pixel by pixel basis. The depth difference maps should have similar features and are essentially equivalent since the scenes have been normalized for K and tidal state differences. Random features in these difference maps suggest that the

influence of spatially varying noise due to atmospheric conditions is evident. In the former case, bottom reflectance adjustments can be accomplished as follows. First the depth difference maps (high minus low tide) should be smoothed and averaged (for usable scene dates) to reduce random noise components. Pixels in the resulting difference map which have value greater than the average (normal high tide minus normal low) suggest a bottom reflectance which is greater than that assumed in the original calculations. Alternatively those with lower value suggest a lower value in bottom reflectance. Depth deviations due to bottom reflectance are calculated by simply subtracting the mean difference (using APPLY). These deviations can then be subtracted from the individual scenes to remove the unwanted effects due to bottom reflectance variations.

(4) For this case surface truth measurements are available to calibrate water depths extracted from remote sensing data. First the SCATTERPLOT and REGRESSION routines are used to analyze the multitemporal data set as in the previous examples. Having done so, the APPLY routine is used to adjust date-to-date differences due to algorithm parameter variations. At this point the multidate sets are essentially equivalent and any remaining date to date differences are likely due to random noise components. The best depth estimate, in this case, is a pixel-by-pixel average over the available scene dates. This latter estimate is the best one can do without supporting surface truth calibration data. The extent to which such truth data can be used to improve the predicted depths depends on its quality and applicability. The level of representativeness dictates the spatial area(s) of the subarea where calibration depths can be used to make further adjustments to the remote sensor extracted water depths. Three types of conditions seem important. (1) If the measured depths are evenly distributed

across the subarea and if they cover a sufficiently wide range of depths then, resulting calibrated predictions can be applied to the entire subarea. (2) If on the other hand the measured depths are taken from a single small area then it is doubtful that they could be applied elsewhere in the subarea. (3) If multiple calibration areas are used and each representative of a separate bottom type, it may be possible to iterate over values of bottom reflectance to obtain a suitable fit for each calibration area. Depth algorithms calibrated in this way could be applied to other locations in the subarea with similar bottom types.

6.0

CONCLUSIONS AND RECOMMENDATIONS

The project discussed in the report documents ERIM's effort to develop a multi-temporal processing algorithm for DMA's Digital Image Processing System (DIPS). The project utilized a Landsat Multidate data set which includes the Bahamas Photobathymetric Calibration Area. The processing algorithm developed, however, is not dependent on the specific use of Landsat data but rather can be applied in principle to any multitemporal data set. Development and evaluation of this algorithm as discussed in section 5.0 and elsewhere has led to the following conclusions and recommendations.

6.1 CONCLUSIONS

(1) The multi-temporal algorithm developed under this contract and its accompanying software could not be fully implemented on the ERIM PDP/11 computer because of critical differences in the DIPS hardware and software. This situation precluded any multi-temporal image processing. In view of this situation a data set was assembled consisting of coincident ship survey data and multi-date Landsat signal values.

(2) The available Bahamas Landsat data was found to vary widely from data to date in terms of its utility for water depth extraction and for multi-temporal processing. The observed variation is considered to be due principally to atmospheric and system noise. Of the six available data sets, three were found to be of comparably good quality and three of relatively poor quality. When we attempted to utilize any of these latter scene dates, the predicted depths were less reliable when compared to measured ship survey soundings. In view of this experience it is concluded that preliminary quality review and noise analysis must accompany the selection of comparable multi-date imagery. Further this experience suggests that a typical multi-date Landsat data set will consist of two or three scenes.

(3) During the present study, three multi-temporal depth procedures were implemented. In the first procedure, ship transect data was used along with data from the three best dates to obtain an averaged depth file by first adjusting parameters of the depth algorithm for each date to minimize the mean square errors between calculated and ship data, then averaging the three revised depth files. In the second procedure, the depth files from the three best dates were adjusted, then the files averaged. Results were compared to ship data. In the third procedure, depth files from the best three dates were simply averaged, with no parameter adjustments, and results compared to the ship data.

Results were evaluated by assessing the bias (mean error) and standard error (mean square error) between the ship data and the resultant average depth files. Results are shown in Table 9. For the first procedure, the bias is identically zero as a result of the least squares regression normalization. The standard error, for the points examined, is 2.38 m. Because this error depends on depth, the standard error for a set of points different from those used for this analysis will generally not be the same as the standard error we obtained. For procedure 2, there was a bias of 1.51 m and the same standard error, 2.38 m. Bias occurs because ship data were not used in the normalization procedure. Procedure 3 produced a bias of 1.94 m and a standard error of 4.13 m. These numbers are poorer than for procedure 2 because no parameter normalization was performed. The differences between the biases and standard errors of procedure 2 and procedure 3 are an indication of the improvement brought about by parameter normalization. The increase in bias of procedure 3 when going from three scenes to six may be a reflection on the poorer data quality of the additional three scenes.

Another evaluation of procedure 1 was to compare standard errors of one, two, and three data average depth files. Results are shown in Table 10. The fact that the three data standard error is lower than the one date standard error shows the improvement to be obtained using the multi-temporal procedure. The results for two dates appears anomalous, but few definitive conclusions can be drawn based on this data set alone.

TABLE 9

COMPARISON OF BIAS AND STANDARD ERROR FOR THREE MULTI-TEMPORAL DEPTH TECHNIQUES

Procedure	Bias (m)	Standard Error (m)
(1) Parameter normalization with ship data - 3 scene	0	2.38
(2) Parameter normalization without ship data - 3 scene	1.51	2.38
(3) Straight average no normalization - 3 scene	1.94	4.13
- 6 scene	2.71	4.13

TABLE 10

COMPARISON OF PROCEDURE 1 USING ONE, TWO, AND THREE DATE DEPTH DATA

Number of Dates	Standard Error (m)
1	2.89
2	3.1
3	2.38

(4) Because of the complex character of the Bahamas multi-date Landsat data set it is not possible to predict general performance of the algorithm for other such data sets and for other types of multi-temporal data from which bathymetric/hydrographic information could be extracted.

(5) The multi-date algorithm has been designed with flexibility of precise procedure to allow the DIPS operator to investigate various processing procedures to enhance not only the accuracy of water depth predictions but also the image detection of submerged hazards.

(6) The application of Kalman filtering theory was briefly investigated as a basis for a multi-temporal algorithm. The Kalman theory presents a very generalized least squares formulation adaptable to

imperfect parameter information and various Gaussian noise variables. This approach was, however, considered infeasible because of a practical requirement for large number of scene dates. Because of the expected limited number of dates available for any one scene, it is concluded that the multi-temporal algorithm must be so formulated to rely more heavily on the spatial variations within any one scene and less on the actual date-to-date variations for any scene location (pixel).

6.2 RECOMMENDATIONS

(1) The algorithm developed for multi-temporal remote sensing data should be evaluated against other Landsat multi-date sets and also those that may be derived from aircraft and other sources of high resolution spatial information systems.

(2) Research and development should be initiated to construct an algorithm which normalizes satellite and aircraft radiometric data on a pixel-by-pixel basis so as to extend the applicability of water depth predictions beyond the immediate area of surface truth.

(3) Since the software delivered to DMA/HTC has not been completely checked out we recommend DMA staff, familiar with DIPS, to initiate a test using the Bahamas data set. Documentation files provided with the delivered software are sufficient to allow installation and operation.

(4) Since DMA has a requirement to upgrade the DIPS as improved and special purpose algorithms are developed, it would be advantageous to have a DIPS simulator on the ERIM PDP/11 to provide a means for complete checkout of future software and to allow development of special options to operator processing procedures.

REFERENCES

1. Stewart, L.L. Preliminary Report on the Photobathymetric Calibration Project Great Bahama Bank, 7 July-2 August 1980, University of Connecticut, Marine Sciences Institute, September 1980.

2. Doak, E., J. Livisay, D. Lyzenga, J. Ott, and F. Polcyn, Evaluation of Water Depth Extraction Techniques Using Landsat and Aircraft Data, ERIM Report No. 135900-2-F, January 1980.

3. Lyzenga, D.R., and F.C. Polcyn, Analysis of Optimum Spectral Resolution and Band Location for Satellite Bathymetry, ERIM Report No. 128200-1-F, January 1978.

4. Polcyn, F.C., F.J. Tanis, and J.P. Livisay, Photobathymetric Calibration Project Great Bahama Bank, 7 July-2 August 1980, ERIM Report 154100-9-F, May 1982.

5. Digital Image Processing System User's Manual DBA Systems, Inc., Under Contract DMA800-78-C-0101, 8 November 1979.

6. Naylor, L.D. Status of Equipment for Exploitation of Landsat Data, USG Memorandum, 28 October 1981.

APPENDIX A

SOFTWARE DESCRIPTION AND INSTALLATION INSTRUCTIONS

This Appendix contains listings of documentation files as provided on the ERIM generated magnetic tape. These listings include INSTALL.DOC which provides detailed instructions to DMA DIPS operators on the proper installation of the ERIM MTP software. Also included are documentation files describing the overall MTP software (OVERVIEW.DOC), a checkout procedure (CHECKOUT.DOC), and a sequence for running the various MTP menu options (RUNNING.DOC).

```
README1ST.DOC RHH ERIM NOV. 1982

        THIS "README1ST.DOC" FILE IS THE FIRST DOCUMENTATION FILE YOU SHOULD
READ FOR THE ERIM MTP MULTI-TEMPORAL PROCESSING DEPTH ALGORITHM SOFTWARE.
FOR INSTALLATION SEE INSTALL.DOC AND INSTALL.CMD.  OTHERWISE, USE README1ST.DOC
TO DIRECT YOU TO ALL THE OTHER DOCUMENTATION, AS FOLLOWS:

        1) INSTALL.DOC  -- PROVIDES DOCUMENTATION AND A COMMAND FILE TO
           INSTALL.CMD     INSTALL THE ERIM SOFTWARE AUTOMATICALLY AND
                           PAINLESSLY (WELL, ALMOST, WE HOPE).

        2) OVERVIEW.DOC -- PROVIDES AN OVERVIEW OF THE ERIM MTP SYSTEM.

        3) CHECKOUT.DOC -- DISCUSSES USE OF SAMPLE DATA FOR A RUNTHROUGH TO
                           SEE IF YOU GET THE SAME RESULTS WE DO.  THE FOLLOWING
                           RUNNING.DOC SHOULD BE READ IN CONJUNCTION WITH THIS.

        4) RUNNING.DOC  -- DESCRIBES GENERALLY WHAT YOU WANT TO DO WITH THE
                           VARIOUS PARTS OF THE MTP SYSTEM FROM AN OVERALL
                           ALGORITHMIC VIEWPOINT, AND DESCRIBES THE
                           SIGNIFICANT OPTIONS AVAILABLE IN THE PROGRAMS.
                           IT WILL BE USEFUL TO READ CHECKOUT.DOC WITH THIS.

********************************************************************************
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THE INDIVIDUAL PROGRAMS ARE:

1) MUJ -- MAIN MENU AND DRIVER PROGRAM MODIFIED FOR ERIM

2) ESCATT -- NEW SCATTERPLOT AND REGRESSION PROGRAM

3) EAPPLY -- NEW PROGRAM TO CALCULATE MODIFIED DEPTH IMAGE

4) EERROR -- NEW PROGRAM TO CALCULATE ERROR PROPAGATION

5) DEPTH -- MODIFIED DIPS SINGLE-TIME DEPTH ALGORITHM TO PUT OUT INFORMATION NEEDED BY ERIM MTP PROGRAMS (VIA MODIFIED KDP AND IMDEEP SUBROUTINES, Q.V.)

6) KDP -- MODIFIED KDP KNOWN DEPTH POINT SUBROUTINE FOR DEPTH

7) IMDEEP -- MODIFIED IMDEEP DEPTH IMAGE GENERATION SUBROUTINE FOR DEPTH

8) EPOLY -- NEW INTERFACE TO ALLOW USING ORIGINAL DIPS POLYGON DEFINITION ROUTINES FROM ERIM MTP MENU FOR CONVENIENCE

9) ESMOTH -- NEW INTERFACE TO ALLOW USING ORIGINAL DIPS SMOOTHING ROUTINES FROM ERIM MTP MENU FOR CONVENIENCE

10) AREA -- DIPS POLYGON SUBROUTINE WITH ERROR FIXED FOR ESCATT

OTHER EXISTING ROUTINES REUSED BY THE ERIM MTP MENU FOR CONVENIENT ACCESS ARE NOT MODIFIED:

11) PICTTA -- TASK TO LOAD IMAGES INTO COMTAL IMAGE PLANES

12) CCYTTA -- TASK TO CYCLE COMTAL IMAGE PLANES FOR VIEWING

13) CAYTTA -- TASK TO PERFORM MISCELLANEOUS IMAGE OPERATIONS (SUCH AS ADDING TWO IMAGES, OR SCALING).

14) HISTTA -- TASK TO HISTOGRAM AN IMAGE.

THE PROGRAM SOURCE CODE FOR ALL NEW ERIM PROGRAMS, AND THE SECTIONS OF DIPS PROGRAMS MODIFIED FOR ERIM USE, ARE GENERALLY REASONABLY THOROUGHLY COMMENTED AND SELF-DOCUMENTING THROUGHOUT (UNLIKE MUCH OF DBA'S DIPS SOFTWARE). ALSO, THE PROMPTS FOR USER INPUT ARE INTENDED TO BE AS SELF-DESCRIPTIVE AS POSSIBLE (LIKE DBA'S), AND CONSISTENT WITH DBA'S USAGE AND STYLE.

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        IN ADDITION TO THE OVERALL DOCUMENTATION FILES REFERENCED ABOVE, THIS
DISSEMINATION TAPE SHOULD INCLUDE THE FOLLOWING FILES.

        FIRST, FOR THE ERIM PROGRAMS AND ERIM-MODIFIED DIPS PROGRAMS:

           PROGRAM       FILE EXTENSIONS INCLUDED (USUAL MEANINGS)
           -------       ----------------------------------------
        1) MUJ           .FTN     .F4P     .TKB     .OBJ     .LST
        2) ESCATT        .FTN     .F4P     .TKB     .OBJ     .LST
        3) EAPPLY        .FTN     .F4P     .TKB     .OBJ     .LST
        4) ERROR         .FTN     .F4P     .TKB     .OBJ     .LST
        5) EPOLY         .FTN     .F4P     .TKB     .OBJ     .LST
        6) ESMOOTH       .FTN     .F4P     .TKB     .OBJ     .LST
        7) DEPTH(OLD)*   .FTN              .TKB     .OBJ     .LST
             "                             .ODL
        8) KDP           .FTN     .F4P              .OBJ     .LST
        9) IMDEEP        .FTN     .F4P              .OBJ     .LST
       10) AREA          .FTN                       .OBJ     .LST
* DEPTHOLD.FTN IS UNCHANGED FROM THE ORIGINAL DIPS DEPTH.FTN.  IT IS INCLUDED HERE
  FOR COMPLETENESS SINCE IT IS NECESSARY FOR RE-TASKBUILDING DEPTH TO INCLUDE
  THE ERIM-MODIFIED SUBROUTINES KDP AND IMDEEP FOLLOWING.  IT IS STORED IN
  FILE NAME "DEPTHOLD.FTN" AS A REMINDER OF THIS.

        SECOND, FOR INSTALLING:

        1) INSTALL.CMD  -- (AS MENTIONED ABOVE TO INITIALLY SET UP ERIM SOFTWARE).
        2) STTD,1,2.CMD -- ERIM MODIFIED STANDARD DIPS COMMAND FILES TO INSTALL TASKS
        3) STTS,1,2.CMD -- ERIM MODIFIED STANDARD DIPS COMMAND FILES TO REMOVE TASKS
        4) IMAGE.CMD    -- ERIM MODIFIED STANDARD DIPS COMMAND FILE TO START UP DIPS
        5) ERIM.CMD     -- COMMAND FILE TO DO ONLY THE ERIM PART OF STTS.CMD

        AND THIRD, FOR DATA TO CHECK THE SOFTWARE INSTALLATION (FOR USE SEE
        CHECKOUT.DOC):

        1) DMA1,2,3,4.IMG -- BAHAMA IMAGES, BAND 4, AT 4 TIMES (REGISTERED DEPTH IMAGES)
        2) DMAAV1234.IMG  -- EQUALLY WEIGHTED AVERAGE OF ABOVE 4 DEPTH IMAGES,
                             AS GENERATED BY EAPPLY AND USED AS A REFERENCE
                             IMAGE FOR ESCATT
        3) BIMPOL2.POL    -- POLYGONS APPLYING TO ABOVE IMAGES, AS EXTRACTED
                             DURING THE DEMO ON OCT. 1 AT DMA
        4) ESCATT.DAT;1...4 (COPIES.DAT;1...4) -- SAMPLE SCATTERPLOT/REGRESSIONS
                             FROM RUNNING ESCATT ON DMA1...4.IMG VERSUS DMAAV1234.IMG
                             WITH BIMPOL2.POL POLYGONS (EXCEPT DEEP WATER).
```

```
INSTALL.DOC RHH ERIM NOV. 1982

        DOCUMENTS PROCEDURES FOR INSTALLING ERIM MULTI-TEMPORAL PROCESSING
DEPTH ANALYSIS SOFTWARE ON THE PDP 11/45 AT DMA.

        THE ERIM MTP DEPTH ANALYSIS SOFTWARE CAN BE INSTALLED ON DMA'S 11/45
BY DOING THE FOLLOWING STEPS:

     1) MCR>HELLO 30,2/ERIM
        LOG ON [30,2] (THE UIC USED FOR THE ERIM SOFTWARE)
     2) MCR>PIP *.*;*/DE
        CLEAN OFF ANY FILES LEFT FROM THE PREVIOUS USE
     3) MCR>MOUNT MT0:DMA
        MOUNT THE ERIM DISSEMINATION TAPE (NOTING VOLUME LABEL=DMA; 800 BPI; AND
        BLOCKSIZE BS:512., THE DEFAULT ON THE 11/45, FOR EASIEST COMPATIBILITY).
     4) MCR>PIP =MT0:[*,*]*.*;*
        COPY IN A COMPLETE SET OF NEW SOFTWARE, COMMAND FILES, DOCUMENTATION,
        AND TEST DATA FROM THE TAPE.
     5) MCR>@INSTALL.CMD
        USE THE INSTALL COMMAND FILE TO AUTOMATICALLY COMPILE AND TASKBUILD
        ALL NEW AND MODIFIED PROGRAMS.
     6) MCR>BYE
        MCR>HELLO 3,2
        LOG ON THE PRIVILEGED MASTER UIC TO COPY SOME STARTUP COMMAND FILES:
     7) MCR>PIP /NV=[30,2]STT0.CMD,STT1,STT2,ETT0,ETT1,ETT2,IMAGE
        COPY IN A NEW VERSION OF THE DIPS COMMAND FILES TO INSTALL OR REMOVE
        ALL THE ORIGINAL DIPS, ERIM MODIFIED, AND NEW ERIM TASKS.
     8) MCR>@IMAGE
        FINALLY, INITIALIZE DIPS WITH THE NEW ERIM TASKS IN THE USUAL WAY.

*****************************************************************************
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* * *

THE FOLLOWING DISCUSSION IN SIMILAR TO THE COMMENTS AND SELF-DOCUMENTATION IN THE INSTALL.CMD FILE, Q.V.

THE INSTALL.CMD FILE INSTALLS ALL ERIM MULTI-TEMPORAL PROCESSING PROGRAMS. THIS SOFTWARE IS ASSUMED TO BE PUT ON [30,2], WHICH SHOULD BE CLEANED OFF FIRST. THEN LOG ON [30,2] AND DO MCR>@INSTALL. (A FEW COMMAND FILES WILL HAVE TO BE COPIED TO [3,2] SUBSEQUENTLY).

IT IS ASSUMED THAT [3,2] HAS HC.OLB, SYST.INC, PMCOM.INC, AND THE SYST.OBJ RESIDENT COMMON, WHILE [120,100] HAS TCSLIB.OLB (NONE SUPPLIED ON THE ERIM TAPE).

SINCE EVERYTHING HAD TO BE RUN ON THE ONE UIC [30,2] AT ERIM, THE INSTALL COMMAND FILE PLUS *.F4P AND *.TKB FILES COULD NOT BE TESTED. IT IS POSSIBLE THERE ARE SOME MINOR EDITING ERRORS CONVERTING FOR INSTALLATION ON THE DMA 11/45, PARTICULARLY IN REFERENCING FILES ON OTHER UIC'S. I APPOLOGIZE FOR ANY INCONVENIENCES THIS MAY CAUSE.

THE *.OBJ AND *.LST FILES ARE INCLUDED ON THE ERIM TAPE, BUT IT IS BEST, TO INSURE THAT YOU HAVE A COMPLETE COMPATIBLE SYSTEM, TO REGENERATE THEM FROM FORTRAN SOURCE CODE AND THE *.F4P, *.TKB COMMAND FILES AS IS DONE IN THE INSTALL.CMD FILE.

