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Technical Report

DOCUMENTATION OF COMPUTER PROCEDURES FOR LABELING SPRING GRAINS AND DISCRIMINATING BETWEEN SPRING WHEAT AND BARLEY USING LANDSAT DATA

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NOTICES

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16. Abstract

The computer software necessary to perform two research labeling procedures is described and documented in this report. The first labeling technique identifies spring small grain fields based on similarity of growing season and temporal-spectral patterns of development in Landsat data. The second technique further labels these fields as either wheat, barley or unknown spring grain, based on their spectral position in Tasseled Cap Greenness-Brightness space for a given day around the dough stage of wheat. The development and evaluation of the techniques have previously been described and short descriptions of the technology are included in this report. The subroutines which carry out the steps of the procedure are coded in PREFOR, a preprocessed FORTRAN, designed by IBM and available on computer systems at Purdue University (LARS), NASA/Johnson Space Center (EODL), and the University of Michigan (MTS). The subroutines use certain functions available on these systems, and were designed to fit into the U.S. Corn/Soybean baseline procedure software developed for use in the AgRISTARS Program. Documentation of the subroutines are provided in an Appendix.

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TECHNICAL REPORT

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BY

Jack A. Finkler and Eric P. Crist

This report describes results of research carried out in support of the Area Estimation Design Element of the Supporting Research Project.

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PREFACE

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing program, AgRISTARS, is a six-year program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources, which began in Fiscal Year 1980. This program is a cooperative effort of the National Aeronautics and Space Administration, the U.S. Agency for International Development, and the U.S. Departments of Agriculture, Commerce, and the Interior. AgRISTARS consists of eight individual projects.

The work reported herein was sponsored by the Supporting Research (SR) Project under the auspices of the National Aeronautics and Space Administration, NASA. Robert B. MacDonald, NASA Johnson Space Center, was the NASA Manager of the SR Project and Dr. Cecil R. Hallum was the Technical Coordinator for the reported effort.

The Environmental Research Institute of Michigan and the Space Sciences Laboratory of the University of California at Berkeley comprise a consortium having responsibility for development of corn/soybeans area estimation procedures for use on data from South America within both the Supporting Research and Foreign Commodity Production Forecasting Projects. Other supporting research activities are also conducted by them.

This reported research, directed at the labeling of small grains and the discrimination of wheat and barley in multi-date Landsat data, was performed within the Environmental Research Institute of Michigan's Infrared and Optics Division, headed by Richard R. Legault, a Vice-President of ERIM, under the technical direction of Robert Horvath, Program Manager, and Dr. William A. Malila, Task Leader.

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INTRODUCTION

The success of a crop estimation procedure using Landsat image data depends largely on its ability to accurately label sampling entities (e.g., pixels, fields, clusters, etc.). Manual assignment of labels during the LACIE project was found to be both time consuming and a source of considerable error. In response to the need for increased accuracy and objectivity, procedures were sought in which the labeling decisions were left to the machine. At ERIM, two research procedures were developed, one to identify spring small grains and another to discriminate between spring wheat and barley.

The two procedures have recently been implemented as FORTRAN subroutines for delivery to NASA/JSC. This report, along with its appendices, describes the computer algorithms used in the procedures, and documents the subroutines performing the operations. Reports discussing the development and testing of the technology have previously been released [1, 2, 3], and therefore only brief technical overviews are included here.

2
GENERAL PROCEDURES DESCRIPTION

A procedure for labeling spring grain fields and further classifying the interior pixels of these fields as either wheat, barley or unknown spring small grains is presented here. The overall procedure can be functionally viewed in three major stages, the output of which can be used in a proportion estimation procedure (Figure 1). The purpose of the first stage is to normalize the data, identify fields or quasi-fields as targets and provide analyst inputs. In Stage 2, the fields are labeled spring small grain or other. The interior pixels of the small grain fields are further classified in Stage 3 as wheat, barley or unknown small grain. The subroutines performing Stages 2 and 3 are documented in Appendix A and it is intended that they be linked with a computer/analyst system that provides the necessary function of Stage 1. This section provides an overview of all three stages.

2.1 STAGE 1 - DATA NORMALIZATION AND ANALYST INPUTS (Not included in the software documented in this report)

One purpose of this stage is to generate normalized, Tasseled Cap transformed data in which fields or quasi-fields have been identified. Normalization is required in order to remove variance in the data due to the extraneous effects of sun angle, satellite calibration and atmospheric haze, as well as to flag bad data such as clouds, water, etc. Modules which perform these functions exist on the U.S. Corn/Soybean Baseline Procedure software system developed by ERIM and UCB [4] and will not be described in this report.

This is the only stage where an analyst-interpreter is necessary (Table 1). The analyst must provide initial screening of the segment, acquisition selection, and parameter inputs for Stage 2. Decision logic

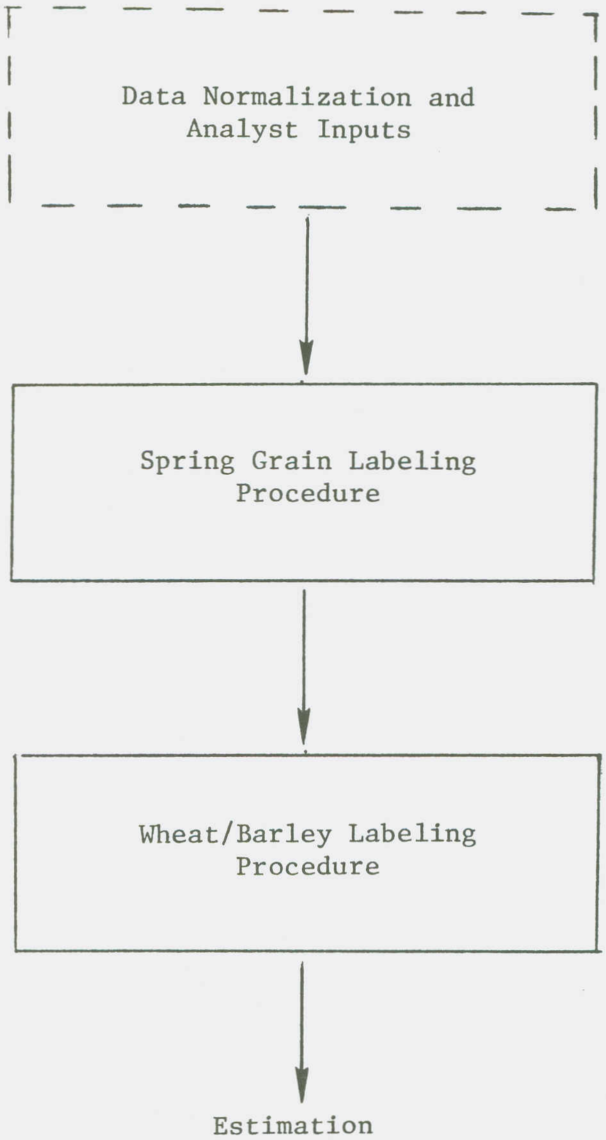

FIGURE 1. OVERALL PROCEDURE FLOW DIAGRAM

TABLE 1. OUTLINE OF STEPS FOR STAGE 1: DATA NORMALIZATION AND ANALYST INPUTS

STAGE 1 - Procedure Requirements

1. Initial Screening of Segment - Analyst Function
   a. Presence of unusual phenomena, anomalous conditions
   b. Inadequate acquisition history
2. Data Normalization
   a. Satellite calibration
   b. Cosine sun angle correction
   c. Screening for bad data, clouds, etc.
   d. Haze correction
3. Tasseled Cap Transformation
4. Assignment of Pixels to Fields or Quasi-Fields
   a. Pixel assignment
   b. Generation of statistics for quasi-fields
5. Procedural Parameters - Analyst Function
   a. Expected mean day of spectral emergence for each crop
   b. Three weights for Fisher's Omnibus Procedure
      i. The crop calendar shift weight
      ii. The Greenness profile fit weight
      iii. The Brightness profile correlation weight

for the analyst is not provided here and in certain cases has yet to be determined.

2.2 STAGE 2 - SPRING GRAIN PROCEDURE

Stage 2 represents an application of 'profile technology', that is, the use of features derived directly or indirectly from characterizations of the continuous patterns of temporal-spectral crop development. The central element in this stage is a group of profile sets representing the spectral development of a number of crops in Tasseled Cap Greenness and Brightness space. A series of comparisons is carried out between these profile sets and the target data.

First, a temporal shift is determined which maximizes the cross-correlation of the Greenness data points to the Greenness profile. The shift is then applied to the target data and a multiplicative scale factor is computed between the Greenness data and profile. After both adjustments are made, a chi-squared goodness-of-fit of the data to the profile is computed. For the Brightness data, a cross-correlation calculation is used to evaluate the fit to the Brightness profiles.

After these statistics have been calculated for a particular crop, a separate probability is computed for the shift estimate, Greenness fit, and Brightness correlation associated with the profile set. The Greenness probability uses a standard chi-squared test. For the other two features, previously derived empirical distributions are used. The shift estimate probability is based on the expected mean day of spectral emergence for a crop, which must be provided at Stage 1. The three probabilities are then combined into a single statistic using Fisher's omnibus procedure. The probability of this statistic is then determined using a chi-squared test with degrees of freedom equal to twice the sum of the weights used. If the combined probability exceeds a threshold value, the crop represented by the profile set is considered probable enough to be retained as a candidate. Otherwise, the crop is rejected.*

The modules necessary to carry out Stage 2 in its entirety are documented in Appendix A, and the algorithms used by these modules are outlined in Table 2.