```
        ENTIRELY NEW ERIM TASKS INSTALLED ARE:
                  1) ESCATT -- SCATTERPLOT AND REGRESSION
                  2) EAPPLY -- COMPUTE MULTI-TEMPORALLY ADJUSTED NEW DEPTH IMAGE
                               (ALSO USEFUL TO GET AN AVERAGE OF UP TO 5 DEPTH IMAGES)
                  3) EERROR -- CALCULATE ERROR PROPAGATION
MODIFIED DIPS ROUTINES ARE:
                  4) MCU    -- MAIN MENU PROGRAM, MODIFIED TO ADD ERIM MENU
                  5) DEPTH  -- ORIGINAL DIPS SINGLE-TIME DEPTH ALGORITHM, WITH
                               KDP (KNOWN DEPTH POINTS) AND IMDEEP (DEPTH IMAGE
                               GENERATION) MODIFIED TO PROVIDE OUTPUTS FOR
                               ERIM PROGRAMS
SOME DIPS ROUTINES ARE REUSED HERE FOR CONVENIENCE VIA NEW ERIM INTERFACES:
                  6) ESMOTH -- NEW INTERFACE TO CALL EXISTING SMOOTHING ROUTINES
                  7) EPOLY  -- NEW INTERFACE TO CALL EXISTING POLYGON DEFINITION
AND FINALLY SOME ORIGINAL DIPS TASKS COULD BE REUSED WITHOUT ADAPTION:
                  8) DISTTA -- LOADING IMAGES ONTO COMTAL
                  9) DCITTA -- CYCLING IMAGE PLANES FOR DISPLAY
                 10) RAMTTA -- IMAGE CALCULATIONS (E.G. ADDING TWO IMAGES)
                 11) HISTTA -- HISTOGRAM IMAGES.
```

* * *

SUBROUTIN'S KDP AND IMDEEP IN THE ORIGINAL DIPS DEPTH TASK MUST BE MODIFIED. COMMAND FILES KDP.F4P, IMDEEP.F4P AND DEPTH.TKB (ONLY!) ARE INCLUDED (KDP.F4P AND IMDEEP.F4P INVOKE DEPTH.TKB FOR DEBUGGING KDP AND IMDEEP). ALSO FOR COMPLETENESS THE ORIGINAL DIPS DEPTH.FTN (AS "DEPTHOLD.FTN") AND MATCHING DEPTH.OBJ AND DEPTH.LST ARE INCLUDED ON THE ERIM TAPE. HOWEVER IT WOULD BE SAFEST TO USE THE ORIGINAL DIPS DEPTH FROM [3,2] IN CASE IT HAS ANY REVISIONS

FINALLY, YOU MAY WANT TO PUT KDP.OBJ, IMDEEP.OBJ, AND AREA.OBJ IN THE MASTER LIBRARY[3,2]HC.OLB CONSISTENT WITH PRIOR DIPS USE (AND SUBSEQUENTLY USE [3,2]DEPTH.F4P AND DEPTH.TKB NORMALLY).

IF YOU WISH TO PUT ALL ERIM PROGRAMS UNDER [3,2] ALONG WITH THE ORIGINAL DIPS PROGRAMS, THERE PROBABLY WILL BE NO PROBLEMS. JUST CHECK FOR EXPLICIT REFERENCES TO THE UIC [30,2]. I INTENTIONALLY LEFT THEM IN FOR THE STT0,1,2 AND IMAGE COMMAND FILES AND MODIFIED [30,2]DEPTH.TKB FILES, AND MAY HAVE OVERLOOKED SOME ELSEWHERE.

```
; [30,2]INSTALL.CMD PHH ERIM NOV, 1982
;        THIS FILE INSTALLS ALL ERIM MULTI-TEMPORAL PROCESSING PROGRAMS.
; THIS SOFTWARE IS ASSUMED TO BE PUT ON [30,2], WHICH SHOULD BE CLEANED OFF
; FIRST.  THEN LOG ON [30,2] AND DO MCR>@INSTALL.
; (A FEW COMMAND FILES WILL HAVE TO BE COPIED TO [3,2] SUBSEQUENTLY).
;
; IT IS ASSUMED THAT [3,2] HAS HC.OLB, SYST.INC, PMCOM.INC, AND THE SYST.OBJ
; RESIDENT COMMON, WHILE [100,122] HAS TCSLIB.OLB (NONE SUPPLIED ON THE ERIM TAPE).
;
; SINCE EVERYTHING HAD TO BE RUN ON THE ONE UIC [30,2] AT ERIM, THIS INSTALL
; COMMAND FILE PLUS *.F4P AND *.TKB FILES COULD NOT BE TESTED.  IT IS POSSIBLE
; THERE ARE SOME MINOR EDITING ERRORS CONVERTING FOR INSTALLATION ON THE DMA 11/45,
; PARTICULARLY IN REFERENCING FILES ON OTHER UIC'S.  I APPOLOGIZE FOR ANY
; INCONVENIENCES THIS MAY CAUSE.
;
; *.OBJ AND *.LST FILES ARE INCLUDED ON THE ERIM TAPE, BUT IT IS BEST, TO INSURE
; THAT YOU HAVE A COMPLETE COMPATIBLE SYSTEM, TO REGENERATE THEM FROM FORTRAN
; SOURCE CODE AND THE *.F4P AND *.TKB COMMAND FILES AS IS DONE IN THIS FILE.
;
; THE FOLLOWING HAS PRESUMABLY ALREADY BEEN DONE OR YOU WOULDN'T BE USING THIS FILE:
;HELLO 30,2/ERIM
;MOUNT MT2:DMA
;PIP *.*;*/DE
;PIP =MT0:[*,*]*.*;*
;@INSTALL.CMD
;
; COMPILE AND TASKBUILD ALL PROGRAMS WRITTEN AND MODIFIED BY ERIM
;
@MUIJ.F4P                !* DIPS MAIN MENU ROUTINE MODIFIED
@ESMOTH.F4P              !* DIPS SMOOTHING MENU REUSED
@ESPOLY.F4P              !* DIPS POLYGON DEFINITION ROUTINES REUSED
F4P AREA,AREA/-SP=AREA   !* THIS FOOLPROOFED AREA IS NEEDED BY ESCATT.TKB
@ESCATT.F4P              !* NEW ERIM SCATTERPLOT AND REGRESSION ROUTINE
@EAPPLY.F4P              !* NEW ERIM ROUTINE TO APPLY ADJUSTMENT TO (AVERAGED) DEPTH IMAGES
@EERROP.F4P              !* NEW ERIM ROUTINE TO CALCULATE ERROR PROPAGATION
; SUBROUTINES KOP AND IMDEEP IN THE ORIGINAL DIPS DEPTH TASK MUST ALSO BE
; MODIFIED.  COMMAND FILES KOP.F4P, IMDEEP.F4P AND DEPTH.TKB (ONLY!) ARE
; INCLUDED (KOP.F4P AND IMDEEP.F4P INVOKE DEPTH.TKB FOR DEBUGGING KOP AND IMDEEP).
; ALSO FOR COMPLETENESS THE ORIGINAL DIPS DEPTH.FTN (AS "DEPTHOLD.FTN") AND
; MATCHING DEPTH.OBJ AND DEPTH.LST ARE INCLUDED ON THE ERIM TAPE.  HOWEVER IT
; WOULD BE SAFEST TO USE THE ORIGINAL DIPS DEPTH FROM [3,2]:
F4P DEPTH,DEPTH/-SP=[3,2]DEPTH
F4P KOP,KOP/-SP=KOP
F4P IMDEEP,IMDEEP/-SP=IMDEEP
@DEPTH.TKB        !* FINALLY TASKBUILD THE ORIGINAL DIPS DEPTH WITH NEW ERIM KOP, IMDEEP
;
; NOW, LOGGING ON [3,2], DO:
;PIP [3,2]/NV=[30,2]STT0.CMD,STT1,STT2,ETT0,ETT1,ETT2,IMAGE
; AND USE AS PREVIOUSLY.
;
; FINALLY, YOU MAY WANT TO PUT KOP.OBJ, IMDEEP.OBJ, AND AREA.OBJ IN THE MASTER
; LIBRARY[3,2]HC.OLB CONSISTENT WITH PRIOR DIPS USE (AND SUBSEQUENTLY USE
; [3,2]DEPTH.F4P, DEPTH.TKB NORMALLY).
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OVERVIEW.DOC RHH ERIM NOV. 1982

        SEE README1ST.DOC BEFORE USING THIS DOCUMENTATION FILE.

        THIS OVERVIEW.DOC DOCUMENTATION FILE IS INTENDED TO PROVIDE A BROAD
OVERVIEW OF THE ERIM MTP MULTI-TEMPORAL PROCESSING DEPTH ANALYSIS PROGRAMS.
FOR MORE DETAILS CONSULT README1ST.DOC AS A DIRECTORY TO THE REMAINING DOCUMENTATION,
AND RUNNING.DOC FOR OVERALL INSTRUCTIONS ON HOW TO PROCEED USING THE ERIM SOFTWARE.

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        ENTIRELY NEW ERIM TASKS INSTALLED ARE:
                1) ESCATT -- SCATTERPLOT AND REGRESSION
                2) EAPPLY -- COMPUTE MULTI-TEMPORALLY ADJUSTED NEW DEPTH IMAGE
                             (ALSO USEFUL TO GET AN AVERAGE OF UP TO 5 DEPTH IMAGES)
                3) EERROR -- CALCULATE ERROR PROPAGATION
MODIFIED DIPS ROUTINES ARE:
                4) MUJ    -- MAIN MENU PROGRAM, MODIFIED TO ADD ERIM MENU
                5) DEPTH  -- ORIGINAL DIPS SINGLE-TIME DEPTH ALGORITHM, WITH
                             KDP (KNOWN DEPTH POINT) AND IMDEEP (DEPTH IMAGE
                             GENERATION) MODIFIED TO PROVIDE OUTPUTS FOR
                             ERIM PROGRAMS
SOME DIPS ROUTINES ARE REUSED HERE FOR CONVENIENCE VIA NEW ERIM INTERFACES:
                6) ESMOTH -- NEW INTERFACE TO CALL EXISTING SMOOTHING ROUTINES
                7) EPOLY  -- NEW INTERFACE TO CALL EXISTING POLYGON DEFINITION
AND FINALLY SOME ORIGINAL DIPS TASKS COULD BE REUSED WITHOUT ADAPTION:
                8) DIGTTA -- LOADING IMAGES ONTO COMTAL
                9) DCYTTA -- CYCLING IMAGE PLANES FOR DISPLAY
               10) RAYTTA -- IMAGE CALCULATIONS (E.G. ADDING TWO IMAGES)
               11) HISTTA -- HISTOGRAM IMAGES.

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* * *

THE FIRST NEW ROUTINE IS "MUJ," THE INITIALLY RUN ROUTINE WHICH DISPLAYS THE MAIN MENUS. IT IS IDENTICAL TO THE ORIGINAL DIPS "MUJ" WITH THE ADDITION OF ANOTHER SUBMENU FOR THE ERIM "MTP" MULTI-TEMPORAL PROCESSING DEPTH ANALYSIS (NUMBER 12, JUST AFTER THE ORIGINAL DIPS DEPTH ANALYSIS IN THE MAIN MENU).

BEFORE YOU ARE READY TO DO THE ERIM MULTI-TEMPORAL DEPTH ANALYSIS, IT IS NECESSARY TO DO ALL IMAGE WARPING AND REGISTRATION, TRUE DEPTH CALCULATIONS, DEFINITION OF POLYGONS, AND ANY OTHER DESIRED ANALYSIS THROUGH THE ORIGINAL DIPS SINGLE-TIME DEPTH ANALYSIS FOR EACH OF THE IMAGE DATES TO BE USED AS INPUT FOR THE MULTI-TEMPORAL DEPTH ANALYSIS. THE NEW ERIM SOFTWARE IS NOT INVOLVED HERE, EXCEPT FOR TWO MODIFICATIONS TO SUBROUTINES UNDER THE DIPS DEPTH PROGRAM TO ALLOW PUTTING OUT INFORMATION NEEDED FOR THE ERIM PROGRAMS:

1) (OPTIONALLY), IN KDP, THE KNOWN DEPTH ROUTINE, PUT OUT THE TRUE DEPTH POINTS IN A PSEUDO-IMAGE THAT CAN BE INPUT TO THE ERIM ESCATT SCATTERPLOT AND REGRESSION ROUTINE, IF COMPARISONS TO TRUE DEPTH WILL BE WANTED LATER. AND
2) (MANDATORY FOR MTP PROCESSING), IN IMDEEP, THE ROUTINE WHICH NORMALLY GENERATES A SINGLE-TIME DEPTH DISPLAY ON THE COMTAL, ALSO PUT OUT AN IMAGE FILE CONTAINING THE TRUE SINGLE-TIME DEPTHS NEEDED AS INPUT FOR THE MULTI-TEMPORAL CALCULATIONS, TO FAR GREATER PRECISION THAN THE NORMAL DISPLAY (NORMALLY .1 METERS, BUT CAN BE SPECIFIED BY USER). THIS OUTPUT FILE CAN BE SKIPPED IF NO MTP PROCESSING IS INTENDED.

THE TWO MOST IMPORTANT NEW ROUTINES FOR THE ERIM MULTI-TEMPORAL DEPTH PROCESSING ARE

1) ESCATT, WHICH PRINTS SCATTERPLOTS AND CALCULATES REGRESSIONS BETWEEN DIFFERENT SINGLE-TIME DEPTH IMAGES, OR AVERAGE, OR REFERENCE IMAGES, OR TRUE DEPTHS; NORMALLY FOR POLYGONS OF SELECTED BOTTOM REFLECTANCE TYPES, OR OPTIONALLY BETWEEN WHOLE IMAGES AS A FINAL CHECK OF THE RESULTS.
2) EAPPLY, WHICH APPLIES THE REGRESSION COEFFICIENTS, SELECTED AS A RESULT OF USING ESCATT, TO SOME COMBINATION OF THE INDIVIDUAL SINGLE-TIME DEPTH IMAGES TO GET AN IMPROVED DEPTH IMAGE. ANY ARBITARY WEIGHTED AVERAGE OF SINGLE-TIME IMAGES CAN BE USED AS THE INPUT. EAPPLY ALSO PROVIDES A CONVENIENT WAY TO OBTAIN A PURE AVERAGED IMAGE (A STRAIGHT AVERAGE OF SEVERAL SINGLE-TIME DEPTH IMAGES) TO USE AS ONE OF THE POSSIBLE REFERENCES FOR ESCATT.

EERROR IS ANOTHER NEW ROUTINE WHICH MERELY CALCULATES THE RESULTANT PROPAGATED ERRORS WHICH RESULT FROM APPLYING THE REGRESSION TRANSFORMATIONS TO USER-SPECIFIED ERRORS IN THE ASSUMED PARAMETERS (K AND RHO).

SOME OLDER EXISTING DIPS PROGRAMS ARE ALSO SUPPLIED IN THE ERIM MTP MENU FOR CONVENIENCE JUST BECAUSE THEY ARE LIKELY TO BE FREQUENTLY USED IN CONJUNCTION WITH THE MULTI-TEMPORAL STAGE OF THE PROCESSING. TWO ARE CALLED BY NEW ERIM INTERFACE MENU PROGRAMS, THOUGH BASICALLY UNMODIFIED DIPS ROUTINES:

1) ESMOTH -- SMOOTHING ROUTINES TO SMOOTH ANY (512X512) DEPTH IMAGE BEFORE USE IN ESCATT AND EAPPLY (PARTICULARLY RECOMMENDED IF USING ESCATT TO COMPARE A DEPTH IMAGE TO TRUE DEPTH POINTS)
2) EPOLY -- TO DEFINE ADDITIONAL POLYGONS OF KNOWN BOTTOM REFLECTANCE TYPES.

AND FOUR EXISTING DIPS ROUTINES COULD BE CALLED AS IS WITHOUT A NEW INTERFACE:

3) DIOTTA -- LOADING IMAGES INTO THE THREE COMTAL IMAGE PLANES FOR DISPLAY
4) DSTTTA -- SELECTING WHICH IMAGE PLANE TO DISPLAY
5) RAYTTA -- PERFORMING MISCELLANEOUS OPERATIONS (ADDING, SCALING, ET. AL. ON IMAGES (BUT USE ALSO EAPPLY TO GET A WEIGHTED AVERAGE OF IMAGES).
6) HISTTA -- CALCULATING HISTOGRAMS OF IMAGES.

CHECKOUT.DOC RHH ERIM NOV. 1982

SEE README1ST.DOC BEFORE USING THIS DOCUMENTATION FILE.

THIS CHECKOUT.DOC DOCUMENTATION FILE DESCRIBES SOME SAMPLE DATA AND OUTPUT FROM THE ERIM PROGRAMS WHICH CAN BE COMPARED WITH RESULTS OBTAINED AT DMA TO VERIFY YOUR INSTALLATION AND RUNNING PROCEDURES. INCLUDED ON THIS TAPE ARE SOME INPUT IMAGES, POLYGONS, AND SAMPLE OUTPUTS FROM THE ERIM PROGRAMS WHICH YOU CAN COMPARE WITH YOUR RESULTS.

FOUR FILES DMA1.IMG THROUGH DMA4.IMG ARE SINGLE-TIME DEPTH IMAGES, REGISTERED TO EACH OTHER, FROM THE BIMINI AREA.

FILE DMAAV1234.IMG IS AN UNWEIGHTED STRAIGHT AVERAGE OF THESE FOUR SINGLE-TIME IMAGES. IT WAS OBTAINED BY RUNNING THE EAPPLY PROGRAM (VIA THE ERIM MIP MENU SELECTION FOR APPLY). IN RUNNING EAPPLY, 4 INPUT IMAGES WERE REQUESTED, WEIGHTS WERE DEFAULTED (HENCE EQUALLY 1.0,1.0,1.0,1.0, NORMALIZED TO .25 EACH TO SUM TO 1.0 OVERALL), AND UNITY TRANSFORMATION SELECTED BY DEFAULT (MULTIPLIER 1.0, ADDITIVE CONSTANT 0.0). OBVIOUSLY THE INPUT FILE NAMES WERE ENTERED AS DMA1.IMG, DMA2.IMG, ETC., AND THE OUTPUT FILE NAME AS DMAAV1234.IMG.

THE FILE BIMPOL2.POL IS A DEFINITION OF POLYGONS OBTAINED FOR THESE IMAGES AT DMA DURING THE DEMO ON OCTOBER 1 ,1982.

THE FOUR FILES ESCATT.DAT;1...4 ARE THE PRINTOUTS RESULTING FROM RUNNING ESCATT FOR THE AVERAGE IMAGE DMAAV1234.IMG AS A REFERENCE ON THE Y-AXIS, VERSUS EACH OF THE FOUR INDIVIDUAL INPUT IMAGES DMA1.IMG...DMA4.IMG IN TURN ON THE X-AXIS. NORMALLY THIS APPEARS ON THE LINE PRINTER, BUT IT WAS SWITCHED TO A DISK FILE BY REASSIGNING UNIT 3 (OR SEE ESCATT.TKB ASG=LP:3).

TO AVOID INCLUDING SATURATED VALUES FROM DEEP WATER OR ANOMALIES, THE INPUT DATA SCALE WAS LIMITED TO 0-250 ON THE X-AXIS (254 WOULD HAVE WORKED). THE DATA BOUNDS ARE PRINTED IN THE CAPTIONS UNDER THE SCATTERPLOTS.
NOTE THESE INPUT IMAGES WERE DEPTH-PROCESSED AT ERIM, WITH NO PROBLEMS AT THE LOWER END OF THE DATA SCALE. HOWEVER, FOR IMAGES GENERATED BY THE ERIM-MODIFIED IMDEEP ROUTINE UNDER THE DIPS DEPTH PROGRAM AT DMA, IT WOULD BE NECESSARY TO SKIP 0 (LAND CODE) AND 1 (UNDERFLOW CODE) IN NORMAL SINGLE-TIME DEPTH IMAGES (E.G., FOR TRUE DEPTHS FROM THE ERIM-MODIFIED KDP ROUTINE UNDER THE DIPS DEPTH PROGRAM, 0'S WOULD ALWAYS HAVE TO BE SKIPPED AS A NO-DATA CODE).

POLYGON AREAS RATHER THAN THE ENTIRE IMAGE FILE AREA WERE SELECTED, AND BIMPOL2.POL GIVEN AS THE POLYGON FILE, THE PROMPT QUESTION WHETHER ALL POLYGONS WERE WANTED WAS ANSWERED NO, THEN AS THE DESIRED POLYGONS, ALL BOTTOM TYPE AREA CODES (PRINTED BY ESCATT) WERE INDIVIDUALLY ENTERED EXCEPT "7" FOR DEEP WATER. THESE CAN BEEN SEEN LISTED IN THE CAPTIONS AT THE BOTTOM OF THE SCATTERPLOTS. ALSO, BOTTOM REFLECTANCE CODES INSTEAD OF COUNT SYMBOLS WERE PICKED FOR THE PLOT.

THE TRANSFORMATION REQUIRED FOR USE IN EAPPLY TO MATCH EACH OF THESE INDIVIDUAL SINGLE-TIME DEPTH IMAGES DMA1.IMG...DMA4.IMG ON THE X-AXIS, TO THE AVERAGED IMAGE DMAAV1234.IMG USED AS A REFERENCE ON THE Y-AXIS, IS GIVEN AT THE BOTTOM OF THE SCATTERPLOT CAPTIONS BY THE REGRESSION LINE Y = A*X+B. (ALTHOUGH NOT SHOWN IN THESE SAMPLE SCATTERPLOTS RUN BY AN EARLIER VERSION OF THE PROGRAM, THE FINAL ESCATT ALSO GIVES THE INVERSE REGRESSION LINE X = A'*Y+B', IN CASE THE REFERENCE IMAGE IS PUT ON THE Y-AXIS). THIS REGRESSION FIT IS OF COURSE DEPENDENT ON THE CHOICE, QUALITY, AND REPRESENTATIVENESS OF THE POLYGONS -- IT IS UP TO THE OPERATOR TO MAKE SURE HE SUPPLIES POLYGONS COVERING A GOODLY RANGE OF KNOWN BOTTOM TYPES AND DEPTHS, AND THAT HE VERIFIES THE REASONABLENESS OF THE TRANSFORMATION). THESE RESULTS SHOWN IN THE SAMPLE SCATTERPLOTS ARE TYPICAL FAIRLY REASONABLE RESULTS.

FINALLY, GIVEN A SATISFACTORY TRANSFORMATION AS OBTAINED ABOVE FROM THE ESCATT RUNS, THE EAPPLY PROGRAM IS RUN AS ABOVE, USING EITHER ONE SINGLE-TIME DEPTH IMAGE, OR AN (OPTIONALLY WEIGHTED) AVERAGE OF SEVERAL AS THE INPUT, AND THE Y=A*X+B TRANSFORMATION SELECTED FROM THE BEST SCATTERPLOTS, TO GENERATE THE IMPROVED OUTPUT DEPTH IMAGE. SINCE A SATISFACTORY CHOICE OF TRANSFORMATION IS TO SOME EXTENT DEPENDENT ON THE OPERATOR'S SELECTION, NO PARTICULAR SAMPLE IS INCLUDED HERE.

RUNNING.DOC RHH ERIM NOV. 1982

SEE README1ST.DOC BEFORE USING THIS DOCUMENTATION FILE.

THIS RUNNING.DOC DOCUMENTATION IS INTENDED TO DESCRIBE IN OVERALL DETAIL HOW THE OPERATOR SHOULD PROCEED TO USE THE ERIM "MTP" MULTI-TEMPORAL PROCESSING DEPTH ANALYSIS SOFTWARE AS AN INTEGRAL PART OF DMA'S DIPS WATER DEPTH PROCESSING ON DMA'S PDP 11/45 COMPUTER FACILITY. THIS REQUIRES AN INTEGRATED USE OF THE ORIGINAL DIPS PROCESSING THROUGH COMPLETE SINGLE-TIME DEPTH IMAGES, FOLLOWED BY USE OF THE NEW ERIM SOFTWARE. WHEN RUNNING THE SECOND ERIM PART, IT MAY BE HELPFUL FOR THE READER TO CONSULT THE SAMPLES DESCRIBED IN THE "CHECKOUT.DOC" DOCUMENTATION, AND FOR MORE DETAIL THAN CAN BE PROVIDED HERE THE INDIVIDUAL PROGRAMS SHOULD BE CONSULTED.

THE FIRST STAGES OF THE PROCESSING REQUIRE USE OF THE ORIGINAL DIPS SOFTWARE IN THE USUAL WAY.

IT IS ASSUMED THAT THERE ARE GOOD PROCESSABLE IMAGES COLLECTED FOR TWO OR MORE DATES OVER THE SAME AREA FOR THE ERIM MULTI-TEMPORAL PROCESSING TO BE OF USE. IT IS MANDATORY THAT THESE IMAGES BE SPATIALLY REGISTERED TO EACH OTHER. WHILE IT MAY NORMALLY BE PREFERRED TO DO THIS BY REGISTERING AND WARPING EACH TO THE SAME STANDARD MAP COORDINATE SYSTEM, THIS IS NOT NECESSARY FOR THE ERIM ALGORITHM PER SE.

AFTER REGISTRATION AND SELECTION OF MATCHING AREA 512X512 SUBIMAGES, THE NORMAL DIPS SINGLE-TIME DEPTH PROCESSING SHOULD BE COMPLETED THROUGH OBTAINING THE DEPTH IMAGES. TWO OR THREE DIFFERENCES SHOULD BE NOTED HERE IF THIS STAGE IS TO BE FOLLOWED BY THE ERIM MULTI-TEMPORAL PROCESSING.

1) IF IT MIGHT BE DESIRED TO COMPARE ANY OF THE DEPTH IMAGES, BEFORE OR AFTER ADDITIONAL MULTI-TEMPORAL PROCESSING, TO TRUE DEPTHS IN THE ERIM ESCATT SCATTERPLOT PROGRAM, THEN DURING THE TRUE DEPTH PROCESSING THE OPERATOR SHOULD REQUEST WRITING THE TRUE DEPTHS IN THE NEW ERIM (PSEUDO)-IMAGE FILE FORMAT.
2) WHEN SELECTING POLYGON AREAS, THE OPERATOR SHOULD KEEP IN MIND THAT HE WILL BE WANTING REPRESENTATIVE BOTTOM TYPES AND DEPTHS OVER AS WIDE A RANGE OF DEPTHS AS HE CAN RELIABLY IDENTIFY, IN ORDER TO GET GOOD STABLE, SIGNIFICANT RESULTS FROM THE SUBSEQUENT SCATTERPLOTS AND REGRESSION CALCULATIONS.
3) AND FINALLY, WHEN CALCULATING THE DEPTH IMAGE, THE OPERATOR MUST NOT ONLY DISPLAY IT ON THE COMTAL, BUT ALSO REQUEST THE NEW MORE PRECISE DEPTH IMAGE OUTPUT FILE. HERE THERE IS ALSO A CHOICE OF SIGNIFICANCE, DEFAULTING TO .1 METER PER COUNT (HENCE ENCODING A MAXIMUM DEPTH OF 25.5 METERS). IF GREATER DEPTHS ARE REQUIRED THE OPERATOR SHOULD PICK PERHAPS .2 METERS/COUNT (IT MIGHT BE PREFERABLE TO USE THE SAME FOR ALL DEPTH IMAGES TO AVOID FUTURE CONFUSION INTERMIXING THEM).