2.3 STAGE 3 - WHEAT/BARLEY LABELING

Several studies at ERIM have indicated that for a period of time toward the end of the growing season (around the dough stage of wheat), wheat and barley occupy different locations in Greenness-Brightness space. Once crop calendar shift differences have been removed, barley tends to be brighter and less green than wheat on any given day within this range. The separability during this interval is the basis of ERIM's wheat/barley procedure.

In Stage 3A, a temporal shift is calculated for each small grain field in the segment in the same manner as in Stage 2, and the shift is then applied to the target data. The Brightness values with shifted days between -15 and -5 are summed and averaged to obtain a segment-level estimate of soil Brightness. Using linear regression analysis applied to the field means a segment-specific crop profile is generated from which a peak Greenness value is obtained. These two quantities serve to describe key conditions which affect the spectral appearance of the crops of interest.

In Stage 3B a set of values, a 'decision line', is computed for this time period according to the spectral conditions of the segment. The segment-level condition indicators (Brightness mean and peak Greenness

---

*This description was adapted from: "A Technique for Automatic Labeling of Landsat Agricultural Scene Elements by Analysis of Temporal-Spectral Patterns", E. Crist and W. Malila, 15th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, May 1981

TABLE 2. OUTLINE OF STEPS FOR STAGE 2: SPRING GRAIN LABELING OF QUASI-FIELDS

STAGE 2 -

- Do for each quasi-field in segment that has interior pixels -

1. Initial Standardization and Subsetting of Target Data (Values reflect Tasseled Cap Greenness input with offset of 32).

    a. Subtract 25.0 from each Greenness value.

    b. If resulting value is greater than 0 include acquisition in subset.

    c. If there are at least three acquisitions in subset and at least one with a value greater than 10, continue with processing, else label field 'unknown'.

    d. Subroutine GPREP.

- Do for each profile set -

2. Compute Crop Calendar Shift Using Greenness Profile.

    a. Estimate data peak by fitting a quadratic equation to the three greatest Greenness values.

    b. Shift = (day of profile peak) - (day of data peak)

    c. Adjust shift by choosing that shift within 30 days of the initial value which gives the greatest cross-correlation between data and profile.

    d. Subroutine CSHIFT.

3. Assign Probability to Shift.

    a. Probabilities are assigned using a function based on a prior empirical analysis of planting date variability.

    b. Equal probabilities (.99) are assigned for any shift within 14 days of the expected mean.

    c. For shifts >14 days of the expected mean decreasing probabilities are assigned.

    d. Subroutine SHPROB.

TABLE 2. OUTLINE OF STEPS FOR STAGE 2: SPRING GRAIN LABELING OF QUASI-FIELDS (Continued)

4. Subset Data

   a. Shifted day must be between 1 and number of days in profile, inclusive.

   b. If <3 acquisitions in subset label target 'unknown'.

   c. Subroutine DATSUB.

5. Scale Data to Profile

   a. There must be at least two acquisitions in day-range 20 to (Number of days in profile - 20).

   b. If <2 acquisitions in specified range label target 'unknown'.

   c. $\text{Scale} = \frac{\Sigma F_i * F_i}{\Sigma F_i * G_i}$ F_i = profile value (Greenness); G_i = data value (Greenness)

   d. Scale <u>all</u> acquisitions in profile range.

   e. Subroutine PSCALE.

6. Compute Chi-squared Fit of Greenness Data to Profile.

   a. $\text{Fit} = \Sigma \frac{(F_i - kG_i)^2}{S_i}$

      F_i = profile value

      G_i = Greenness value

      S_i = variance for G_i

      k = scale

   b. Chi-squared probability: degrees of freedom = (number of acquisitions) - 1.

   c. Subroutine PFIT and IMSL routine MDCH.

- Do for each Brightness profile in set -

7. Compute Cross-Correlation of Brightness Data to Profile.

   a. $r = \frac{\Sigma (f_i * g_i)}{\sqrt{(\Sigma g_i^2) * (\Sigma f_i^2)}}$

      f_i = (profile value) - (profile mean)

      g_i = (data value) - (data mean)

TABLE 2. OUTLINE OF STEPS FOR STAGE 2: SPRING GRAIN LABELING OF QUASI-FIELDS (Continued)

b. Subroutine RCORR.

8. Compute Probability of the Correlation (use the greatest cross-correlation obtained).

   a. This probability is assigned using a function based on a prior empirical study of the cumulative distribution of correlations of known grain data with the grain profile.

   b. Subroutine RPROB.

- End loop over Brightness profiles in set -

9. Combine Probabilities Using the Fisher Omnibus Procedure.

   a. $T = -2 \sum_{i=1}^{3} w_i P_i$ where

      w_1, P_1 = weight and probability of shift

      w_2, P_2 = weight and probability of Greenness Fit

      w_3, P_3 = weight and probability of Brightness correlation (if more than 1 Brightness profile use the profile with the greatest correlation)

   b. Subroutine FISPRO.

10. Assign Probability to T.

   a. Chi-squared test.

   b. Degrees of freedom equal twice the sum of the weights.

   c. Subroutine FISPRO using IMSL routine MDCH.

11. Assign Label.

   a. Label field as crop which gives the greatest probability, or

   b. Assign probability labels for all crops which give a probability greater than a specific threshold (not implemented in software).

   c. Subroutine ASIGNL.

- End loop over profile set -

- End loop over fields -

value) are used to determine the starting day of the decision line and the decision value for that day (Figure 2). The slope of the line is fixed.

Finally in Stage 3C, labels are affixed to the interior pixels of fields. A temporal shift is calculated for each pixel, and the earliest shifted acquisition within the range of the decision line is used to calculate a test statistic, GBDIST (Table 3, Step 9B). If GBDIST is greater than the decision value, the pixel is labeled barley; otherwise, it is labeled wheat.

The modules necessary to carry out Stage 3 are documented in Appendix A and the functions performed by these modules are outlined in Table 3.

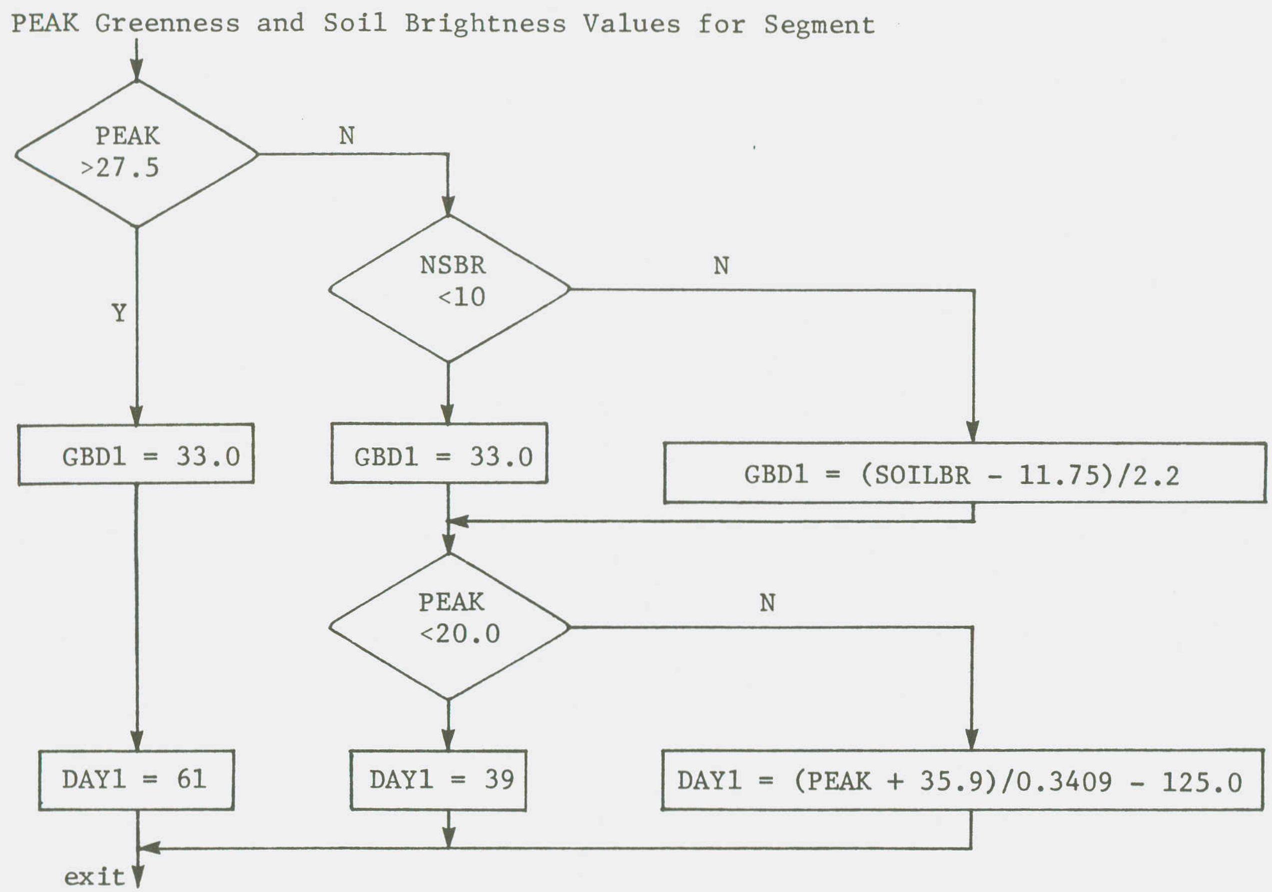

FIGURE 2. FLOW DIAGRAM OF LOGIC FOR DECISION LINE MODIFICATION

Abbreviations are described in Steps 4, 5, and 6 of Table 3.