AFTER THE SINGLE-TIME DEPTH IMAGES ARE OBTAINED, THE OPERATOR IS READY TO ENTER THE ERIM MULTI-TEMPORAL PROCESSING MENU. THERE ARE TWO KEY STEPS TO THE MULTI-TEMPORAL PROCESSING TO OBTAIN AN IMPROVED DEPTH IMAGE. FIRST IS TO RUN ESCATT TO DO SCATTERPLOTS AND REGRESSION CALCULATIONS OF THE INDIVIDUAL SINGLE-TIME DEPTH IMAGES VERSUS SOME SELECTED STANDARD OR REFERENCE, RESTRICTING THE DATA TO POLYGON AREAS SELECTED TO REPRESENT A VARIETY OF BOTTOM REFLECTANCE TYPES AND DEPTHS. THE OPERATOR THEN EXAMINES THE SCATTERPLOTS, DECIDES HOW TO REJECT ANY POLYGONS OR WILD DATA VALUES THAT SEEM TO BE UNFAIRLY BIASING THE RESULTS, AND RERUNS THIS STEP AS NECESSARY. ONCE SATISFIED HERE, THE SECOND STEP IS A SIMPLE MATTER OF MECHANICS RUNNING THE EAPPLY PROGRAM ON EACH INDIVIDUAL INPUT SINGLE-TIME DEPTH IMAGE (OR AVERAGE OF THEM) WITH THE SELECTED REGRESSION TRANSFORMATION TO MAKE THEM MORE CLOSELY MATCH THE REFERENCE.

THE READER MAY HERE WANT TO CONSULT THE "RUNNING.DOC" DOCUMENTATION FILE AND SAMPLE RUNS IT DISCUSSES.

A HIDDEN INITIAL STEP BEFORE RUNNING THE SCATTERPLOT AND REGRESSION PROGRAM ESCATT IS TO CHOOSE A SUITABLE REFERENCE IMAGE. THIS CAN BE THE BEST INDIVIDUAL SINGLE-TIME IMAGE, A (WEIGHTED OR UNWEIGHTED) AVERAGE OF SUCH INDIVIDUAL IMAGES, OR POSSIBLY TRUE DEPTH POINTS ENCODED IN AN ERIM (PSEUDO)-IMAGE FILE IN THE PRIOR DIPS KDP KNOWN DEPTH POINT ROUTINE UNDER THE DIPS DEPTH.

THEN THE ERIM MULTI-TEMPORAL PROCESSING PROGRAM ESCATT IS RUN, VIA THE SCATTERPLOT CHOICE ON THE ERIM MTP MENU. EACH INDIVIDUAL SINGLE-TIME DEPTH IMAGE SHOULD BE RUN VERSUS THE REFERENCE, USING ALL POLYGONS FELT TO BE RELIABLE AND RELEVANT OVER A GOODLY SELECTION OF BOTTOM TYPES AND DEPTHS (EXCEPT "DEEP WATER" AND UNRELIABLE OR NON-UNIFORM DEPTH POLYGONS). THE PRINTED SCATTERPLOTS SHOULD BE EXAMINED FOR DEVIANT POLYGON AREAS (IT WILL BE DESIRABLE TO REQUEST POLYGON AREA BOTTOM TYPE SYMBOLS INSTEAD OF COUNTS ON THE SCATTERPLOT TO SEE THIS), AND FOR WILD DATA VALUES, OVERFLOW (255), UNDERFLOW (1), AND LAND (0) DEPTH CODES. IF THE SCATTERPLOT IS TOO CLUTTERED TO ALLOW DISTINGUISHING ALL THE INDIVIDUAL POLYGON AREAS, THE OPERATOR CAN MAKE RUNS USING A FEW POLYGONS AT A TIME. THEN THE OPERATOR SHOULD RERUN SELECTING OUT UNDESIRABLE POLYGONS, AND RESTRICTING THE DATA LOWER AND UPPER BOUNDS AS NECESSARY, PARTICULARLY DELETING 0, 1, AND 255 CODES. IF TOO MANY POLYGONS HAVE TO BE REJECTED, AND THE RESULTING REGRESSION FITS SEEM UNREALISTIC OR UNSTABLE, THE OPERATOR CAN ATTEMPT TO USE THE POLYGON MENU ENTRY UNDER THE ERIM MULTI-TEMPORAL DEPTH PROCESSING MENU TO SELECT ADDITIONAL BETTER POLYGONS.

ONE ALTERNATIVE WAY TO DO THIS REGRESSION STEP INVOLVES USING THE TRUE DEPTHS ENCODED IN A (PSEUDO)-IMAGE AS THE REFERENCE. IN THIS CASE, THE SCATTERPLOTS SHOULD BE RUN OVER THE WHOLE 512X512 IMAGE AREA AND THE LOWER BOUND SET TO 1 OR HIGHER ON THE TRUE DEPTH IMAGE (SINCE 0 DENOTES LACK OF ANY TRUE DEPTH DATA). THE NUMBER OF PIXELS INCLUDED IN THE SCATTERPLOT WILL THEN BE LIMITED TO THOSE ENTERED AS TRUE DEPTH POINTS. IT WOULD BE ADVISABLE TO DO SOME SMOOTHING OF THE ACTUAL CALCULATED DEPTH IMAGE TO REDUCE THE EFFECT OF NOISE IN THE CALCULATED IMAGE AT THE (PRESUMABLY VERY SPARSE) TRUE DEPTH POINTS. THE SMOOTH ROUTINES ARE INCLUDED IN THE ERIM MENU TO FACILITATE THIS.

THIS REGRESSION FIT IS OF COURSE DEPENDENT ON THE CHOICE, QUALITY, AND REPRESENTATIVENESS OF THE POLYGONS -- IT IS UP TO THE OPERATOR TO MAKE SURE HE SUPPLIES POLYGONS COVERING A GOODLY RANGE OF KNOWN BOTTOM TYPES AND DEPTHS, AND THAT HE VERIFIES THE REASONABLENESSS OF THE TRANSFORMATION). THE RESULTS SHOWN IN THE SAMPLE SCATTERPLOTS ARE TYPICAL FAIRLY REASONABLE RESULTS.

AS THE SECOND KEY STEP, GIVEN A SATISFACTORY TRANSFORMATION AS OBTAINED FROM THE ESCATT RUNS, THE EAPPLY PROGRAM IS RUN, USING EITHER ONE SINGLE-TIME DEPTH IMAGE, OR AN (OPTIONALLY WEIGHTED) AVERAGE OF SEVERAL AS THE INPUT, AND THE Y=A*X+B TRANSFORMATION SELECTED FROM THE BEST SCATTERPLOTS, TO GENERATE THE IMPROVED OUTPUT DEPTH IMAGE.

FINALLY, THE ESCATT SCATTERPLOT/REGRESSION PROGRAM CAN BE RUN AGAIN ON THE RESULTING MULTI-TEMPORALLY DERIVED DEPTH IMAGE VERSUS A REFERENT, AND THE RESULTS COMPARED WITH THOSE FOR INDIVIDUAL SINGLE-TIME DEPTH IMAGES, AS A WAY OF MEASURING HOW REASONABLE THE DEPTH CALCULATIONS SEEM OVER THE ENTIRE IMAGE. TO DO THIS, THE WHOLE IMAGE AREA SHOULD BE USED INSTEAD OF THE SELECTED POLYGONS, BUT THE LOWER AND UPPER BOUNDS CAN BE RESTRICTED ON EACH AXIS TO SELECT MEANINGFUL SHALLOW AND MODERATE DEPTHS WHERE REASONABLE RESULTS SHOULD BE EXPECTED.

APPENDIX B

SOFTWARE LISTINGS

This Appendix contains FORTRAN IV listings of the two principal programs contained in the MTP software package. These listings include EAPPLY.FTN and ESCATT.FTN. A list of all of the MTP individual programs is contained in Appendix A (README1ST.DOC). Many of these programs are modified programs from the DIPS software package. Listings of these latter programs are available from the delivered MTP tape.

```
FORTRAN IV-PLUS V02-51E        17:32:13    12-DEC-82           PAGE 1
EAPPLY.FTN       /TR:BLOCKS/WR
         CCC     EAPPLY - APPLY ERIM MULTI-TEMPORAL PROGRAM DEPTH ANAYLSIS LINEAR TRANSFORMATION
         C                 LAST REVISED OCT. 1982 ROSS H. HIEBER ERIM
         C
         C
         C       CATEGORY -  ERIM MTP DEPTH ANALYSIS
         C
         C
         CIX     EAPTTA - INSTALLED TASK NAME FOR 'EAPPLY'
         C
         C
         C                         --- DESCRIPTION ---
         C
         C                 READS ONE OR MORE 512*512 INPUT DEPTH IMAGES, AVERAGES THEM WITH WEIGHTS,
         C       AND CALCULATES REVISED OUTPUT DEPTH IMAGE BY APPLYING LINEAR TRANSFORMATION
         C                         OUTPUT IMAGE = A*(AVERAGE OF INPUT IMAGES) + B
         C       WHERE A AND B WERE DETERMINED BY SCATTERPLOTS, REGRESSIONS, AND OTHER
         C       ANALYSES BETWEEN ORIGINAL (SINGLE-TIME) DEPTH IMAGES.
         C
         C
         C
         C                         --- BUILD COMMANDS ---
         C
         C
         C                         --- SUBROUTINES USED ---
         C
         C    CODE EXTENSIONS NOT CURRENTLY IN EFFECT (ALL CAN BE REMOVED FOR MORE READABLE CODE):
         C
         C
         C*COM*  STATEMENTS PREFACED "C*COM*" ARE INTENDED TO USE THE COMTAL DISPLAY
         C*COM*  FOR IMAGE INPUT AND CAN BE REINSERTED BY
         C*COM*  MERELY DELETING ALL "C*COM*".  HOWEVER, THIS CODE WAS NEVER
         C*COM*  DEBUGGED WITH THE COMTAL HARDWARE.
         C
         CD      STATEMENTS PREFACED "D" OR "CD" ARE DEBUG OUTPUTS NORMALLY
         CD      NOT COMPILED (USE F4P SWITCH /DEBUG).
         C
         C
         C!*** ERIM DEBUG ***    INCLUDE '[3,2]SYST.INC/NO LIST'
         C!*** ERIM DEBUG ***    INCLUDE '[3,2]PMCOM.INC/NO LIST'
                 INCLUDE 'SYST.INC/NO LIST'               !*** ERIM DEBUG CHANGE UIC ***
                 INCLUDE 'PMCOM.INC/NO LIST'              !*** ERIM DEBUG CHANGE UIC ***
         C
                 PARAMETER NINPUT = 5             !* MAXIMUM NUMBER OF INPUT IMAGES TO AVERAGE
                 PARAMETER IMGLNG = 512           !* NUMBER OF PIXELS PER LINE
                 INTEGER N, COMSW(NINPUT), IUNIT(NINPUT), OUNIT, ITEMP
                 INTEGER RLNGTH
                 REAL*4 W(NINPUT), WNORM, A, B, SUM(IMGLNG), RESULT
                 BYTE NAME(36), NAMOUT(36), BLNK
                 BYTE BUFIN(IMGLNG), BUFOUT(IMGLNG)
```

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FORTRAN IV-PLUS V02-51E        17:32:13    12-DEC-82          PAGE 2
EAPPLY.FTN      /TR:BLOCKS/WR

        C
0016              EQUIVALENCE (NAME(1),NAMOUT(1))
        C
0017              DATA IUNIT/2,3,9,8,7/, OUNIT/1/
0018              DATA BLNK/' '/
        C
        C
0019              CALL PMINIT
        C
0020              BLNGTH = 512
0021              IRECS = 522
0022              IRSTRT = 11
0023              IREC = IMGLNG/4
        C
0024              CONTINUE
        C*************************************************************
        C*************************************************************
0025              CALL HOME
0026              TYPE 3
        C234567890123456789012345678901234567890123456789012345678901234567890
0027      3       FORMAT(22X,'ERIM MTP DEPTH REVISION, APPLICATION PROGRAM',/)
        C
0028      5       TYPE 6
0029      6       FORMAT(/2X,'ENTER NUMBER OF INPUT IMAGE(S) TO AVERAGE'/)
0030              ACCEPT 7, N
0031      7       FORMAT(I5)
0032              IF(N.LE.0.OR.N.GT.NINPUT)  GO TO 5
0033              IF(N.EQ.1)  GO TO 12
0034      8       TYPE 9, N
        C234567890123456789012345678901234567890123456789012345678901234567890
0035      9       FORMAT(2X,'ENTER',I3,' RELATIVE WEIGHTS (DEFAULT EQUAL'
             2              ' WEIGHTS 0),'/
             3              2X,'SEPARATED BY COMMAS, E.G. "1.0,1.0,1.5")'/
             4              2X,'NOTE WEIGHTS WILL BE NORMALIZED TO SUM TO 1.0')
0036              ACCEPT 10, (W(I),I=1,N)
0037     10       FORMAT((10F10.0))
0038              IF(W(1).EQ.0.0)  GO TO 12        !* DEFAULT WEIGHTS IF W(1)=0.0
0039              DO 11 I=1,N
        C   REMOVE NEGATIVE WEIGHT CHECK TO ALLOW USING  APPLY FOR MISC. IMAGE SUMS, DIFFERENCES
0040                IF(W(I).EQ.0.0)  GO TO 8       !* IF NO  ALL NON-ZERO RE-ENTER
        C           IF(W(I).LE.0.0)  GO TO 8       !* IF NO  ALL POSITIVE RE-ENTER
0041     11       CONTINUE
0042              GO TO 15
0043     12       DO 13 I=1,N
0044     13         W(I) = 1.0                     !* DEFAULT UNIFORM WEIGHTING OF INPUT IMAGES
0045     15       WNORM = 0.0
0046              DO 17  I=1,N
0047     17         WNORM = WNORM + ABS(W(I))
```

```
FORTRAN IV-PLUS V02-51E         17:32:13    12-DEC-82            PAGE 3
EASPLY.FTN       /TR:BLOCKS/WR

0048             CONTINUE
        C
        C***     CALL HOME
0049             TYPE 21
0050    21       FORMAT(/6X,'COEFFICIENT SELECTION',//,
              2  2X,'ENTER "A,B" MULTIPLICATIVE AND ADDITIVE COEFFICIENTS'/
              3  2X,'FOR "OUTPUT IMAGE = A * (AVERAGE OF INPUT IMAGES) + B",'/
              4  2X,'SEPARATED BY A COMMA, E.G. "1.0,0.0"')
0051             ACCEPT 23, A,B
0052    23       FORMAT(2F20.0)
        C*****************************************************
0053             DO 25  I=1,N
0054    25         W(I) = W(I)*A/WNORM            !* FINAL WEIGHTED MULT. COEFFICIENT TO USE
        C
        C  READ INPUT COMTAL IMAGE PLANES AND/OR INPUT FILE NAMES
        C
0055             CALL HOME
0056             DO 50  I=1,N
        C*COM*31           TYPE 32, I
        C*COM*C234567890123456789012345678901234567890123456789012345678901234567890
        C*COM*32           FORMAT(2X,'ENTER "0" IF INPUT IMAGE',I3,' IS FROM DISK ',
        C*COM*     2                   '(DEFAULT);'/
        C*COM*     3                   2X,'OTHERWISE ENTER COMTAL IMAGE PLANE NUMBER (1...3)')
        C*COM*  ACCEPT 33, COMSW(I)
        C*COM*33           FORMAT(I5)
        C*COM*  IF(COMSW(I).LT.0 .OR. COMSW(I).GT.3)  GO TO 31
        C*COM*  IF(COMSW(I).GT.0)  GO TO 40
        C*****************************************************
0057             TYPE 35,  I
0058       35    FORMAT(//,2X,'ENTER IMAGE',I3,' INPUT FILE NAME')
0059             ACCEPT 36, NAME
0060    36       FORMAT(36A1)
0061             DO 37 J = 1,36
0062               IF(NAME(J).NE.BLNK) GO TO 37
0063                 NAME(J) = 0
0064                 GO TO 39
0065    37         CONTINUE
0066    39       CONTINUE
        CD                 TYPE 938, I,  NAME
        CD938              FORMAT(' I='I3,' NAME IN='/(2X,4A4,1X,4A4))
        CD                 TYPE 939, NAME
        CD939              FORMAT((2X,4A4,1X,4A4))
        C*****************************************************
        C
0067             J = IUNIT(I)                 !* UNIT FOR READING INPUT
        D        TYPE 940, I, J, IREC, NAME
        D940     FORMAT(/'0IMAGE',I3,', UNIT',I3,', IREC=',I4,', NAME=',36A1)
0068             OPEN(UNIT=J,NAME=NAME(1),READONLY,ACCESS='DIRECT',
```

```
           A  TYPE='OLD',RECORDSIZE=IREC)
      C*****************************************************
                GO TO 50
      C*COM*40           CONTINUE          !* READ FROM COMTAL IMAGE PLANE COMSW(I)>0
      C*COM*
      C*COM*
      C*COM*                     TYPE 45
      C*COM*45                             FORMAT(/' *** COMTAL INPUT NOT IMPLEMENTED.***')
      C*COM*                     GO TO 31         !***** NOT IMPLEMENTED YET *****
      C*COM*
      C*COM*
      50        CONTINUE          !* END OF LOOP TO READ INPUT IMAGE FILE OR PLANE
      C*****************************************************
                TYPE 55
      55        FORMAT(/,2X,'ENTER THE OUTPUT FILE NAME')
                ACCEPT 56,NAMOUT
      56        FORMAT(36A1)
      C
                DO 60 J = 1,36
                IF(NAMOUT(J).NE.BLNK) GO TO 60
                NAMOUT(J) = 0
                GO TO 65
      60        CONTINUE
      65        CONTINUE
      C*****************************************************
      C
                OPEN(UNIT=OUNIT,NAME=NAMOUT(1),ACCESS='DIRECT',
           A    TYPE='NEW',RECORDSIZE=IREC)
      C
      C  READ, WRITE HEADER RECORDS FROM FIRST INPUT IMAGE
      C
                DO 100 L = 1,IRSTRT-1
                J = INUNIT(1)               !* READ HEADER FROM FIRST INPUT IMAGE
                READ  (J'L) (BUFOUT(K),K=1,IMGLNG)
                WRITE (OUNIT'L) (BUFOUT(K),K=1,IMGLNG)
      100       CONTINUE
      C*****************************************************
      C
      C                  TYPE 9100, A,B,ANORM,N,(A(I),I=1,N)
      C9100              FORMAT(1X,A,B,ANORM,N,A(I)'1X,3F12.3,I3,5F10.3)
      C
      C  LOOP TO READ ALL INPUT IMAGES, AVERAGE, TRANSFORM, AND WRITE OUTPUT IMAGE
      C
      C???      CALL FRGRTN(IFLG)                  !***** ????? WHY?
      C
      C
                DO 800 L = IRSTRT,IRECS           !* LOOP OVER LINES
      C
```

```
FORTRAN IV-PLUS V02-51E         17:32:13    12-DEC-82           PAGE 5
EAPPLY.FTN      /TR:BLOCKS/WR

        C234567890123456789012345678901234567890123456789012345678901234567890
        D                    IF(L.LE.IRSTRT+3) TYPE 9100, A,B,WNORM,N,(W(I),I=1,N)
0088                DO 200  K=1,IMGLNG                ! CLEAR SUM FOR EACH PIXEL
0089    200         SUM(K) = 0.0
        C
0090                DO 500 I = 1,N                               !* LOOP OVER INPUT IMAGES
        C
0091                  J = IUNIT(I)                    !* LOGICAL UNIT NUMBER
        C
        C*COM*        IF(COMSW(I).GT.0) GO TO 250 !* GO TO READ THIS INPUT FROM COMTAL
        C
0092                  READ(J'L) (BUFIN(K),K=1,IMGLNG)      !* READ I'TH INPUT IMAGE LINE L FROM DISK
        C
        C*COM*        GO TO 300
        C*COM*250           CONTINUE                         !* COME HERE TO READ INPUT I FROM COMTAL
        C*COM*
        C*COM*               TYPE 270, I
        C*COM*270                    FORMAT('0***** FOR INPUT IMAGE',I3,
        C*COM*        2                           ' COMTAL INPUT NOT IMPLEMENTED. *****')
        C*COM*               STOP 270




        C*COM*300           CONTINUE
        D
        C234567890123456789012345678901234567890123456789012345678901234567890
        D                    IF(L.LE.IRSTRT+2) TYPE 9300, I, (BUFIN(K),K=1,10)
        D                    IF(L.LE.IRSTRT+2) TYPE 9301,    (BUFIN(K),K=503,512)
        D9300                FORMAT(' INPUT',I2,(T10,5I4,2X,5I4))
        D9301                FORMAT(                (T11,5I4,2X,5I4))
        C
0093                DO 400 K = 1,BLNGTH               !* LOOP OVER PIXELS WITHIN THIS ONE LINE
        C
0094                  ITEMP = (BUFIN(K).AND."377)
0095                  SUM(K) = SUM(K) + W(I)*ITEMP           !* ADD CURRENT IMAGE VALUE FOR THIS PIXEL
        C
0096    400         CONTINUE                          !* END LOOP OVER PIXELS
        D
        D                    IF(L.LE.IRSTRT+2) TYPE 9400, (SUM(K),K=1,5)
        D9400                FORMAT(' SUM(K)=',(T10,5F10.3))
        C
0097    500         CONTINUE                          !* END LOOP OVER INPUT IMAGES
        C
0098                DO 600  K=1,IMGLNG                !* LOOP OVER PIXELS
0099                  RESULT = SUM(K) + B + .5      !* ADD LINEAR TRANSFORMATION OFFSET
0100                  IF(RESULT.LT.0.0)  RESULT = 0.0
```

```
FORTRAN IV-PLUS V02-51E          17:32:13    12-DEC-82            PAGE 6
EAPPLY.FTN        /TR:BLOCKS/WR

                        IF(RESULT.GT.255.) RESULT = 255.
                        ITEMP = RESULT
                        BUFOUT(K) = ITEMP.AND."377
          600       CONTINUE
          D                 IF(L.LE.IRSTRT+2) TYPE 9600, (BUFOUT(K),K=1,10)
          D                 IF(L.LE.IRSTRT+2) TYPE 9601, (BUFOUT(K),K=503,512)
          D9600             FORMAT(' BUFOUT=',(T10,5I4,2X,5I4))
          D9601             FORMAT(           (T11,5I4,2X,5I4))
          C
                    WRITE (OUNIT'L) (BUFOUT(K),K=1,IMGLNG)
          C
          D                 IF(L/100*100.EQ.L)  TYPE 9800, L
          D9800             FORMAT(' RECORD',I3,' DONE.')
          800     CONTINUE                             !* END LOOP OVER LINES
          C
          C
          C*******************************************************
          C
            900   CONTINUE
                  DO 910  I = 1,N              !* CLOSE ALL INPUT IMAGE UNITS
                  J = IUNIT(I)
                  CLOSE(UNIT=J)
            910   CONTINUE
                  CLOSE(UNIT=OUNIT)            !* CLOSE OUTPUT IMAGE UNIT
          C
                  CALL FINIS
                  END
```

```
FORTRAN IV-PLUS V02-51E          17:32:13    12-DEC-82           PAGE 7
EAPPLY.FTN        /TR:BLOCKS/WR

PROGRAM SECTIONS

NUMBER   NAME         SIZE                    ATTRIBUTES

  1      $CODE1  002354   630                 RW,I,CON,LCL
  3      $IDATA  001146   307                 RW,D,CON,LCL
  4      $VARS   006164  1594                 RW,D,CON,LCL
  5      $TEMPS  000006     3                 RW,D,CON,LCL
  6      SYST    020000  4096                 RW,D,OVR,GBL
  7      PMCOM   000012     5                 RW,D,OVR,GBL


VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 A       R*4   4-000132    B       R*4   4-000134    BLNGTH  I*2   4-000076    BLNK    L*1   4-004144    I       I*2   4-006154
 IATT    I*2   7-000006    IAXT    I*2   6-017716    ICTRLX  I*2   7-000010    IREC    I*2   4-006152    IRECS   I*2   4-006146
 IRSTRT  I*2   4-006150    ITEMP   I*2   4-000074    ITTY    I*2   7-000004    J       I*2   4-006156    K       I*2   4-006162
 L       I*2   4-006160    N       I*2   4-000044    NCOM    I*2   6-000000    NTTY    I*2   6-000002    OUNIT   I*2   4-000072
 PMNAME  R*4   7-000000    RESULT  R*4   4-004140    WNORM   R*4   4-000124


ARRAYS

 NAME    TYPE  ADDRESS         SIZE            DIMENSIONS

 BKGCEF  R*4   6-003332    000220     72       (6,6)
 BKGCSP  R*4   6-003552    000220     72       (6,6)
 BUFFIN  L*1   4-004145    001000    256       (512)
 BUFOUT  L*1   4-005145    001000    256       (512)
 COMSN   I*2   4-007046    000012      5       (5)
 COMTAB  I*2   6-000010    002260    600       (200,3,1)
 COMTR4  I*2   6-003776    000014      6       (6,1)
 CURSE   I*2   6-002320    000014      6       (6)
 DRDR1   I*2   6-003772    000002      1       (1)
 DRDR2   I*2   6-003774    000002      1       (1)
 FLICK1  I*2   6-002270    000014      6       (6)
 FLICK2  I*2   6-002304    000014      6       (6)
 FSTAC1  R*4   6-003076    000220     72       (6,6)
 HOMEC2  L*1   6-002724    000074     30       (12,6)
 ICGXC   I*2   6-002714    000002      1       (1)
 ICGYC   I*2   6-002716    000002      1       (1)
 ICHIG1  I*2   6-002722    000002      1       (1)
 ICWID1  I*2   6-002720    000002      1       (1)
 ICRPY   I*2   6-003074    000002      1       (1)
 ILSV    I*2   6-004012    000240     80       (82)
 IMSEL1  I*2   6-002564    000014      6       (6)
```

```
FORTRAN IV-PLUS V02-51F          17:32:13    12-DEC-82           PAGE 8
EAPPLY.FTN        /TR:BLOCKS/WR

 IMGFLG  I*2    6-032700   000014     6      (6)
 IPSV    I*2    6-004252   000240    80      (80)
 ISPARE  I*2    6-000512   013204  2882      (2882)
 IUNIT   I*2    4-020060   000012     5      (5)
 IXOFF   I*2    6-003220   000002     1      (1)
 IYOFF   I*2    6-003222   000002     1      (1)
 JPESTK  I*2    6-003316   000014     6      (6)
 LITCOM  I*2    6-017720   000060    24      (24)
 LUNARG  I*2    6-000004   000002     1      (1)
 LUNNUM  I*2    6-000006   000002     1      (1)
 MCEL    I*2    6-002334   000330   108      (18,6)
 NAME    L*1    4-000000   000044    18      (36)
 NAMOUT  L*1    4-000000   000044    18      (36)
 REPET   I*2    6-003024   000050    20      (20,1)
 SUM     R*4    6-000140   004000  1024      (512)
 W       R*4    4-000100   000024    10      (5)


LABELS

 LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS           LABEL   ADDRESS

 3'      3-000000          5       1-000116          6'      3-000062          7'      3-000142          8       1-000224
 9'      3-000146          10'     1-000472          11         **             12      1-000432          13         **
 15      1-000526          17         **             21'     3-000412          23'     3-000724          25         **
 35'     3-000712          36'     3-000760          37      1-001066          39      1-001110          50      1-001142
 55'     3-000764          56'     3-001024          60      1-001272          65      1-001314          100        **
 200        **             400        **             500        **             600        **             820        **
 900        **             912        **

FUNCTIONS AND SUBROUTINES REFERENCED

 CLOSS   FINIS   HOME    OPENS   SMINIT

TOTAL SPACE ALLOCATED = 031726  6635

EAPPLY EAPPLY/-SP=EAPPLY/CO:32.
```

```
FORTRAN IV-PLUS V02-51E          17:21:59     12-DEC-82            PAGE 1
ESCATT.FTN      /TR:BLOCKS/WR

          C    ESCATT -- ERIM MTP SCATTER PLOT PROGRAM
          C    ERIM
          C    T.N. WESSLING
          C    SEPTEMBER, 1982
          C    LAST REVISION 25 OCT 1982 ROSS H. HIEBER ERIM
          C
          C         TASK FOR ERIM MULTI-TEMPORAL PROGRAM DEPTH ANALYSIS
          C         INSTALLED TASK NAME:  ESCTT
          C
          C
          C
          C    CODE EXTENSIONS NOT CURRENTLY IN EFFECT (ALL CAN BE REMOVED FOR MORE READABLE CODE):
          C
          C**       STATEMENTS PREFACED "C**" ARE TO SET INITIAL CONDITIONS, NEEDED
          C**       ONLY IF ESCATT IS EXTENDED TO GENERATE MORE THAN ONE SCATTERPLOT
          C**       PER CALL.  THIS MAY NOT BE A COMPLETE SET NECESSARY FOR INITIALIZATION.
          C
          C*COM*    STATEMENTS PREFACED "C*COM*" ARE INTENDED TO USE THE COMTAL DISPLAY
          C*COM*    FOR IMAGE INPUT OR SCATTERPLOT OUTPUT AND CAN BE REINSERTED BY
          C*COM*    MERELY DELETING ALL "C*COM*".  HOWEVER, THIS CODE WAS NEVER
          C*COM*    DEBUGGED WITH THE COMTAL HARDWARE, AND NEEDS AN OVERLAY TASKBUILD
          C*COM*    TO FIT IN MEMORY LIMITS IN LIEU OF POLYGON AND OTHER SUBROUTINES.
          C
          CD        STATEMENTS PREFACED "D" OR "CD" ARE DEBUG OUTPUTS NORMALLY
          CD        NOT COMPILED (USE F4P SWITCH /DEBUG).
          C
          C*********************************************************************
          C*                                                                  *
          C*                    VARIABLE DECLARATIONS                         *
          C*                                                                  *
          C*********************************************************************
          C
0001                PARAMETER MNPOLY = 50           !* MAXIMUM NUMBER OF POLYGONS
0002                PARAMETER MNVERT =  6           !* MAXIMUM NUMBER OF VERTICES PER POLYGON
          C
0003                INCLUDE 'SYST.INC/NO LIST'
0004                INCLUDE '[illegible].INC/NO LIST'
          C
          C  VARS FOR REGRESSION
0011                REAL*4 XMEAN,YMEAN,ALPHA,BETA,RESID,ALPHA2,BETA2
0012                REAL*8 SUMX,SUMY,SUMYX,SUMXY,SUMYY,X
          C
0013                INTEGER*2 OUTLAY,TOTALP,NPOINT
0014                INTEGER COLIM(2), PLIM(2),START,FINISH,COMOUT(2)
0015                INTEGER [illegible](2),SKIPPE([illegible]),[illegible]
0016                INTEGER MINLIN(MNPOLY), MAXLIN(MNPOLY)
0017                INTEGER MINPIX(MNPOLY), MAXPIX(MNPOLY)
0018                INTEGER KEYPL(MNPOLY),NVERT(MNPOLY)
```