TABLE 3. OUTLINE OF STEPS FOR STAGE 3: WHEAT/BARLEY LABELING OF PIXELS

STAGE 3A - Generate Segment-Level Statistics

- Do for all spring small grain quasi-fields -

1.* Initial Standardization and Subsetting of Target Data (Values reflect Tascap Greenness input with offset of 32).

   a. Subtract 25.0 from each Greenness value.

   b. If resulting value is greater than 0 include acquisition in subset.

   c. If there are at least three acquisitions in subset and at least one with a value greater than 10, continue with processing, otherwise label field 'unknown'.

   d. Subroutine GPREP.

2.* Compute Crop Calendar Shift Using Reference Greenness Profile.

   a. Estimate data peak by fitting a quadratic equation to the three greatest Greenness values.

   b. Shift = (day of profile peak) - (day of data peak).

   c. Adjust shift by choosing that shift within 30 days of the initial value which gives the greatest cross-correlation between data and profile.

   d. Subroutine CSHIFT.

3. Estimate Parameters for Segment Specific Greenness Profile Using Linear Regression.

   a. Convert observations to regression variables Y, X1, X2.

$$Y = \ln_e(G)$$

$$X1 = \begin{cases} (T - T_{MAX})^2 & \text{for } T < T_{MAX} \\ 0 & \text{for } T \geq T_{MAX} \end{cases}$$

*These steps are duplicated from Stage 2, enabling Stage 3 to be performed without Stage 2 being run prior to it. This would necessitate the spring small grain fields be identified by some other procedure.

TABLE 3. OUTLINE OF STEPS FOR STAGE 3: WHEAT/BARLEY LABELING OF PIXELS (Continued)

$$X2 = \begin{cases} 0 & \text{for } T < T_{MAX} \\ (T - T_{MAX})^2 & \text{for } T > T_{MAX} \end{cases}$$

T_{MAX} = day of maximum profile Greenness = 35

G = Tascap Greenness (offset by 32) - 25.0

T = shifted day of year

b. Compute the elements of the system of normal equations.

c. Subroutine MLRSET.

4. Compute Segment-Level Soil Brightness Sum.

a. Check for all acquisitions between shifted days -15 and -5.

b. Increment the soil Brightness sum (TSBR) by the Brightness values of said acquisitions and the number of points used in the sum (NSBR) by the number of said acquisitions.

c. Subroutine COMPSB.

- End of spring grain field loop -

STAGE 3B - Establish Decision Line

5. Solve Regression Equation and Calculate Profile Peak.

a. Equation: $Y = \beta_o + \beta_1 X1 + \beta_2 X2$

Variables defined in Step 3

b. Peak of profile = e^{β_o}

c. Subroutine MLRFIT.

6. Modify Decision Line According to the Greenness peak as defined in Step 5 and the soil brightness estimate, SOILBR = TSBR/NSBR.

a. Decision line has a fixed slop of 0.61 and spans an 18-day range.

TABLE 3. OUTLINE OF STEPS FOR STAGE 3: WHEAT/BARLEY LABELING OF PIXELS (Continued)

b. Day 1, the day associated with the first point of the line, and the Greenness-Brightness distance value (GBD1) assigned to Day 1 are determined using the logic described in Figure 2.

c. Subroutine DECLIN.

STAGE 3C - Labeling of Pixels

- Do for all interior pixels of spring grain fields -

7. Initial Standardization and Subsetting of Target Data (Values reflect Tascap Greenness input with offset of 32).

   a. Subtract 25.0 from each Greenness value.

   b. If resulting value is greater than 0 include acquisition in subset.

   c. If there are at least three acquisitions in subset and at least one with a value greater than ten, continue with processing, otherwise label field 'unknown'.

   d. Subroutine GPREP.

8. Compute Crop Calendar Shift Using Greenness Profile.

   a. Estimate data peak by fitting a quadratic equation to the three greatest Greenness values.

   b. Shift = (day of profile peak) - (day of data peak).

   c. Adjust shift by choosing that shift within 30 days of the initial value which gives the greatest cross-correlation between the data and the profile.

   d. Subroutine CSHIFT.

9. Label Pixel.

   a. Select the first acquisition with shifted day between Day 1 and (Day 1 + 17), inclusive (see Figure 2). If no acquisition exists, label pixel 'unknown'.

TABLE 3. OUTLINE OF STEPS FOR STAGE 3: WHEAT/BARLEY LABELING OF PIXELS (Continued)

b. For said acquisition, if GBDIST, defined as (.681*Brightness - .7323*Greenness)†, is greater than the decision line value for that day, label the pixel barley, otherwise label the pixel wheat.

c. Record for each quasi-field the proportion of interior pixels assigned to each label.

d. Subroutine CLASIF.

- End loop over pixels -

---

†Brightness and Greenness as Tasseled-Cap values with an offset of 32.

3
SOFTWARE CONSIDERATIONS AND LIMITATIONS

3.1 LANGUAGE REQUIREMENTS

All subroutines documented in Appendix A are coded in PREFOR [5], a preprocessed FORTRAN with structured constructs designed by IBM. A special preprocessor is required to convert the source code into standard FORTRAN from which object code can be generated using the FORTRAN H or G compiler.

3.2 INDEPENDENCE OF SUBROUTINES

Each step of Stages 2 and 3 (Tables 2 and 3) is performed by a separate FORTRAN subroutine. Each of these subroutines operate on a single target (pixel, blob, etc.) and were designed with the following objectives:

- Easy maintenance and modification
- Independence from any particular data base structure
- Independence from any computer or operational system

Three additional subroutines, SPRIN, REGRESS, and WBLAB, are provided which link certain of the subroutines in order to facilitate the carrying out of the procedure. SPRIN performs spring grain labeling and calls the required subroutines in the manner shown in Figure 3. REGRES fits the field means to the profile regression model obtaining the segment specific peak Greenness value used to modify the wheat/barley decision line (Figure 4). WBLAB labels the interior pixels of spring grain fields as either wheat, barley or unknown spring grain (Figure 4).

```
INPROF                                                  - Read profiles from file
 :
CONVAC                                                  - Convert  Julian dates to
 :                                                        day of year
SPRIN ------ Loop over  big* blobs
                           :
                        GPREP ------- CONGRB            - Standarize and delete bad
                           :          CHEKGR              acquisitions
             Loop over crops
                           :
                        CSHIFT ----- QUFIT              - Crop calendar shift
                           :          XSHIFT
                        SHPROB                          - Probability associated
                           :                              with shift
                        DATSUB                          - Subset  data
                           :
                        FITPRO ------ PSCALE            - Greenness scale factor,
                           :          PFIT                fit and probability, resp.
                           :          MDCH
                        BRCORR ------ RCORR             - Brightness correlation and
                           :          RPROB               probability, resp.
                        FISPRO ------ MDCH              - Cumulative probability
                           :
                        ASIGNL                          - Assign blob to a crop type

               End loop
               End loop
```

FIGURE 3. CALLING SEQUENCE OF SUBROUTINES FOR SPRING GRAIN LABELING PROCEDURE

---

*A big blob is a blob with at least one interior pixel (i.e., a pixel whose 'rook-move' neighbors are all from the same blob).

```
INPROF                                                      - Reads profiles from external
  :                                                           file
CONVAC                                                      - Converts Julian day to day
  :                                                           of year
REGRES ----- MLRSET (Stage 1) ----- COMPXY                  - Initializes regression
  :            :                    FILMAT                    matrices
  :          COMPSB (Stage 1)                               - Initialize soil Brightness
  :            :
  :      Loop over blobs
  :            :
  :          GPREP ----- CONGRB                             - Standardizes Greenness value
  :            :         CHEKGR                               and deletes bad acquisitions
  :          CHSIFT ---- QUFIT                              - Crop calendar shift
  :            :         XSHIFT
  :          MLRSET ---- (Stage 2) ----- COMPXY             - Converts observations to
  :            :                         FILMAT               regression variables and
  :            :                                              fills matrices
  :          COMPSB                                         - Increments soil Brightness
  :            :                                              for segment
  :      End loop
  :            :
  :          MLRFIT ---- SLUD                               - Solves regression equation
DECLIN                   SIR                                - Generates decision line
  :
SIMIND                                                      - Generates index by blob
  :                                                           number to blob statistics
Loop over scan lines+
  :
  :          Loop over pixels in scan line
WBLAB ------ if (pixel OK*)
               :
             GPREP ----- CONGRB (no opt)                    - CONGRB is not called
               :         CHEKGR
             CSHIFT ---- QUFIT (no opt)                     - QUFIT is not called
               :         XSHIFT
             CLASIF                                         - Carries out decision logic
             endif                                            and assigns pixel to wheat,
                                                              barley or unknown
             endloop
End loop
```

*Unscreened, interior pixel of a spring small grain field.

+The convention of storing Landsat images by scan line is adopted here. This requires special input/output routines as discussed in Section 3.3.

FIGURE 4. CALLING SEQUENCE OF SUBROUTINES FOR WHEAT/BARLEY LABELING PROCEDURE

3.3 DATA REQUIREMENTS

Tasseled Cap Greenness and Brightness data are required by the system. An offset of 32 is not required but the user must inform the system whether or not it is there. It is highly recommended that the data receive some form of normalization to correct for the external effects of sun angle, sensor calibration, atmospheric haze, clouds, etc.

The only data provided as part of this system are the reference profiles. Profiles are stored on external files in a specific format. Obtaining this data is the responsibility of the subroutines INPROF and GETPRO which use FORTRAN formatted read statements. Different profiles can be used by substituting new files for the files containing the standard reference profiles, as long as the new files adhere to the specifications of the input routines.

The procedural description given in this report was designed to fit into the U.S. Corn/Soybean Baseline software system. This system provides two necessary functions. Firstly, it provides the computer capabilities of data normalization and quasi-field (Blob) generation (Table 1). Secondly, it handles all data management which involves the acquisition of blob and pixel data, as well as the storage of intermediate results and target labels.

Pixel data present a special problem becuase of the number of pixels in a sample segment. By convention, a Landsat segment (five miles by six miles) is stored and accessed by scan line (196 pixels long). WBLAB (Figure 4), the only subroutine interfacing directly with pixel data, expects one scan line at a time. The baseline software, external to WBLAB, handles all scan line I/O since this involves interaction with the data base.

Finally, it should be noted that by slightly modifying SPRIN, REGRES, and WBLAB, pixels rather than quasi-fields could be used as labeling targets for Stage 2.

3.4 COMPUTER SYSTEM CONSTRAINTS

3.4.1 COMPUTER SYSTEMS ON WHICH SOFTWARE IS IMPLEMENTED

The subroutines have been implemented on three computer systems:

Location	Computer	Operating System
University of Michigan	Amdahl	MTS
NASA/Johnson Space Center EODL	ES 3000	CMS
Purdue University, LARS	IBM	CMS

The software is largely transportable, limited only by minor language constraints (Section 3.1) and the system-dependent subroutines described in Section 3.4.2.

3.4.2 EXTERNAL ROUTINES USED

- MDCH — International Mathematical and Statistical Libraries (IMSL) routine to calculate probability associated with a chi-squared goodness-of-fit statistic.

- SLUD*, SIR* — Michigan Terminal System (MTS) routines to calculate the inverse of a matrix and to multiply two matrices, respectively.

- MOVEC†, EQUC†, LCOMC† — MTS character manipulation routines to do the the following:

  1. Copy character string from one position in memory to another.
  2. Compare two characters for equality.
  3. Compare two character strings for equality.

---

*Code provided with the subroutines.

†Available on MTS, LARS, and EODL computer systems.

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APPENDIX A

DOCUMENTATION OF PREFOR SUBROUTINES

ERIM

A S I G N L (Continued)

COMMENTS

ASIGNL IS INTENDED TO BE CALLED ONCE FOR EACH POTENTIAL CROP/LABEL. MAXPRO SHOULD BE SET TO ZERO PRIOR TO THE FIRST CALL TO ASIGNL. THE PROBABILITY OF CUMPRO IS CALCULATED USING A CHI-SQUARED TEST WITH DEGREES OF FREEDOM EQUAL TO TWICE THE SUM OF THE WEIGHTS. IF THIS VALUE IS GREATER THAN MAXPRO AND THRESH, THEN MAXPRO WILL RECEIVE THE VALUE AND ILABEL WILL BE ASIGNED TO LABEL. IF NOT, MAXPRO AND LABEL WILL NOT BE ALTERED FROM THEIR INCOMING VALUES. IF DEFER IS TRUE, NO TESTS ARE MADE, NO VALUES CHANGED.

B R C O R R

PURPOSE

TO COMPUTE THE CROSS-CORRELATION BETWEEN A SET OF POINTS AND A BRIGHTNESS PROFILE(S).

CALLING SEQUENCE

```
 CALL     BRCORR  (NACQ,DATA,DAY,SHIFT,
&                  NPROF,PROFLS,NDAYS,DIM1,
&                  BBEST,BCORR,BPROB,RC)
```

INPUTS

```
  NACQ     I*4   NUMBER OF ELEMENTS IN DATA
  DATA     R*4   SET OF VALUES TO BE FIT TO PROFILE
                 VECTOR OF LENGTH NACQ
  DAY      I*4   DAY OF YEAR(1-366) CORRESPONDING TO EACH
                 DATA VALUE.  (VECTOR OF LENGTH NACQ)
  SHIFT    I*4   CROP CALENDAR SHIFT :   SHIFT IS ADDED
                 TO DAY TO DETERMINE CORRESPONDING
                 POSITION IN PROFLS.
  NPROF    I*4   NUMBER OF PROFILES TO FIT
  PROFLS   R*4   ARRAY DIMENSIONED DIM1 BY NPROF CONTAINING
                 THE REFERENCE PROFILES.  EACH PROFILE HAS
                 ITS OWN NUMBER OF DAYS INDICATED
                 BY NDAYS(I). HOWEVER DIM1 MUST BE EQUAL
                 TO OR GREATER THAN THE LARGEST NDAYS(I).
  NDAYS    I*4   NUMBER OF DAYS IN A PROFILE
                 VECTOR OF LENGTH NPROF
  DIM1     I*4   LENGTH OF FIRST DIMENSION OF PROFLS
```

OUTPUTS

```
  BBEST    I*4   THE POSITION IN THE ARRAY 'PROFLS' OF THE
                 PROFILE GIVING THE BEST CORRELATION.
  BCORR    R*4   CROSS-CORRELATION OF THE DATA TO THE
                 PROFILE SPECIFIED BY BBEST.
  BPROB    R*4   PROBABILITY ASSOCIATED WITH BCORR
  RC       I*4   RETURN CODE
             0 = ALL WENT WELL
            <0 = UNABLE TO CALCULATE CORRELATION
            >0 = INSUFFICIENT NUMBER OF POINTS TO COMPUTE
                 PROBABILITY
```

B R C O R R (Continued)

EXTERNALS

RCORR   CALCULATES CORRELATION
RPROB   ASSIGNS A PROBABILITY TO THE CORRELATION

COMMENTS

- THE CROSS-CORRELATION IS CALCULATED USING THE FOLLOWING FORMULA:

- THE PROBABILITY IS BASED ON CUMULATIVE DISTRIBUTIONS OF THE CROSS-CORRELATION OF KNOWN GRAIN BRIGHTNESS DATA TO THE GRAIN BRIGHTNESS PROFILE. A DIFFERENT DISTRIBUTION IS USED DEPENDING ON THE NUMBER OF ACQUISITIONS IN THE SAMPLE.

C L A S I F

PURPOSE

LABELS TARGET AS EITHER WHEAT, BARLEY
OR UNKNOWN SPRING GRAIN

CALLING SEQUENCE

```
  CALL    CLASIF(BRIGHT,GREEN,SHFDAY,NUSED,DAY1,LINE,
 &                      CODE,COUNT,RC)
```

INPUTS

BRIGHT	R*4	BRIGHTNESS VALUES FOR GIVEN ACQUISITIONS. VECTOR OF LENGTH NUSED
GREEN	R*4	GREENNESS VALUES FOR GIVEN ACQUISITIONS. VECTOR OF LENGTH NUSED
SHFDAY	I*4	SHIFTED DAY OF YEAR FOR GIVEN ACQUISITIONS. VECTOR OF LENGTH NUSED
NUSED	I*4	NUMBER OF ACQUISITIONS
DAY1	I*4	DAY OF YEAR CORRESPONDING TO FIRST POINT IN THE VECTOR 'LINE'
LINE	R*4	DECISION VALUES FOR 18 DAYS STARTING AT DAY1. VECTOR OF LENGTH 18

OUTPUTS

CODE	I*4	LABEL : 1 = WHEAT ; 2 = BARLEY ; 3 = UNKNOWN SPRING GRAIN.
COUNT	I*4	NUMBER OF 1,2, AND 3 LABELS ASSIGNED. VECTOR OF LENGTH THREE
RC	I*4	RETURN CODE: 1 = NO CLASIFICATION POSSIBLE.