```
FORTRAN IV-PLUS V02-51E          17:21:59    12-DEC-82           PAGE 2
ESCATT.FTN         /TR:BLOCKS/WP

0019               INTEGER IX(MNVERT,MNPOLY),IY(MNVERT,MNPOLY)
0020               REAL RES(4)
0021               INTEGER RESPT(2),POLYID,N
0022               INTEGER YAXIS(52),XAXIS(25)
0023               LOGICAL*1 USEIT(MNPOLY),USER(100),LHOLD(2)
0024               INTEGER SCALES(4),RANGE(4),SCALE(2)
0025               INTEGER COUNTS(52,52),COM(2,2),TOTALS(40)
0026               INTEGER OUTPUT,K,I,J,L,N1,N2, P
0027               LOGICAL*1 MAP(52,52),BLANK,XY(2),NAME(36,3)
0028               LOGICAL*1 IBUF(2,512),SYMBOL(40),YLABEL(52)
0029               LOGICAL*1 OPR(40),COMMA,LFLAG(512)
0030               LOGICAL*1 LN1(2),LN2(2)
0031               LOGICAL SYM
          C*COM*   LOGICAL COMYES(2)
0032               LOGICAL POLYES
0033               LOGICAL HAVLIN
0034               INTEGER IUNIT(3)                 !* 2 INPUT UNITS, 1 OUTPUT
0035               EQUIVALENCE (N1,LN1),(N2,LN2)
0036               EQUIVALENCE (HOLD,LHOLD)
          C
0037               DATA IUNIT/1,2,3/                !* DEFAULT UNITS (COMTAL WOULD RESET?)
0038               DATA SKIPF/2,5,5,10/
0039               DATA RES/.5,.4,.2,.1/
0040               DATA SCALES/5,4,2,1/
0041               DATA RANGE/255,200,100,50/
0042               DATA OPR/9*'=',31*'>'/
0043               DATA SYM/.FALSE./
0044               DATA POLYES/.FALSE./
          C*COM*   DATA COMYES/2*.FALSE./
0045               DATA XY/'Y','X'/
0046               DATA BLANK/' '/
0047               DATA COMMA/','/
0048               DATA SYMBOL/'1','2','3','4','5','6','7','8','9',
              1    'A','B','C','D','E','F','G','H','I','J','K','L',
              1    'M','N','O','P','Q','R','S','T','U','V','W','X','Y','Z',
              1    '.','*','%','$','+'/
0049               DATA TOTALS/1,2,3,4,5,6,7,8,9,10,20,30,40,50,60,
              1    70,80,90,100,200,300,400,500,600,700,800,900,1000,
              1    2000,3000,4000,5000,6000,7000,8000,9000,10000,
              1    20000,30000,32767/
          C
          C*****************************************************************************
          C*                                                                          *
          C*                    EXECUTABLE CODE -- INITIALIZATION                      *
          C*                                                                          *
          C*****************************************************************************
          C
0050               CALL PMINIT
```

```
FORTRAN IV-PLUS V02-51E           17:21:59    12-DEC-82         PAGE 3
ESCATT.FTN          /TR:BLOCKS/WR

0051                  DO 1 I=1,52
0052                    DO 2 J=1,52
            C**           COUNTS(I,J) = 0
0053                      MAP(I,J) = BLANK
0054        2           CONTINUE
0055        1         CONTINUE
            C***      XY = BLANK
            C**       N1 = 0
            C**       N2 = 0
            C**       TOTALP = 0
            C**       OUTLAY = 0
            C***      MINLIN = 1
            C***      MAXLIN = 100
            C***      MINPIX = 1
            C***      MAXPIX = 512
            C**       HOLD = 0
            C**       ALPHA = 0.0
            C**       BETA  = 0.0
            C**       RESID = 0.0
            C**       XMEAN = 0.0
            C**       YMEAN = 0.0
            C**       SUMX = 0.0
            C**       SUMY = 0.0
            C**       SUMXY = 0.0
            C**       SUMYY = 0.0
            C**       SUMXY = 0.0
            C**       X = 0.0
            C**       NPOINT = 0
            C
0056                  DO 55 I=1,50
            C**         KTYPE(I) = 0
            C**         NVERT(I) = 0
0057                    USER(I) = BLANK
0058                    USER(I+50) = BLANK
0059                    USFIT(I) = .FALSE.
            C**         DO 56 J=1,6
            C**           IX(J,I) = 0
            C**           IY(J,I) = 0
            C**56       CONTINUE
0060        55        CONTINUE
            C
            C***      DO 30 I=1,2
            C***        LOLIM(I) = 0
            C***        UPLIM(I) = 0
            C***        COMOUT(I) = 0
            C***        DO 31 J=1,36
            C***          NAME(J,I) = BLANK
            C***          INAME(J) = BLANK
```

```
FORTRAN IV-PLUS V02-51E         17:21:59    12-DEC-82           PAGE 4
ESCATT.FTN       /TR:BLOCKS/WR

        C***         NAME(J,3) = BLANK
        C***31     CONTINUE
        C***       DO 32 J=1,2
        C***         COM(I,J) = 0
        C***32     CONTINUE
0061    32      CONTINUE
        C
        C
0062            DO 53 I=1,52
        C**         YAXIS(I) = 0
0063              YLABEL(I) = BLANK
0064    53      CONTINUE
        C**     DO 54 I=1,25
        C**       XAXIS(I) = 0
        C**54   CONTINUE
        C
0065            DO 340 I=1,512
0066              LFLAG(I) = .TRUE.               !* ASSUME PROCESS ALL LINES
0067    340     CONTINUE
        C
        C*****************************************************************************
        C*                                                                           *
        C*                         USER INPUT AND SETUP                              *
        C*                                                                           *
        C*****************************************************************************
        C
        C  LET USER KNOW HE/SHE HAS THE SCATTER PLOT ROUTINE
0068            TYPE 3
0069    3       FORMAT(2X,'              SCATTER PLOT ROUTINE',///)
        C
        C  GET USER INPUT FOR THE TWO FILES TO PLOT
        C
0070            DO 4 I=1,2                 !* START LOOP TO SET UP TWO INPUT IMAGES
        C
        C***     IF (I.EQ.1) XY = 'Y'
        C***     IF (I.EQ.2) XY = 'X'
        C*COM*999        TYPE 12,XY(I)
        C*COM*12         FORMAT(2X,'IS IMAGE FOR THE ',A1,'-AXIS ON  1=DISK 2=COMTAL')
        C*COM*  ACCEPT 14,N
        C*COM*  IF(N.LT.1.OR.N.GT.2) GOTO 999
        C*COM*C
        C*COM*C  IF DATA IS ON DISK GOTO STATEMENT 997
        C*COM*  IF(N.EQ.1) GOTO 997
        C*COM*C
        C*COM*C  INPUT IMAGE IS ON A COMTAL
        C*COM*
        C*COM*  COMYES(I) = .TRUE.
        C*COM*C  GET NECESSARY COMTAL INFORMATION
```

```
FORTRAN IV-PLUS V02-51E          17:21:59    12-DEC-82           PAGE 5
ESCATT.FTN       /TR:BLOCKS/WR

          C*COM*  TYPE 15
          C*COM*15          FORMAT(2X,'ENTER COMTAL INDEX')
          C*COM*  ACCEPT 14,N
          C*COM*  COM(I,1) = N
          C*COM*C  NEED ERROR CHECK HERE
          C*COM*  TYPE 17
          C*COM*17          FORMAT(2X,'ENTER COMTAL IMAGE PLANE')
          C*COM*  ACCEPT 14,N
          C*COM*C  ERROR CHECK NEEDED HERE
          C*COM*  COM(I,2) = N
          C*COM*CD          TYPE 9991, I, COM, IUNIT
          C*COM*CDC         WRITE (3,9991) I, COM, IUNIT
          C*COM*CD9991      FORMAT(/' GETCOM I=',I2,', COM(1,N)=',2I4,', COM(2,N)=',
          C*COM*CD    2                 2I4,', IUNIT=',3I4,10I2/)
          C*COM*  CALL GETCOM(COM(I,1),IUNIT(I))           !* GET COMTAL, ASSIGN UNIT
          C*COM*CD          TYPE 9991, I, COM, IUNIT
          C*COM*CDC         WRITE (3,9991) I, COM, IUNIT
          C*COM*  GOTO 4
          C*COM*C
          C*COM*C  INPUT IMAGE IS FROM A DISK FILE
          C*COM*C
          C*COM*997         CONTINUE
          C*COM*C
0071                TYPE 21,  XY(I)
0072      21        FORMAT(2X,'ENTER NAME OF DISK IMAGE FOR ',A1,' AXIS',
               2              ', LIMIT 36 CHARACTERS')
0073                ACCEPT 22, (NAME(J,I),J=1,36)
0074      22        FORMAT(36A1)
          C  ASSIGN INPUT UNITS FROM DISK
0075                OPEN(UNIT=I,NAME=NAME(1,I),TYPE='OLD',ACCESS='DIRECT')
          C***      IF(I.EQ.2) GOTO 992
          C***      OPEN(UNIT=1,NAME=INAME,TYPE='OLD',ACCESS='DIRECT')
          C***      GOTO 991
          C***992 OPEN(UNIT=2,NAME=INAME,TYPE='OLD',ACCESS='DIRECT')
          C***991 CONTINUE
          C***      DO 33 J=1,36
          C***        NAME(J,I) = INAME(J)
          C***        INAME(J) = BLANK
          C***33  CONTINUE
          C
          C  CHOOSE SCALE OF MAP
          C
0076      620       TYPE 621,XY(I)
0077      621       FORMAT(/2X,'ENTER SCALE SELECTION FOR ',A1,'-AXIS'/
               2              2X,'OPTIONALLY FOLLOWED BY LOWER AND UPPER LIMITS'/
               3              2X,'OF DATA TO PLOT (0-255), E.G. "1,0,255"'/
               4              2X,'CHOICE OF SCALES SHOULD BE INDICATED BY:'/
               5              2X,' 1 = .5 METER RESOLUTION, MAX DATA SPREAD 255'/
```

```
         6          2X,' 2 = .4 METER RESOLUTION, MAX DATA SPREAD 200'/
         7          2X,' 3 = .2 METER RESOLUTION, MAX DATA SPREAD 100'/
         8          2X,' 4 = .1 METER RESOLUTION, MAX DATA SPREAD  50')
              ACCEPT 14, N, LOLIM(I), UPLIM(I)
      14      FORMAT(3I5)
              IF(N.LT.1.OR.N.GT.4) GOTO 600
              SCALE(I) = SCALES(N)
              RESPT(I) = N
              IF(UPLIM(I).GT.0)  GO TO 620     !* HAVE LOWER, UPPER LIMITS ALREADY
      C  GET LOWER AND UPPER LIMITS OF DATA TO PLOT
      605     TYPE 606
      606     FORMAT(2X,'LOWER LIMIT OF DATA TO PLOT')
              ACCEPT 14,LOLIM(I)
              IF(LOLIM(I).LT.0.OR.LOLIM(I).GT.255) GOTO 605
      610     TYPE 611
      611     FORMAT(2X,'UPPER LIMIT OF DATA TO PLOT')
              ACCEPT 14,UPLIM(I)
              IF(UPLIM(I).LT.0.OR.UPLIM(I).GT.255) GOTO 610
      620     IF(      LOLIM(I).LT.0.OR.LOLIM(I).GT.255
         2       .OR. UPLIM(I).LT.0.OR.UPLIM(I).GT.255
         3       .OR. LOLIM(I).GT.UPLIM(I))  GO TO 600
      C  CHECK DATA SPREAD FOR  HIS SCALE
              L = UPLIM(I) - LOLIM(I)
              IF(L.GT.RANGE(N)) GOTO 600
      C
      C  NEED THIS TO  FORMAT Y-AXIS OUTPUT
      C
              JUMP(I) = SKIPF(N)
      C***    N = 2
      C
      1       CONTINUE                           !* END OF LOOP TO SET UP TWO INPUT IMAGES
      C
      996     TYPE 19
      19      FORMAT(2X,'IS THIS  1=ENTIRE IMAGE  2=POLYGONS')
              ACCEPT 14,N
              IF(N.LT.1.OR.N.GT.2) GOTO 996
      C**     NUMPOL = 0                  !* ASSUME NOT USING POLYGONS
              IF(N.EQ.1) GOTO 900
      C***C  CHECK THAT HAVE ONLY ONE POLYGON FILE
      C***    IF(I.NE.2) GOTO 301
      C***    IF(.NOT.POLYES(1)) GOTO 301
      C***    WRITE(4,302)
      C***302 FORMAT(2X,'ONLY ONE POLYGON INPUT ALLOWED')
      C***    GOTO 996
      C
      C  DEFAULT NOT TO READ ANY LINES, WILL RESET
      C  LATER WHEN WE LOOK AT THE ACTUAL POLYGON DATA.  THIS SHOULD REALLY SPEED UP THINGS
      C  UNLESS MOST OF THE SCENE IS DEFINED BY THE POLYGONS.
```

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        C
        301     CONTINUE
                DO 341 J=1,512
                  LFLAG(J) = .FALSE.
        341     CONTINUE
        C
        C  GET NAME OF POLYGON FILE
                TYPE 323
        323     FORMAT(2X,'ENTER NAME OF POLYGON FILE, LIMIT 36 CHAR')
                ACCEPT 22, (NAME(J,3),J=1,36)
                OPEN(UNIT=6,NAME=NAME(1,3),TYPE='OLD',ACCESS='DIRECT')
        C***    DO 305 L=1,36
        C***      NAME(L,3) = INAME(L)
        C***305 CONTINUE
        C
        C***    POLYES(I) = .TRUE.
                POLYES = .TRUE.
        C
        C  READ POLYGON FILE
        C
                J = 0
        D       TYPE 9325
        D       WRITE(3,9325)
        D       TYPE 9326
        D       WRITE(3,9326)
        D9325   FORMAT(//' *** POLYGONS READ: ***:'/)
        D9326   FORMAT('  NR LN KT NV    X...',22X,'Y...',22X,'MNL MXL MNP MXP')
                DO 325 L=1,MNPOLY
                  READ(6'L) K
                  IF(K.EQ.0) GOTO 325
                  J = J + 1
                  READ(6'L)KTYPE(J),NVERT(J),(IX(M,J),M=1,MNVERT),
            2            (IY(M,J),M=1,MNVERT)
        D         TYPE 9327,J,L,KTYPE(J),NVERT(J),(IX(M,J),M=1,MNVERT),
        D   2            (IY(M,J),M=1,MNVERT)
        D         WRITE(3,9327) J,L,KTYPE(J),NVERT(J),(IX(M,J),M=1,MNVERT),
        D   2            (IY(M,J),M=1,MNVERT)
        D9327   FORMAT(1X,4I3,2X,4I4,2X,4I4,2X,4I4)
        325     CONTINUE
        CD      TYPE 9329
        D       WRITE(3,9329)
        D9329   FORMAT(//' *** END OF POLYGONS. ***'//)
        C
        C  FIND OUT WHICH REF TYPES OF POLYGONS
        C  THE USER WANTS TO INCLUDE IN HIS/HER
        C  PLOT
                TYPE 42
        42      FORMAT(2X,'REFLECTENCE TYPES IN THE POLYGON FILE')
```

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0120              M = 0
0121              DO 70 J=1,MNPOLY
0122                IF(KTYPE(J).EQ.0) GOTO 70
0123                HOLD = KTYPE(J) + 64
0124                M = M + 1
0125                USER(M) = LHOLD(1)
0126       70     CONTINUE
           C
0127              TYPE 41,(USER(M),M=1,MNPOLY)
0128       41     FORMAT(2X,50(A1,1X))
0129       833    TYPE 42
0130       42     FORMAT(2X,'USE ALL TYPES  1=YES  2=NO')
0131              ACCEPT 14,N
0132              IF(N.LT.1.OR.N.GT.2) GOTO 833
           C
0133              IF(N.NE.1) GOTO 776
0134              GOTO 777
           C
0135       776    TYPE 43
0136       43     FORMAT(2X,'ENTER REF TYPES TO USE, SEPARATED BY COMMAS')
0137              ACCEPT 44,USER
0138       44     FORMAT(120A1)
           C
           C  PARSE USER INPUT AND FLAG POLYGONS TO USE
0139              DO 71 J=1,100
0140                IF(USER(J).EQ.COMMA.OR.USER(J).EQ.BLANK) GOTO 71
0141                LHOLD(1) = USER(J)
           C  LOOK FOR GARBAGE AND SKIP IT
0142                IF(HOLD.LT.65.OR.HOLD.GT.90) GOTO 71
0143                HOLD = HOLD - 64
0144                USEIT(HOLD) = .TRUE.
           CD        TYPE 679,HOLD
           D679     FORMAT(2X,'HOLD = ',I4)
0145       71     CONTINUE
           C
           C  DELETE ALL UN-WANTED POLYGONS FROM
           C  THE INTERNAL LIST
           C
0146              DO 72 J=1,50
0147                IF(USEIT(KTYPE(J))) GOTO 72
0148                KTYPE(J) = 0
0149       72     CONTINUE
           C
           C  COMPRESS POLYGON DATA STRUCTURES
           C
0150              M = 0
0151       77     IF(M.EQ.51) GOTO 777
0152              M = M + 1
```