C L A S I F (Continued)

COMMENTS

```
PROGRAM WILL ASSIGN A CODE OF 1,2 OR 3 TO THE TARGET
 CORRESPONDING TO WHEAT,BARLEY, OR UNKNOWN SPRING GRAIN.
THE CORRESPONDING POSITION IN 'COUNT' WILL BE INCREMENTED
BY 1.  THE PROGRAM CHECKS FOR A SHFDAY  BETWEEN DAY1 AND
DAY1 + 17.  IF GBDIST FOR THAT AQUISITION, GIVEN BY THE
FORMULA:    GBDIST = (.681*BRIGHTNESS) - (.7323*GREENNESS),
IS LESS THAN THE RESPECTIVE VALUE IN LINE, THEN CODE IS
SET TO 1 CORRESPONDING TO WHEAT, ELSE CODE IS SET TO 2
CORRESPONGING TO BARLEY.  IF NO ACQUISITION IN THE
APPROPRIATE RANGE EXISTS THEN CODE IS SET TO 3,
CORRESPONDING TO UNKNOWN SPRING GRAIN.
** NOTE - THE GREENNESS VALUES ARE EXPECTED TO
          BE 'STANDARDIZED'. (EG. IF AN OFFSET OF 32 WAS
          ADDED WHEN THE TASSELED CAP TRANSFORMATION WAS
          APPLIED, 25 SHOULD BE SUBTRACTED FROM THEM)
```

C H E K G R

PURPOSE

PARTITIONS DATA ACCORDING TO THE FOLLOWING RULE :
IF GREENNESS VALUE IS AT LEAST 'THRESH' THEN IT IS INCLUDED IN THE SUBSET. IT THEN SUBTRACTS 'THRESH' FROM EACH GREENNESS VALUE IN THE SUBSET, AND SUBTRACTS THRESH-25 FROM EVERY BRIGHTNESS VALUE IN THE SUBSET.

CALLING SEQUENCE

```
 CALL     CHEKGR(NACQ,DAYS,GREEN,BRITE,SCSWIT,SCREEN,
&                THRESH,NOUT,ODAYS,OGREEN,OBRITE,MAXGR)
```

INPUTS

NACQ	I*4	LENGTH OF INPUT VECTORS
DAYS	I*4	VECTOR CONTAINING DAYS OF YEAR. VECTOR OF LENGTH NACQ
GREEN	R*4	GREENNESS VALUES. VECTOR OF LENGTH NACQ
BRITE	R*4	BRIGHTNESS VALUES. VECTOR OF LENGTH NACQ
SCSWIT	LOG	.TRUE. IF SCREEN IS TO BE USED
SCREEN	I*4	INDICATES IF ACQUISITION IS TO BE CONSIDERED FOR SUBSETTING. VECTOR OF LENGTH NACQ 0 = GOOD DATA >0 = BAD DATA
THRESH	R*4	GREENNESS THRESHOLD BELOW WHICH AN ACQUISITION IS EXCLUDED

OUTPUTS

NOUT	I*4	NUMBER OF ELEMENTS IN SUBSET
ODAYS	I*4	DAY OF YEAR FOR EACH DATA ENTRY IN SUBSET. VECTOR OF LENGTH NACQ
OGREEN	R*4	MODIFIED GREENNESS VALUES IN SUBSET. VECTOR OF LENGTH NACQ
OBRITE	R*4	MODIFIED BRIGHTNESS VALUES IN SUBSET. VECTOR OF LENGTH NACQ
MAXGR	R*4	MAXIMUM GREENNESS VALUE IN VECTOR OGREEN

LINKAGE

GPREP

C O M P S B

PURPOSE

TO INCREMENT A SUM SOIL BRIGHTNESS STATISTIC BY THE BRIGHTNESS VALUE OF ALL APPROPRIATE ACQUISITIONS OF THE TARGET.

CALLING SEQUENCE

```
  CALL     COMPSB (STAGE,SHIFT,NDAYS,DAYS,BR,
 &                     NSBR,SOILBR)
```

INPUTS

STAGE	I*4	PROCESSING STAGE 1 - INITIALIZE NSBR AND SOILBR TO ZERO 2 - INCREMENT NSBR AND SOILBR
SHIFT	I*4	CROP CALENDAR SHIFT
NDAYS	I*4	NUMBER OF ACQUISITIONS
DAYS	I*4	DAY OF YEAR FOR EACH ACQUISITION. VECTOR OF LENGTH NDAYS
BR	R*4	BRIGHTNESS VALUE FOR EACH ACQUISITION. VECTOR OF LENGTH NDAYS
NSBR	I*4	NUMBER OF ENTRIES ALREADY INCLUDED IN SOILBR
SOILBR	R*4	A RUNNING TOTAL OF THE SOIL BRIGHTNESS VALUES FOR ALL TARGETS IN THE POOL

OUTPUTS

NSBR	I*4	INCREMENTED BY THE NUMBER OF BRIGHTNESS VALUES ADDED TO SOILBR
SOILBR	R*4	A RUNNING TOTAL OF THE SOIL BRIGHTNESS VALUES FOR ALL TARGETS IN THE POOL

COMMENTS

THIS MODULE IS INTENDED TO BE CALLED ONLY ONCE AT STAGE=1, THEN ONCE AT STAGE=2 FOR EACH TARGET IN THE POOL AT WHICH TIME THE BRIGHTNESS VALUES FOR ALL SHIFTED DAYS BETWEEN -15 AND -5 WILL BE ADDED TO THE RUNNING TOTAL SOILBR AND NSBR WILL BE INCREMENTED BY THE NUMBER OF SAID ACQUISITIONS.

C O M P X Y

PURPOSE

COMPUTES THE REGRESSION VARIABLES X1,X2, AND Y FOR EACH ACQUISITION WITH A SHIFTED DAY OF YEAR GREATER THAN 0 AND LESS THAN 121. (SEE ROUTINE MLRSET)

CALLING SEQUENCE

```
 CALL     COMPXY (STAGE,SHIFT,NDAYS,DAYS,BGR,
&                  Y,X1,X2,NBEFOR,NAFTER,NPTS)
```

INPUTS

```
STAGE    I*4   PROCESSING STAGE
               1 - INITIALIZE NBEFOR AND NAFTER TO 0
               2 - COMPUTE X1,X2 AND Y FOR EACH ACQUISITION
                     IN PROFILE RANGE, RECORDING THE NUMBER OF
                     SAID ACQUISITIONS IN THE VARIABLE NPTS.
                     INCREMENT THE VARIABLES NBEFOR AND NAFTER.
SHIFT    I*4   CROP CALENDAR SHIFT
NDAYS    I*4   NUMBER OF ACQUISITIONS
DAYS     I*4   DAY OF YEAR FOR EACH ACQUISTION
                VECTOR OF LENGTH NDAYS
BGR      R*4   GREENNESS VALUE FOR EACH ACQUISITION
                VECTOR OF LENGTH NDAYS
```

OUTPUTS

```
Y        R*4   THE NATURAL LOGS OF THE GREENNESS VALUES.
                VECTOR OF LENGTH NDAYS
X1,X2    R*4   FOR SHIFTED DAYS BETWEEN 1 AND 120:
               IF DAYS(I)+SHIFT < 35  AND > 0 ;
                          X1(I) = ( (DAYS(I)+SHIFT)-35 )**2
                          X2(I) = 0
                      OTHERWISE IF < 121 ;
                          X1(I) = 0
                          X2(I) = ( (DAYS(I)+SHIFT)-35 )**2.
                  VECTORS OF LENGTH NDAYS
NBEFOR   I*4   CUMULATIVE NUMBER OF POINTS BEFORE
               PROFILE PEAK
NAFTER   I*4   CUMULATIVE NUMBER OF POINTS AFTER
               PROFILE PEAK
NPTS     I*4   NUMBER OF ACQUISITIONS IN PROFILE RANGE
```

C O M P X Y (Continued)

LINKAGE

MLRSFT

COMMENTS

- THIS MODULF IS INTENDED TO BE CALLED ONCE AT STAGE=1
  THEN AT STAGE=2 FOR EACH TARGET.
- SEE MLRSET

C O N G R B

```
PURPOSE
  CONVERTS GRABS VALUES TO GREENNESS VALUES

CALLING SEQUENCE
     CALL    CONGRB(NACQ,GRABS,BRITE,GREEN)

INPUTS
  NACQ    I*4   NUMBER OF ENTRIES IN ARRAYS
  GRABS   R*4   VECTOR OF GRABS VALUES
                      LENGTH=NACQ
  BRITE   R*4   VECTOR OF BRIGHTNESS VALUES
                      LENGTH=NACQ
OUTPUTS
  GREEN   R*4   VECTOR OF GREENESS VALUES
                      LENGTH=NACQ

COMMENTS

  ASSUMES THAT DATA IS TASSELED CAP TRANSFORMED
  WITHOUT AN OFFSET VECTOR ADDED TO IT.

LINKAGE

  GPREP
```

C O N V A C

```
PURPOSE

  CONVERTS DATE(YYDDD) TO DAY OF YEAR(DDD).

CALLING SEQUENCE

   CALL      CONVAC(NACQ,ACQS,ACDAY)

  INPUTS
    NACQ    I*4   NUMBER OF ACQUISITIONS
    ACQS    I*4   LIST OF ACQUISITIONS AS JULIAN DATES
                         VECTOR OF LENGTH NACQ

  OUTPUTS

    ACDAY    I*4   LIST OF ACQUISITIONS AS DAY OF YEAR
                         VECTOR OF LENGTH NACQ
    RC       I*4   RETURN CODE: 16 - DATES OUT OF ORDER

COMMENTS

 IF THE LIST OF ACQUISITIONS SPANS MORE THAN 1 CALENDAR YEAR
 ACDAY WILL BE GREATER THAN 365(6) FOR THE LATEST YEAR.
 ASSUMES ACQUISITIONS ARE IN ORDER.
```

C S H I F T

PURPOSE

CALCULATES CROP CALENDAR SHIFT OF DATA

CALLING SEQUENCE

```
 CALL     CSHIFT(NACQ,DATA,ACQS,SARRAY,
&                   NDAYS,PROFIL,PROFPK,NTAIL,
&                   SHIFT,XCORR,RCODE)

 INPUTS

   NACQ     I*4   NUMBER OF ELEMENTS IN DATA
   DATA     R*4   LIST OF LANDSAT GREENNESS VALUES.
                   VECTOR OF LENGTH NACQ
   ACQS     I*4   THE DAY OF THE YEAR ASSOCIATED WITH EACH
                   DATA VALUE (VECTOR OF LENGTH NACQ)
   SARRAY   L*4   LIST OF 10 SWITCHES TURNING OFF VARIOUS
                  MODULES OF THE PROGRAM
                     SARRAY(1) - IF TRUE, DO QUADRATIC FIT
                     SARRAY(2) - IF TRUE, DO CROP CALENDAR
                                 SHIFT DETERMINATION
                     SARRAY(3)...(10) - UNDEFINED
   NDAYS    I*4   NUMBER OF DAYS IN PROFILE INCLUDING TAILS
   PROFIL   R*4   REFERENCE CROP PROFILE
                   VECTOR OF LENGTH NDAYS
   PROFPK   I*4   DAY OF PEAK GREENNESS FOR REFERENCE CROP
                  PROFILE
   NTAIL    I*4   NUMBER OF POINTS IN THE LEADING TAIL OF
                  THE PROFILE.  DAY #1 OF THE PROFILE
                  EQUALS PROFIL(NTAIL+1)

 OUTPUTS

   SHIFT    I*4   THE DIFFERENCE BETWEEN THE DAY OF PEAK
                  GREENNESSS CALCULATED FROM THE OBSERVA-
                  TIONS AND THE DAY OF PEAK GREENNESS
                  OF THE PROFILE
   XCORR    R*4   CORRELATION-COEFFICIENT OF PROFILE TO DATA
   RCODE    I*4   RETURN CODE
                    0 - ALL WENT WELL
                    1 - INSUFFICIENT NUMBER OF SHIFTED
                        ACQUISITIONS TO CALCULATE
                        CORRELATION
```

C S H I F T (Continued)

EXTERNALS

```
  QUFIT     DOES QUADRATIC FIT ON THREE POINTS
  XSHIFT    CHOOSES THAT SHIFT WHICH GIVES
            THE GREATEST CROSS-CORRELATION
```

COMMENTS

```
  CALCULATES CROP CALENDAR SHIFT OF DATA USING A TWO STEP
  METHOD:
     1.  CALCULATES PEAK BY FITTING A QUADRATIC TO THE
         DAY HAVING THE GREATEST GREEN VALUE AND ITS TWO
         NEAREST NEIGHBORS
     2.  CHOOSES THE SHIFT THAT GIVES THE GREATEST CROSS
         CORRELATION FACTOR USING THE SHIFT FROM PART ONE
         AS THE SEED.  IT CHECKS ALL DAYS FROM SHIFT-30
         TO SHIFT+30
```

D A T S U B

PURPOSE

DETERMINES SUBSET OF ACQUISITION SET

CALLING SEQUENCE

```
 CALL      DATSUB(SHIFT,MAX,NIN,BRIN,GRIN,ACQIN,
&                 NOUT,BROUT,GROUT,ACQOUT)
```

INPUTS

SHIFT	I*4	CROP CALENDAR SHIFT
MAX	I*4	UPPER BOUND OF ACQIN FOR INCLUDING DATA
NIN	I*4	NUMBER OF ACQUISITIONS.
BRIN	R*4	LIST OF BRIGHTNESS VALUES (LENGTH=NIN)
GRIN	R*4	LIST OF GREENNESS VALUES (LENGTH=NIN)
ACQIN	I*4	DAY OF YEAR CORRESPONDING TO EACH DATA VALUE LENGTH=NIN

OUTPUTS

NOUT	I*4	NUMBER OF ACQUISTIONS IN SUBSET
BROUT	R*4	LIST OF SUBSETTED BRIGHTNESS VALUES (LENGTH=NIN)
GROUT	R*4	LIST OF SUBSETTED GREENNESS VALUES (LENGTH=NIN)
ACQOUT	I*4	CORRESPONDING DAYS (LENGTH=NIN)

COMMENTS

AN ACQUISITION WILL BE INCLUDED IN THE OUTPUT IF ACQIN + SHIFT IS GREATER THAN ZERO AND LESS THAN OR EQUAL TO MAX.

D E C L I N

PURPOSE

COMPUTES THE WHEAT/BARLEY DECISION LINE

CALLING SEQUENCE

```
CALL    DECLIN(PEAK,NSBR,SBR,DAY1,GBD1,SLOPE,INTCPT,LINE)
```

INPUTS

PEAK	R*4	PEAK GREENNESS VALUE OF PROFILE
NSBR	I*4	NUMBER OF DATA VALUES TALLIED IN SBR
SBR	R*4	CUMULATIVE SOIL BRIGHTNESS FOR THE SEGMENT

OUTPUTS

DAY1	I*4	DAY OF YEAR CORRESPONDING TO THE FIRST POINT IN THE VECTOR 'LINE'
GBD1	R*4	DECISION LINE VALUE FOR DAY1
SLOPE	R*4	SLOPE OF DECISION LINE
INTCPT	R*4	POINT AT WHICH DECISION LINE INTERCEPTS THEN GREEN AXIS.
LINE	R*4	VALUE OF DECISION LINE FOR 18 DAYS STARTING AT DAY1

COMMENTS

THE SLOPE HAS A VALUE OF 0.61.
THE PEAK GREENNESS VALUE IS EXPECTED TO BE 'STANDARDIZED' (EG. FOR TASSELED CAP GREENNESS VALUE WITH AN OFFSET OF 32, ONE MUST SUBTRACT 25)

F I L M A T

PURPOSE

INCREMENTS THE ELEMENTS OF THE REGRESSION MATRICES XTX AND XTY WITH THE APPROPRIATE LINEAR COMBINATIONS OF Y, X1, AND X2.

CALLING SEQUENCE

```
   CALL    FILMAT(STAGE,Y,X1,X2,WT,NPTS,TOTAL,SSQY,XTX,XTY)
```

INPUTS

```
     STAGE    I*4   PROCESSING STAGE
                    1 - INITIALIZE OUTPUTS TO ZERO
                    2 - INCREMENT OUTPUTS
     Y        R*4   VECTOR OF LENGTH NPTS
                        Y(I)=LOG(GREENNESS(I))
     X1       R*4   VECTOR OF LENGTH NPTS
     X2       R*4   VECTOR OF LENGTH NPTS
     WT       R*4   THE WEIGHT APPLIED TO EACH GREENNESS VALUE
     NPTS     I*4   NUMBER OF POINTS TO BE ADDED TO XTX AND XTY
```

OUTPUTS

```
     TOTAL    I*4   TOTAL NUMBER OF OBSERVATIONS USED IN
                    THE REGRESSION.  EACH TIME FILMAT IS CALLED
                     TOTAL IS INCREMENTED BY THE VALUE OF NPTS.
     SSQY     R*4   SUM OF SQUARES OF Y
     XTX      R*4   3X3 SYMMETRICAL MATRIX (X'X) TO BE USED IN
                    MLR ANALYSIS.  THE BOTTOM LEFT HAND CORNER
                    IS NOT CALCULATED AS IT IS
                    THE MIRROR IMAGE OF THE UPPER RIGHT CORNER.
     XTY      R*4   3X1 MATRIX (X'Y) TO BE USED IN REGRESSION
                    ANALYSIS.
```

LINKAGE

MLRSFI

F I L M A T (Continued)

COMMENTS

- THE ELEMENTS OF THE MATRICES XTX AND XTY ARE SUMMATIONS, OVER ALL TARGETS, OF LINEAR COMBINATIONS OF X1(I), X2(I), AND Y(I). THEREFORE, FILMAT SHOULD BE CALLED ONCE AT STAGE 1 TO INITIALIZE THESE MATRICES, TOTAL AND SSQY TO ZERO, AND THEN AT STAGE 2 FOR EACH TARGET.
- SEE MLRSET AND MLRFIT FOR DESCRIPTIONS OF THE REGRESSION EQUATIONS.
- THIS SUBROUTINE WAS DESIGNED TO BE CALLED BY MLRSET.

F I S P R O

PURPOSE

REAL FUNCTION CALCULATING A COMBINED TEST STATISTIC
USING THE FISHER OMNIBUS PROCEDURE

CALLING SEQUENCE

```
FISPRO(NPRO,PROBS,WEIGHT,RC)
```

INPUTS

```
NPRO     I*4   NUMBER OF PROBABILITIES TO COMBINE
PROBS    R*4   LIST OF PROBABILITIES
                              VECTOR OF LENGTH NPRO
WEIGHT   R*4   WEIGHT ASSOCIATED WITH EACH PROBABILITY
                              VECTOR OF LENGTH NPRO
```

OUTPUTS

```
FISPRO   R*4   RETURNS THE COMBINED PROBABILITY
RC       I*4   RETURN CODE: EQUALS 4 IF NPRO IS LESS THAN 1
```

COMMENTS

```
-  WEIGHT(I) MUST BE POSITIVE
-  FISPRO IS COMPUTED BY TAKING THE SUM OVER ALL
-  PROBABILITIES OF :
            2 * WEIGHT(I)*LN(PROBS(I)) .
```

F I T P R O

PURPOSE

FITS TEMPORAL SPECTRAL OBSERVATIONS TO A REFERENCE PROFILE AND COMPUTES THE CHI-SQUARED GOODNESS OF FIT AND THE PROBABILITY OF THE FIT.