```
              L = M
              IF(KTYPE(M).NE.0) GOTO 77
      79      L = L + 1
              IF(L.EQ.51) GOTO 77
              IF(KTYPE(L).EQ.0) GOTO 79
              KTYPE(M) = KTYPE(L)
              NVERT(M) = NVERT(L)
              DO 75 II=1,MNVERT
                IX(II,M) = IX(II,L)
                IY(II,M) = IY(II,L)
      75      CONTINUE
      C  SHOW THAT WE HAVE MOVED 'L' LOCATION
              KTYPE(L) = 0
              GOTO 77
      C
      777     CONTINUE
      C
      C  FIND GLOBAL MAXLIN,MAXPIX
      C  TO COVER ALL POLYGON AREAS,  DOING
      C  THIS TO REDUCE AMOUNT OF LOOPING OVER PIXELS
      C
      C  FIRST SET NUMBER OF POLYGONS AND
      C  THEN SET LINES AND PIXELS TO VALUES
      C  WHICH ARE SURE TO BE OVER-RIDDEN
      C  BY POLYGON DATA
      C
      C  COUNT NUMBER OF POLYGONS LEFT
      C
              NUMPOL = 0
              DO 181 J=1,MNPOLY
                IF(KTYPE(J).EQ.0) GOTO 199
                NUMPOL = NUMPOL + 1
      199     MINLIN(J) = 512
              MAXLIN(J) = 1
              MINPIX(J) = 512
              MAXPIX(J) = 1
      181     CONTINUE
      C
      C
      C
      C  IT IS POSSIBLE THAT THE USER DELETED ALL
      C  BOTTOM REFLECT TYPES.  IF SO THE LEAST
      C  WE CAN DO IS WARN HIM/HER,
      C  AND TERMINATE THE PLOT
      C
              IF(NUMPOL.GT.0) GOTO 111
              TYPE 112
      112     FORMAT(2X,'********* NO POLYGONS LEFT ********')
```

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0179               GOTO 659
          C
0180      111      CONTINUE
          CD       TYPE 9306
          D        WRITE(3,9306)
          CD                        TYPE 9390                           !* *** DEBUG X VERSUS Y USE ***
          CD9390                    FORMAT('0*** ENTER 2 X-Y FLIP SWITCHES>0?:',$)  !**** DEBUG ***
          CD                        ACCEPT 14, IXYFL1,IXYFL2            !* *** DEBUG X VERSUS Y USE ***
          CD                        WRITE(3,9391) IXYFL1, IXYFL2        !* *** DEBUG X VERSUS Y USE ***
          CD9391                    FORMAT('0*** IXYFL1,2=',2I5)        !* *** DEBUG X VERSUS Y USE ***
0181               DO 78 J=1,NUMPOL
0182                 DO 81 M=1,NVERT(J)
0183                   IF(IX(M,J).EQ.0) GOTO 82
          CD                        IF(IXYFL1.GT.0)  GO TO 9381         !* *** DEBUG X VERSUS Y USE ***
0184                   IF(IY(M,J).LT.MINLIN(J)) MINLIN(J) = IY(M,J)
0185                   IF(IY(M,J).GT.MAXLIN(J)) MAXLIN(J) = IY(M,J)
0186                   IF(IX(M,J).LT.MINPIX(J)) MINPIX(J) = IX(M,J)
0187                   IF(IX(M,J).GT.MAXPIX(J)) MAXPIX(J) = IX(M,J)
          CD                        GO TO 9382                          !* *** DEBUG X VERSUS Y USE ***
          CD9381                    CONTINUE                            !* *** DEBUG X VERSUS Y USE ***
          CD                   IF(IX(M,J).LT.MINLIN(J)) MINLIN(J) = IX(M,J)
          CD                   IF(IX(M,J).GT.MAXLIN(J)) MAXLIN(J) = IX(M,J)
          CD                   IF(IY(M,J).LT.MINPIX(J)) MINPIX(J) = IY(M,J)
          CD                   IF(IY(M,J).GT.MAXPIX(J)) MAXPIX(J) = IY(M,J)
          CD9382                    CONTINUE                            !* *** DEBUG X VERSUS Y USE ***
0188      81         CONTINUE
0189      82         CONTINUE
          CD         TYPE 9307,J,0,KTYPE(J),NVERT(J),(IX(M,J),M=1,MNVERT),
          CD     2          (IY(M,J),M=1,MNVERT)
          CD     3          ,MINLIN(J),MAXLIN(J),MINPIX(J),MAXPIX(J)
          D          WRITE(3,9307) J,0,KTYPE(J),NVERT(J),(IX(M,J),M=1,MNVERT),
          D     2          (IY(M,J),M=1,MNVERT)
          D     3          ,MINLIN(J),MAXLIN(J),MINPIX(J),MAXPIX(J)
          C  FLAG LINES THAT IT IS NECESSARY TO READ
0190                 DO 91 L=MINLIN(J),MAXLIN(J)
0191                   LFLAG(L) = .TRUE.
0192      91         CONTINUE
0193      78       CONTINUE
          CD       TYPE 9309
          D        WRITE(3,9309)
          CD       TYPE 9310, LFLAG
          D        WRITE(3,9310)  LFLAG
          D9310    FORMAT(//' LFLAG=',(T8,2(5O4,1X,5O4,2X),2X),2X)
          CD       TYPE 9309
          D        WRITE(3,9309)
          C
          C  DOES USER WANT TO PLOT REFLECTANCE TYPES
          C  OR COUNTS
```

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0194    117     TYPE 113
0195    113     FORMAT(2X,'PLOT  1=COUNTS   2=REFLECTANCE TYPES')
        C***    N = 0
0196            ACCEPT 14,N
0197            IF(N.LT.1.OR.N.GT.2) GOTO 117
        C
0198            IF(N.EQ.2) SYM = .TRUE.
        C***    N = 0
        C
0199    900     CONTINUE                       ! END OF POLYGON SETUP
        C
        C  SET Y-AXIS VALUES - INVERT THE LIST
        C
0200            START = LOLIM(1) / 10
0201            INC = 0
0202            DO 61 J=1,52,JUMP(1)
0203              K = 53 - J
0204              YAXIS(K) = START + INC
0205              INC = INC + 1
0206              IF(SCALE(1).EQ.4) INC = INC + 1
0207    61      CONTINUE
        C
        C  SET X-AXIS VALUES
        C
0208            START = LOLIM(2) / 10
0209            FINISH = UPLIM(2) / 10
0210            I = 0
0211            DO 62 J=START,FINISH
0212              I = I + 1
0213              XAXIS(I) = J
0214              IF(SCALE(2).EQ.4.AND.J.NE.START) XAXIS(I) = XAXIS(I-1) + 2
0215    62      CONTINUE
        C
        C  SET THE FILE NAME FOR THE Y-AXIS INTO (YLABEL)
0216            DO 63 I=1,36
0217              K = I + 10
0218              YLABEL(K) = NAME(I,1)
0219    63      CONTINUE
        C
0220            OUTPUT = 1                     ! ASSUME SCATTERPLOT OUTPUT ON LINE PRINTER
        C*COM*  N = 0
        C*COM*995       TYPE 25
        C*COM*25            FORMAT(2X,'OUTPUT GOES TO 1=PRINT FILE  2=COMTAL')
        C*COM*  ACCEPT 14,N
        C*COM*  IF(N.LT.1.OR.N.GT.2) GOTO 995
        C*COM*  OUTPUT = N
0221            N = 0
        C
```

```
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ESCATT.FTN      /TR:BLOCKS/WR

         C  GET INFORMATION FOR COMTAL OUTPUT
         C
         C*COM*  IF(OUTPUT.EQ.1) GOTO 619
         C*COM*  TYPE 618
         C*COM*618        FORMAT(2X,'ENTER COMTAL INDEX FOR OUTPUT')
         C*COM*  ACCEPT 14,N
         C*COM*  COMOUT(1) = N
         C*COM*C***        N = 0
         C*COM*  TYPE 617
         C*COM*617        FORMAT(2X,'ENTER COMTAL INDEX FOR OUTPUT')
         C*COM*  ACCEPT 14,N
         C*COM*  COMOUT(2) = N
         C*COM*  N = 0
         C*COM*CD         TYPE 9991, 3, COMOUT, IUNIT
         C*COM*CDC        WRITE (3,9991) 3, COMOUT, IUNIT
         C*COM*  CALL GETCOM(COMOUT(1),IUNIT(3))          !* GET COMTAL, ASSIGN UNIT
         C*COM*CD         TYPE 9991, 3, COMOUT, IUNIT
         C*COM*CDC        WRITE (3,9991) 3, COMOUT, IUNIT
         C
         CD       TYPE 9991, 0, COM, IUNIT
         CDC      WRITE (3,9991) 0, COM, IUNIT
         C
         C******************************************************************************
         C*                                                                            *
         C*                      PROCESSING OF INPUT IMAGES                            *
         C*                                                                            *
         C******************************************************************************
         C
         C  DECIDE WHETHER WE'RE DOING WHOLE SCENE, OR POLYGONS
         C
0222              IF(NUMPOL.GT.0)  GO TO 1200
0223                NP = 1                       !* POLYGON LOOP LIMIT FOR WHOLE SCENE
0224                IN = 1                       !* ALWAYS IN THE "POLYGON" FOR WHOLE SCENE
0225                MINPX = 1                    !* PIXEL MIN,MAX LOOP LIMITS FOR WHOLE SCENE
0226                MAXPX = 512
0227                GO TO 1210
0228     1200     CONTINUE                       !* DOING POLYGON
0229                NP = NUMPOL                  !* LOOP LIMIT FOR POLYGONS = NUMBER OF POLYGONS
0230     1210     CONTINUE
         C
         C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
         C        LOOP OVER ALL 512 LINES OF IMAGES;  FIND LINES IN POLYGONS TO PROCESS
         C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
         C
0231              DO 100 L=1,512                 !* START LOOP TO READ IMAGE LINES
         C
         C  CHECK TO SEE IF WE NEED TO READ THIS LINE, IF NOT SKIP IT
0232                IF(.NOT.LFLAG(L)) GOTO 100
```

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0233                  HAVLIN = .FALSE.      !* HAVEN'T YET READ THIS NEW LINE FROM IMAGES
        CD            TYPE 9101, L
        D             WRITE(3,9101)  L
        D9101         FORMAT(' ********** START PROCESSING LINE',I4,', ************.')
        C
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C                   LOOP OVER POLYGONS (OR PROCESS WHOLE SCENE)
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C
0234                  DO 200  P = 1,NP                 !* LOOP OVER POLYGONS (OR WHOLE SCENE)
        C
0235                    IF(NUMPOL.LE.0)  GO TO 1230 !* CONTINUE IF DOING WHOLE SCENE
        C  DECIDE WHETHER THIS POLYGON INCLUDES THIS IMAGE SCAN LINE
0236                    IF(L.LT.MINLIN(P) .OR. L.GT.MAXLIN(P)) GO TO 200    !* SKIP IF NOT
0237                    MINPX = MINPIX(P)
0238                    MAXPX = MAXPIX(P)
0239    1230            CONTINUE
        C
        C  READ LINE IF DON'T HAVE IT YET
        C
0240                    IF(HAVLIN)  GO TO 1300
0241                    DO 150 I=1,2
        CD                WRITE(4,1112)I
        CD1112            FORMAT(2X,'READING FROM UNIT ',I4)
        C*COM*            IF(COMYES(I)) GOTO 989
        C
0242                      READ(I*L+10) (IBUF(I,J),J=1,512)
        C
        C*COM*            GO TO 150
        C*COM*C
        C*COM*989                CONTINUE
        C*COM*C
        C*COM*C  READ IMAGE FROM COMTAL
        C*COM*C
        C*COM*            CALL IMGLIN(IBUF(I,1),COM(I,1),L,1,512,0,1,0)
        C*COM*C
0243    150             CONTINUE
0244                    HAVLIN = .TRUE.
0245    1300            CONTINUE
        C
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C  LOOP OVER WHOLE LINE, OR SUPERSCRIBING RECTANGLE WHICH INCLUDES THIS POLYGON
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C
        C               INTOT = 0                     !* COUNT # PIXELS IN THIS POLY ON THIS LINE
0246                    DO 300  N=MINPX,MAXPY                  !* LOOP OVER PIXELS
        C
0247                      IF(NUMPOL.EQ.0)  GO TO 1400       !* ALWAYS IN IF DOING WHOLE AREA
```

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        C  PROCESS POLYGON AREAS TO CHECK WHETHER THIS PIXEL N IS IN THIS POLYGON P
0248                    IN = 0
        CD                                IF(IXYFL2.GT.0) GO TO 9383       !* *** DEBUG X VERSUS Y USE ***
0249                    CALL POLPIX(IN,N,L,IX(1,P),IY(1,P),NVERT(P))
        CD                                GO TO 9384                       !* *** DEBUG X VERSUS Y USE ***
        CD9383                            CONTINUE                         !* *** DEBUG X VERSUS Y USE ***
        CD              CALL POLPIX(IN,L,N,IX(1,P),IY(1,P),NVERT(P))
        CD9384                            CONTINUE                         !* *** DEBUG X VERSUS Y USE ***
0250                    POLYID = KTYPE(P)
0251                    IF(IN.EQ.0) GOTO 300        !* IF PIXEL NOT IN POLY SKIP TO END OF PIXEL LOOP
        C
        C  PROCESS PIXELS FOUND, WHETHER WITHIN A POLYGON OR WHOLE IMAGE
        C
0252    1000            CONTINUE
        D               INTOT = INTOT + 1           !* COUNT # PIXELS IN POLY ON THIS LINE
0253                    LN1(1) = IBUF(1,N)
0254                    LN2(1) = IBUF(2,N)
        C  CHECK THAT DATA IS WITHIN THE PROPER LIMIT
        C
0255                    IF(N1.GT.UPLIM(1).OR.N2.GT.UPLIM(2)) GOTO 987
0256                    IF(N1.LT.LOLIM(1).OR.N2.LT.LOLIM(2)) GOTO 987
        C
        C
        C  REGRESSION COMPUTATIONS
        C
0257                    SUMX = SUMX + N2
0258                    SUMY = SUMY + N1
0259                    SUMXX = SUMXX + (N2 * N2)
0260                    SUMYY = SUMYY + (N1 * N1)
0261                    SUMXY = SUMXY + (N1 * N2)
0262                    NPOINT = NPOINT + 1
        C
        C  SCALE DATA RANGE
        C
0263                    N1 = (N1-LOLIM(1)) / SCALE(1) + 1
0264                    N2 = (N2-LOLIM(2)) / SCALE(2) + 1
        C
        C  CHECK FOR BIN OVERFLOW
        C
0265                    IF (COUNTS(N1,N2).GT.32767) GOTO 300
0266                    COUNTS(N1,N2) = COUNTS(N1,N2) + 1
0267                    TOTALP = TOTALP + 1
0268                    GOTO 444
        C  COUNT OUTLAYER DATA
0269    987             OUTLAY = OUTLAY + 1
0270                    GOTO 300
        C
        C  IF WE WANT TO PRINT REFLECT SYMBOLS
```

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        C  INSTEAD OF COUNTS
        C
0271    444             IF(.NOT.SYM) GOTO 201
        C
        C***            L = 53 - N1
        C***            MAP(L,N2) = SYMBOL(POLYID+9)
0272                    MAP(53-N1,N2) = SYMBOL(POLYID+3)
0273    201             CONTINUE
        C
        C*COM*C
        C*COM*C  OUTPUT TO THE COMTAL
        C*COM*C
        C*COM*          IF(OUTPUT.EQ.1) GOTO 300
        C*COM*          CALL GPOINT(COMOUT,1,L,N,1)
        C*COM*C
        C
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
0274    300            CONTINUE                !* END LOOP OVER PIXELS (WITHIN A POLYGON, OR WHOLE SCENE)
        D              TYPE 9350, L,P,MINPX,MAXPX,MAXPX-MINPX+1,INTOT
        D              WRITE (3,9350) L,P,MINPX,MAXPX,MAXPX-MINPX+1,INTOT
        D9350          FORMAT(' LINE ',I4,', POLY=',I3,', PIXELS',I4,' TO',I4,
        D     2                ' =',I4,' HAS',I4,' POINTS IN POLYGON.')
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
0275    200          CONTINUE                  !* END LOOP OVER POLYGONS (OR WHOLE SCENE)
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
0276    100     CONTINUE                       !* END LOOP OVER ALL 512 IMAGE SCAN LINES
        C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
        C
        CD      TYPE 9991, 0, COM, IUNIT
        CDC     WRITE (3,9991) 3, COM, IUNIT
        C
        C*********************** ************************************************************
        C*                                                                                 *
        C*                            WRITING THE SCATTERPLOT                              *
        C*                                                                                 *
        C*********************** ************************************************************
        C
        C  COMPUTE BETA,ALPHA,RESID FOR REGRESSION LINE   Y = BETA*X + ALPHA
        C
0277            XMEAN = SUMX / NPOINT
0278            YMEAN = SUMY / NPOINT
0279            BETA = (SUMXY-((SUMX*SUMY)/NPOINT))/(SUMXX-((SUMX**2)/NPOINT))
0280            X = ((SUMXY-(SUMX*SUMY/NPOINT))**2)/(SUMXX-SUMX**2/NPOINT)
0281            RESID = (SUMYY - SUMY**2/NPOINT) - X
0282            ALPHA = YMEAN - (BETA*XMEAN)
        C  ALSO CALCULATE INVERSE REGRESSION LINE   X = BETA2*Y + ALPHA2
0283            BETA2 = 1.0 / BETA
0284            ALPHA2  = - ALPHA / BETA
```

```
FORTRAN IV-PLUS V02-51E          17:21:59    12-DEC-82           PAGE 16
ESCATT.FTN       /TR:BLOCKS/WR

      C
      C   IF WE PLOTTED SYMBOLS INSTEAD ON COUNTS
      C   WE ARE READY FOR OUTPUT
      C
                IF(SYM) GOTO 669
      C
      C   SET SYMBOLS IN MAP ARRAY
      C
                DO 400 I=1,52
      C           INVERT Y-AXIS
                  L = 53 - I
                  DO 401 J=1,52
                    IF(COUNTS(I,J).EQ.0) GOTO 401
                    DO 402 K=1,40
                      IF(COUNTS(I,J).LT.TOTALS(K+1)) GOTO 404
      402           CONTINUE
      403           GOTO 401
      404           MAP(L,J) = SYMBOL(K)
      401         CONTINUE
      400       CONTINUE
      C
      C   OUTPUT DATA TO THE LINE PRINTER
      C   WRITE HEADER FOR PLOT
      C
      C   PRINTER PROPER HEADER
      C
      D         WRITE(3,9699)
      CD        TYPE 9699
      D9699     FORMAT('0*** *** END SCATT DEBUG *** ***')
                IF(.NOT.SYM) GOTO 405
      C
      669       WRITE(3,437)
      437       FORMAT('1',63X,'SCATTER PLOT',15X,'SYMBOLS ARE BOTTOM',
           1             ' REFLECTENCE TYPES')
                GOTO 439
      C
      405       WRITE(3,499)
      499       FORMAT('1',63X,'SCATTER PLOT',46X,'LEGEND')
      439       CONTINUE
      C***          WRITE(3,498)
      C***498 FORMAT(' ')
      C
                DO 555 I=1,52
                  IF(I.GT.40.OR.SYM) GOTO 850
                  IF(YAXIS(I).EQ.0) GOTO 849
                  WRITE(3,525)YLABEL(I),YAXIS(I),(MAP(I,J),J=1,52),SYMBOL(I),
           1                        DPR(I),TOTALS(I)
      525         FORMAT(8X,A1,1X,I3,':',52(A1,' '),3X,A1,1X,A1,1X,I5)
```