CALLING SEQUENCE

```
 CALL     FITPRO(NACQ,DATA,DAY,SHIFT,NDAY,PROFIL,VAR,
&                     SCALF,FIT,PROB,NUSE,RCODE)
```

INPUTS

NACQ	I*4	NUMBER OF ELEMENTS IN DATA
DATA	R*4	LIST OF OBSERVED SPECTRAL VALUES TO BE FIT TO THE PROFILE (VECTOR OF LENGTH NACQ)
DAY	I*4	DAY OF YEAR FOR EACH DATA VALUE VECTOR OF LENGTH NACQ
SHIFT	I*4	CROP CALENDAR SHIFT FOR OBSERVED DATA
NDAY	I*4	NUMBER OF POINTS IN THE PROFILE
PROFIL	R*4	LIST OF DISCRETE VALUES FOR REFERENCE PROFILE VECTOR OF LENGTH NDAY
VAR	R*4	VARIANCE ASSOCIATED WITH EACH PROFILE VALUE VECTOR OF LENGTH NDAY

OUTPUTS

SCALE	R*4	VALUE USED TO SCALE OBSERVATIONS TO PROFILE
FIT	R*4	CHI-SQUARED GOODNESS OF FIT VALUE
PROB	R*4	PROBABILITY ASSOCIATED WITH FIT
NUSE	I*4	NUMBER OF OBSERVATIONS USED IN CALCULATING THE FIT
RCODE	I*4	RETURN CODE 0 - ALL WENT WELL 1 - UNABLE TO CALCULATE SCALE FACTOR 2 - UNABLE TO CALCULATE FIT 3 - UNABLE TO OBTAIN PROBABILITY

F I T P R O (Continued)

```
EXTERNALS

   PSCALE     SCALES OBSERVATIONS TO PROFILE
   PFIT       CALCULATES CHI-SQUARED GOODNESS OF FIT
   MDCH       IMSL ROUTINE TO CALCULATE CHI-SQUARED
              PROBABLILITY

COMMENTS

  -  THIS SUBROUTINE WAS DESIGNED TO BE USED WITH
     TASSELED CAP TRANSFORMED GREENNESS VALUES THAT HAVE
     BEEN STANDARDIZED TO A SET OF REFERENCE CROP PROFILES.
     (EG. IF THE GREENNESS VALUES HAVE AN OFFSET OF 32
     SUBTRACT 25 FROM EACH TO STANDARDIZE THEM.)
  -  THE FIT IS CALCULATED AS THE SUM OVER ALL ACQUISITIONS

     OF:   ( PROFIL(I) - (SCALE*DATA(I)) )**2 / VAR(I) .

     WHERE:


SCALE  =  SUMPRO/SUMPRD    ;
       WHERE -
    SUMPRO = SUM OF THE SQUARES OF THE PROFILE POINTS
    SUMPRD = SUM OF THE PRODUCTS OF PROFILE AND
             DATA VALUES
```

G E T P R O

PURPOSE

TO READ BRIGHTNESS AND GREENNESS REFERENCE PROFILES FROM EXTERNAL FILES OF FIXED FORMATS.

CALLING SEQUENCE

```
 CALL     GETPRO(PRSW,PUNIT,P2UNIT,DIM1,NDAYS,GDAYS,NTAIL,
&                  GPROF,BPROF,GPRO2,GVAR,PMAX,PKTIME,RC)
```

INPUTS

```
  PRSW     L*4   LOGICAL SWITCHES,  LENGTH=2 :
                 1. TRUE = PUT PROFILE FROM PUNIT INTO BPROF
                    FALSE = PUT PROFILE FROM PUNIT INTO GPROF
                 2. TRUE = READ FROM BOTH P2UNIT AND PUNIT
                    FALSE = READ ONLY FROM PUNIT
  PUNIT    I*4   FORTRAN UNIT NUMBER OF FILE THAT CONTAINS
                   GPROF AND BPROF
  P2UNIT   I*4   FORTRAN UNIT NUMBER OF FILE THAT CONTAINS
                   GPRO2 AND GVAR
  DIM1     I*4   FIRST DIMENSION OF EACH PROFILE ARRAY.
                 THIS MUST BE LARGER THAN OR EQUAL TO
                 THE LARGEST GDAYS(I).
```

OUTPUTS

```
  NDAYS    I*4   NUMBER OF CROP CALENDAR DAYS FOR PROFILES
  GDAYS    I*4   GDAYS=NDAYS+2*NTAIL
  NTAIL    I*4   THE NUMBER OF POINTS ADDED TO EACH SIDE
                 OF THE GREENNESS PROFILE TO ALLOW
                 CROSS-CORRELATION SHIFT DETERMINATION.
  GPROF    R*4   GREENNESS PROFILE USED IN SHIFT CALCULATION
                 VECTOR OF LENGTH = DIM1
  BPROF    R*4   BRIGHTNESS PROFILE
                 VECTOR OF LENGTH = DIM1
  GPRO2    R*4   GREENNESS PROFILE USED IN FIT CALCULATION
                 VECTOR OF LENGTH = DIM1
  GVAR     R*4   VARIANCE FOR EACH POINT IN GPRO2
                 VECTOR OF LENGTH = DIM1
  PMAX     R*4   MAXIMUM GREENNESS VALUE OF GPROF
  PKTIME   I*4   DAY CORRESPONDING TO MAXIMUM GREENNESS VALUE
  RC       I*4   RETURN CODE
                    16 - UNABLE TO READ FILE
```

GETPRO (Continued)

```
  EXTERNALS

    EQUC     COMPARES TWO CHARACTERS FOR EQUALITY

  LINKAGE

    INPROF

COMMENTS

- P2UNIT SHOULD CONTAIN THE GREENNESS PROFILE FOR FIT.  EACH
  PROFILE POINT SHOULD HAVE A VARIANCE ASSOCIATED WITH IT
  LOCATED ON THE SAME RECORD(SEE BELOW).  IF PRSW(2) IS
  FALSE P2UNIT NEED NOT BE ASSIGNED AND GPRO2 AND GVAR
  WILL NOT BE SET.

- IF PRSW(1) IS TRUE THEN THE FILE READ FROM P1UNIT IS
  EXPECTED TO BE THE GREENNESS PROFILE AND IS PLACED
  IN GPROF, OTHERWISE IT IS EXPECTED TO BE
  THE BRIGHTNESS PROFILE AND IS PLACED IN BPROF.

- PROFILE FILES MUST BE IN THE FOLLOWING FORM :
    RECORD 1:     *TITLE (LENGTH < OR = TO 80)
    RECORD 2:     NDAYS(I*4)
    RECORD 3:     FORTRAN FORMAT STATEMENT USED TO READ A
                   PROFILE, IT MUST CONTAIN OPENING AND
                   CLOSING PARENTHESES
    RECORD 4:   PROFILE (AND VARIANCE FOR P2UNIT)    - PT 1
      .                                                  .
      .                                                  .
      .                                                  .
    REC NDAYS+3: PROFILE (AND VARIANCE FOR P2UNIT) - PT NDAYS
```

GPREP

PURPOSE

PREPARES TASSELED CAP DATA FOR SPRING GRAIN LABELING AND WHEAT/BARLEY LABELING PROCEDURES

CALLING SEQUENCE

```
 CALL     GPREP(SARRAY,NACQ,IDAYS,IGRABS,IBRITE,SCSWIT,
&               SCREEN,THRESH,OUT,ODAYS,OGREEN,OBRITE,
&               PROCED)
```

INPUTS -

```
  SARRAY  L*4   VECTOR OF SWITCHES INDICATING WHETHER A
                PARTICULAR FUNCTION SHOULD BE PERFORMED:
                (LENGTH=10)
                   SARRAY(1): IF TRUE, THEN
                      CONVERT GRABS TO GREENNESS
                   SARRAY(2): IF TRUE, THEN
                      PERFORM SUBSETTING FUNCTION
                   SARRAY(3)...(10): UNDEFINED
  NACQ    I*4   NUMBER OF ENTRIES IN INCOMING VECTORS
  IDAYS   I*4   DAY OF YEAR FOR EACH DATA ENTRY
                  LENGTH=NACQ
  IGRABS  R*4   VECTOR OF GRABS VALUES.
                  LENGTH=NACQ
  IBRITE  R*4   VECTOR OF BRIGHTNESS VALUES.
                  LENGTH=NACQ
  SCSWIT  L*4   .TRUE. IF SCREEN IS TO BE USED
  SCREEN  I*4   VECTOR OF LENGTH NACQ
                 0 = GOOD VALUE
                >0 = BAD VALUE
  THRESH  R*4   GREENNESS VALUE BELOW WHICH AN ACQUISITION
                SHOULD BE EXCLUDED.  FOR TASSELED CAP
                DATA WITH AN OFFSET VECTOR OF 32,
                THRESH = 25. WITHOUT THE OFFSET VECTOR,
                THRESH = -7.
```

G P R E P (Continued)