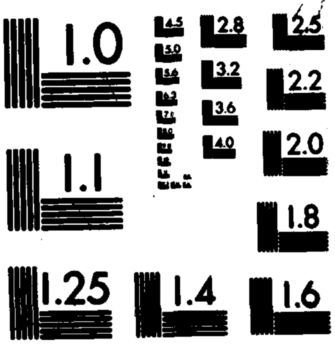
AD-A130 648 MULTI-TEMPORAL ANALYSIS OF LANDSAT IMAGERY FOR
BATHYMETRY(U) ENVIRONMENTAL RESEARCH INST OF MICHIGAN
ANN ARBOR APPLICATIONS DIV F J TANIS ET AL. MAY 83
UNCLASSIFIED ERIM-155500-2-F N00014-81-C-2334 F/G 8/10 NL

2/2

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
                GOTO 555
      849       WRITE(3,506)YLABEL(I),(MAP(I,J),J=1,52),SYMBOL(I),OPR(I),
     1                          TOTALS(I)
      506       FORMAT(8X,A1,4X,':',52(A1,' '),3X,A1,1X,A1,1X,I5)
      C
                GOTO 555
      C
      850     CONTINUE
                IF(YAXIS(I).EQ.0.AND.I.NE.52) GOTO 848
                WRITE(3,507)YLABEL(I),YAXIS(I),(MAP(I,J),J=1,52)
      507     FORMAT(8X,A1,1X,I3,':',52(A1,' '))
                GOTO 555
      848     WRITE(3,508)YLABEL(I),(MAP(I,J),J=1,52)
      508     FORMAT(8X,A1,4X,':',52(A1,' '))
      C
      555     CONTINUE
      C
              WRITE(3,899)
      899     FORMAT(14X,'----------------------------------------------------',
     1  '----------------------------------------------------')
      C2345678901234567890123456789012345678901234567890123456789012345678901234567890
      C  WRITE OUT THE X-AXIS VALUES
      C
               IF(SCALE(2).EQ.5) GOTO 811
               IF(SCALE(2).EQ.4.OR.SCALE(2).EQ.2) GOTO 810
      C  WRITE SCALE = .1
               WRITE(3,801)(XAXIS(J),J=1,6)
      801      FORMAT(13X,I2,5I20)
               GOTO 825
      C  WRITE SCALE = .4 OR .2
      810      WRITE(3,802)(XAXIS(J),J=1,11)
      802      FORMAT(5X,11I10)
               GOTO 825
      C  WRITE SCALE = .5
      811      WRITE(3,803)(XAXIS(J),J=1,26)
      803      FORMAT(11X,26I4)
      C
      825      CONTINUE
      C***     WRITE(3,498)
               WRITE(3,830)(NAME(J,2),J=1,36)
      830      FORMAT(55X,36A1)
      C
      C
               WRITE(3,831)LOLIM(1),UPLIM(1),RES(RESPT(1))
      831      FORMAT(2X,'DATA RANGE ON THE VERTICAL AXIS   ',
     1                  I4,' - ',I4,' RESOLUTION IS ',F2.1,' METER')
               WRITE(3,832)LOLIM(2),UPLIM(2),RES(RESPT(2))
      832      FORMAT(2X,'DATA RANGE ON THE HORIZONTAL AXIS',
```

```
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              1            I4,' = ',I4,' RESOLUTION IS ',F2.1,' METER')
        C
0340                WRITE(3,500)TOTALP,OUTLAY
0341        500     FORMAT(2X,'NUMBER OF POINTS PLOTTED ',I7,
              1            ' NUMBER OF OUTLYERS ',I7)
        C
        C
        C***        IF(.NOT.POLYES(1).AND..NOT.POLYES(2)) GOTO 659
0342                IF(.NOT.POLYES)  GO TO 659
0343                WRITE(3,658)  (NAME(J,3),J=1,36), (USER(J),J=1,100)
0344        658     FORMAT(2X,'POINTS ARE DEFINED BY POLYGON FILE ',36A1/
              2            2X,'USING BOTTOM REFLECTANCES:  ',100A1)
        C
        C
0345        659     WRITE(3,657)BETA,ALPHA,RESID,BETA2,ALPHA2
0346        657     FORMAT('  REGRESSION LINE:  Y =',F12.6,' * X +',F14.6,
              2            ',  RESIDUAL =',E12.3,
              3            ';  OR  X =',F12.6,' * Y +',F14.6)
        C23456789012345678901234567890123456789012345678901234567890123456789012345678900
        C
        C  END OF PROGRAM
0347                CALL FINIS
0348                END
```

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PROGRAM SECTIONS

NUMBER   NAME       SIZE                   ATTRIBUTES

  1      $CODE1   010302   2145            RW,I,CON,LCL
  3      $IDATA   003114    806            RW,D,CON,LCL
  4      $VARS    030002   6145            RW,D,CON,LCL
  5      $TEMPS   000014      6            RW,D,CON,LCL
  6      SYST     020000   4096            RW,D,OVR,GBL
  7      PMCOM    000012      5            RW,D,OVR,GBL


VARIABLES

 NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS     NAME    TYPE  ADDRESS

 ALPHA   R*4   4-000016    ALPHA2  R*4   4-000032    BETA    R*4   4-000022    BETA2   R*4   4-000036    BLANK   L*1   4-024362
 COMMA   L*1   4-024745    FINISH  I*2   4-000150    HAVLIN  L*2   4-027752    HOLD    I*2   4-003030    I       I*2   4-017132
 IAFT    I*2   7-000006    IAXT    I*2   6-017716    ICTRLX  I*2   7-000010    II      I*2   4-027764    IN      I*2   4-027774
 INC     I*2   4-027770    ITTY    I*2   7-000034    J       I*2   4-017134    K       I*2   4-017130    L       I*2   4-017136
 M       I*2   4-027762    MAXPX   I*2   4-030020    MINPX   I*2   4-027776    N       I*2   4-003630    NCOM    I*2   6-000020
 M2      I*2   4-027772    NPOINT  I*4   4-000132    NTTY    I*2   6-000002    NUMPOL  I*2   4-027766    N1      I*2   4-000074
 N2      I*2   4-000002    OUTLAY  I*4   4-000122    OUTPUT  I*2   4-017126    P       I*2   4-017140    PMNAME  R*4   7-202000
 POLYES  L*2   4-027750    POLYID  I*2   4-003626    RESID   R*4   4-000026    START   I*2   4-000146    SUMX    R*8   4-000042
 SUMXX   R*8   4-000062    SUMXY   R*8   4-000072    SUMY    R*8   4-000052    SUMYY   R*8   4-000102    SYM     L*2   4-027746
 TOTALP  I*4   4-000126    X       R*8   4-000112    XMEAN   R*4   4-000006    YMEAN   R*4   4-000012


ARRAYS

 NAME    TYPE  ADDRESS        SIZE         DIMENSIONS

 BKGCEF  R*4   6-003332   000220     72    (6,6)
 BKGCER  R*4   6-003552   000220     72    (6,6)
 CDM     I*2   4-016776   000010      4    (2,2)
 COMOUT  I*2   4-000152   000004      2    (2)
 CONTAR  I*2   6-000010   002260    600    (200,3,1)
 COVTEM  I*2   6-003776   000014      6    (6,1)
 COUNTR  I*2   4-004336   012440   2704    (52,52)
 CURSE   I*2   6-002320   000014      6    (6)
 DHOMA   I*2   6-003772   000002      1    (1)
 DUMMA   I*2   6-003774   000002      1    (1)
 FLICK1  I*2   6-002270   000014      6    (6)
 FLICK2  I*2   6-002304   000014      6    (6)
 FOTACF  R*4   4-003076   000220     72    (6,6)
 HOMEC2  L*1   6-002724   000074     30    (10,6)
 IBUF    L*1   4-020541   002000    512    (2,512)
 ICSYC   I*2   6-002714   000002      1    (1)
```

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ORTRAN IV-PLUS V02-51E         17:21:59    12-DEC-82            PAGE 20
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ICSYC   I*2    6-022716  000002     1    (1)
ICHIGH  I*2    6-002722  000002     1    (1)
ICWIDE  I*2    6-002720  000002     1    (1)
IDSPY   I*2    6-003074  000002     1    (1)
ILSV    I*2    6-004012  000240    80    (80)
IMGFL1  I*2    6-002654  000014     6    (6)
IMGFL2  I*2    6-002700  000014     6    (6)
IPSV    I*2    6-004252  000240    80    (80)
ISPARE  I*2    6-004512  013224  2882    (2882)
IUNIT   I*2    4-027754  000006     3    (3)
IX      I*2    4-001322  001130   300    (6,50)
IXOFF   I*2    6-003020  000002     1    (1)
IY      I*2    4-002452  001130   300    (6,50)
IYOFF   I*2    6-003022  000002     1    (1)
JPFSTK  I*2    6-023316  000014     6    (6)
JUMP    I*2    4-000156  000004     2    (2)
KTYPE   I*2    4-001012  000144    50    (50)
LFLAG   L*1    4-026746  001000   256    (512)
LHOLD   L*1    4-000000  000002     1    (2)
LITCOM  I*2    6-017720  000060    24    (24)
LN1     L*1    4-022224  000002     1    (2)
LN2     L*1    4-020022  000002     1    (2)
LOLIM   I*2    4-002136  000004     2    (2)
LUNASG  I*2    6-000224  000002     1    (1)
LUNNUM  I*2    6-000226  000002     1    (1)
MAP     L*1    4-017142  005220  1352    (52,52)
MAXLIN  I*2    4-000336  000144    50    (50)
MAXPIX  I*2    4-000546  000144    50    (50)
MCOL    I*2    6-002334  000330   108    (18,6)
MINLIN  I*2    4-000172  000144    50    (50)
MINPIX  I*2    4-000572  000144    50    (50)
NAME    L*1    4-023365  000154    54    (36,3)
NVERT   I*2    4-001156  000144    50    (50)
OPR     L*1    4-026675  000050    20    (40)
RANGE   I*2    4-004322  000010     4    (4)
REPET   I*2    6-023024  000050    20    (20,1)
RES     R*4    4-003602  000020     8    (4)
RESPT   I*2    4-003622  000004     2    (2)
SCALE   I*2    4-004332  000004     2    (2)
SCALE1  I*2    4-004312  000010     4    (4)
SKIPF   I*2    4-000162  000010     4    (4)
SYMBOL  L*1    4-026541  000050    20    (40)
TOTAL1  I*2    4-017206  000120    40    (40)
UPLIM   I*2    4-000102  000004     2    (2)
USETT   L*1    4-024054  000062    25    (50)
USER    L*1    4-024146  000144    50    (100)
XAXIS   I*2    4-001022  000062    25    (25)
XY      L*1    4-020363  000002     1    (2)
```

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FORTRAN IV-PLUS V02-51E          17:21:59    12-DEC-82          PAGE 21
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 YAXIS   I*2    4-003632  000150    52    (52)
 YLABEL  L*1    4-026611  000064    26    (52)

LABELS

 LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS         LABEL   ADDRESS

 1          **           2          **           3'      3-000000        4          **           14'     3-000752
 19'     3-001056        21'     3-000050        22'     3-000152        30         **           40'     3-001204
 41'     3-001256        42'     3-001270        43'     3-001330        44'     3-001410        53         **
 55         **           61         **           62         **           63         **           70      1-002120
 71      1-002520        72      1-002602        75         **           77      1-002630        78         **
 79      1-002670        81         **           82      1-003452        91         **           100     1-005510
 111     1-003240        112'    3-001414        113'    3-001462        117     1-003540        150        **
 181        **           199     1-003126        200     1-005462        231     1-005426        300     1-005434
 301        **           303'    3-001126        306     1-001770        340        **           341        **
 400        **           401     1-006166        402        **           403        **           404     1-006132
 425     1-006262        437'    3-001534        439     1-006310        444     1-005356        499'    3-001632
 500'    3-002460        505'    3-001670        506'    3-001724        537'    3-001760        538'    3-002022
 555     1-007202        600     1-030450        601'    3-000156        605     1-002636        606'    3-000756
 610     1-000750        611'    3-001016        620     1-001062        657'    3-002674        658'    3-002554
 659     1-010170        669     1-006232        776     1-002330        777     1-003060        801'    3-002222
 802'    3-002212        803'    3-002220        810     1-007370        811     1-007454        825     1-007550
 830'    3-002226        831'    3-002234        832'    3-002350        833     1-002214        848     1-007074
 849     1-006540        850     1-006724        899'    3-002024        900     1-003656        997     1-005334
 999     1-001230        1200    1-004272        1210    1-004306        1230    1-004450        1300    1-074614
 1400    1-004770

FUNCTIONS AND SUBROUTINES REFERENCED

 FINIS   OPENS   PMINIT  POLPIX

TOTAL SPACE ALLOCATED = 063444 13203

ESCATT,ESCATT/-SP=ESCATT
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