OUTPUTS

```
NOUT      I*4  NUMBER OF ENTRIES IN OUTGOING VECTORS
ODAYS     I*4  DAY OF YEAR FOR EACH DATA ENTRY
                 LENGTH=NACQ
OGREEN    R*4  VECTOR OF GREENNESS VALUES
                 LENGTH=NACQ
OBRITE    R*4  VECTOR OF BRIGHTNESS VALUES
                 LENGTH=NACQ
PROCED    L*4  TRUE IF DATA HAS MET THE FOLLOWING
                CONDITIONS:
                  - AT LEAST 3 ACQUISITIONS WITH
                    GREENNESS >= THRESH
                  - AT LEAST 1 ACQUISITION WITH
                    GREENNESS >= THRESH+10
```

EXTERNALS

```
CONGRB      CONVERTS GRABS TO GREENNESS

CHEKGR      SELECTS USEABLE ACQUISITIONS AND
            SUBTRACTS THRESH FROM GREENNESS VALUES
```

COMMENTS

```
- IF IGRABS CONTAINS GREENNESS VALUES SARRAY(1)
  SHOULD EQUAL FALSE.  IF IGRABS CONTAINS GRABS
  VALUES SARRAY(1) SHOULD EQUAL TRUE. GRABS VALUES
  ARE ASSUMED TO BE COMPUTED FROM TASCAP VALUES WITH NO
  OFFSET APPLIED.  THEREFORE,
  WHEN GRABS VALUES ARE USED BRIGHTNESS VALUES
  MUST NOT HAVE AN OFFSET APPLIED TO THEM.
- ACQUISITIONS ARE EVALUATED AS FOLLOWS
    1.IF GREENNESS VALUE IS NOT LESS THAN THRESH
          INCLUDE ACQUISITION IN SUBSET.
    2.SUBTRACT THRESH FROM ALL GREENNESS VALUES IN SUBSET
    3.SUBTRACT THRESH-25 FROM ALL BRIGHTNESS VALUES IN
      SUBSET
- IN SUMMARY:
        FOR TASCAP DATA(GREENNESS AND BRIGHTNESS) WITH
              AN OFFSET OF 32, SARRAY(1)=.FALSE.,
              SARRAY(2)=.TRUE.,THRESH=25.
        FOR GRABS AND BRIGHTNESS VALUES WITHOUT AN OFFS
              OFFSET OF 32, SARRAY(1)=.TRUE.,
              SARRAY(2)=.TRUE.,THRESH=-7.
        ONE SHOULD NEVER USE GRABS VALUES WITH BRIGHTNESS
                VALUES WHICH HAVE AN OFFSET OF 32.
```

ERIM

I N P R O F (Continued)

```
PMAX      R*4   VECTOR OF LENGTH NCROP
                PEAK GREENNESS VALUE FOR EACH
                GREENNESS PROFILE.
TGREEN    I*4   NUMBER OF PROFILES IN GPROF
TBRITE    I*4   NUMBER OF PROFILES IN BPROF
GPROF     R*4   ARRAY CONTAINING GREENNESS PROFILES USED
                FOR SHIFT CALCULATION  ( DIM1 X TGREEN)
GPRO2     R*4   ARRAY CONTAING GREENNESS PROFILES USED
                FOR GOODNESS-OF-FIT CALCULATION
                (DIM1 X TGREEN)
GVAR      R*4   ARRAY CONTAINING THE VARIANCES FOR EACH
                POINT IN GPRO2 ( DIM1 X TGREEN)
BPROF     R*4   ARRAY CONTAINING THE BRIGHTNESS PROFILES
                  (DIM1 X TBRITE)
BR1       I*4   VECTOR OF LENGTH NCROP
                POSITION OF THE FIRST BRIGHTNESS PROFILE
RC        I*4   RETURN CODE
                  0 = ALL WENT WELL
                 16 = PROBLEMS IN READING FILE

EXTERNALS

 GETPRO     DOES ACTUAL I/O

COMMENTS

- INPROF USES THE FOLLOWING CONVENTIONS:
   1. PUNIT SHOULD CONTAIN THE GREENNESS PROFILES USED FOR
   THE SHIFT CALCULATION AND THE BRIGHTNESS PROFILES.
   PROFILES SHOULD ALTERNATE GREENNESS,BRIGHTNESS ...
   2. P2UNIT CONTAINS THE GREENNESS PROFILES (EACH POINT
   PLUS AN ASSOCIATED VARIANCE) USED FOR THE FIT
   CALCULATION.
   3. PROFILES MUST BE STORED IN FILES IN THE FOLLOWING
      FORM :
 RECORD                 CONTENTS
   1      *TITLE (LENGTH < OR = TO 80)
   2      NDAYS(I)(I*4)
   3      FORTRAN FORMAT STATEMENT USED TO READ PROFILE
          MUST CONTAIN OPENING AND CLOSING PARENTHESIS
   4             PROFILE (AND VARIANCE FOR P2UNIT)
   .                     .
   .                     .
   .                     .
  NDAYS(I)+3:  PROFILE (AND VARIANCE FOR P2UNIT)
- THERE CAN BE MORE THAN ONE BRIGHTNESS PROFILE FOR A CROP
```

```
                         M L R F I T

PURPOSE

     COMPUTES THE PARAMETERS FOR THE REGRESSION EQUATION
     CORRESPONDING TO THE EQUATION :

     FOR   T < TMAX ;        F(T) = A*E**(B1*(T-TMAX)**2)

     FOR   T >= TMAX;        F(T) = A*E**(B2*(T-TMAX)**2)

     WHERE: F(T) = TASCAP GREENNESS - 25.
            T    = SHIFTED DAY OF YEAR
            TMAX = SHIFTED DAY OF PEAK: 35
        A,B1,B2  = PARAMETERS ESTIMATED BY LINEAR REGRESSION

CALLING SEQUENCE

    CALL     MLRFIT (TOTAL,XTX,XTY,SSQY,BETA,ANOVA,PEAK,RC)

INPUTS

     TOTAL    I*4   TOTAL NUMBER OF POINTS USED IN REGRESSION
     XTX      R*4   3X3 SYMMETRICAL MATRIX (X'X) USED TO
                    CALCULATE REGRESSION PARAMETERS.
                    THE LOWER LEFT CORNER NEED NOT BE
                    DEFINED BECAUSE THE PROGRAM FILLS THESE IN
                    USING THE UPPER RIGHT CORNER OF THE MATRIX.
     XTY      R*4   3X3 SYMMETRICAL MATRIX (X'Y) USED TO
                    CALCULATE REGRESSION PARAMETERS.
                    THE LOWER LEFT CORNER NEED NOT BE DEFINED
                    BECAUSE THE PROGRAM FILLS THESE IN USING
                    THE UPPER RIGHT CORNER OF THE MATRIX.
     SSQY     R*4   SUM OF SQUARES FOR Y (DEPENDENT VARIABLE)

OUTPUTS

     BETA     R*4   VECTOR CONTAINING THE REGRESSION PARAMETERS
                           LENGTH = 3
     ANOVA    R*4   CONTAINS THE ENTRIES TO THE ANOVA TABLE,
                    AS FOLLOWS (VECTOR OF LENGTH 10) :
                       1 - SUM SQUARES REGRESSION
                       2 - SUM SQUARES ERROR
                       3 - SUM SQUARES TOTAL
                       4 - MEAN SQUARE REGRESSION
                       5 - MEAN SQUARE ERROR
                       6 - F-STATISTIC = ANOVA(4)/ANOVA(5)
```

M L R F I T (Continued)

```
                    7 - R**2 = ANOVA(1)/ANOVA(3)
                    8 - DEGREES OF FREEDOM REGRESSION
                    9 - DEGREES OF FREEDOM ERROR
                   10 - DEGREES OF FREEDOM TOTAL
   PEAK     R*4  PEAK OF PROFILE AS DETERMINED BY REGRESSION
                      PEAK = EXP(BETA(1))
   RC       I*4  RETURN CODE
                    0 = ALLS WELL
                    1 = XTX IS SINGULAR
                    2 = FAILURE TO CONVERGE

EXTERNALS

   SLUD     UNIVERSITY OF MICHIGAN PROGRAM TO CALCULATE
            LU-DECOMPOSITION.  OBTAINS INVERSE OF XTX.
   SIR      UNIVERSITY OF MICHIGAN PROGRAM TO MULTIPLY
            TWO MATRICES : A*B.
              A BEING DIMENSIONED N X N
              B BEING DIMENSIONED N X 1

COMMENTS

   -  THE ACTUAL REGRESSION EQUATION IS :

         Y = B0 + B1*X1 + B2*X2

        WHERE
           Y = LN(F(T))
          X1 = (T-TMAX)**2 , X2 = 0       FOR T < TMAX
          X1 = 0 , X2 = (T-TMAX)**2       FOR T > OR = TMAX
          B0,B1,B2 = REGRESSION PARAMETERS

   -  SEE MLRSET
```

M L R S E T

PURPOSE

GIVEN A SET OF OBSERVATIONS (S,T), MLRSET
INCREMENTS THE ELEMENTS OF THE MATRICES
X'X AND X'Y. WHERE X AND Y ARE FUNCTIONS OF
S AND T. X'X AND X'Y ARE MATRICES USED TO COMPUTE
THE PARAMETERS OF A REGRESSION EQUATION.
(SEE COMMENTS AND MLRFIT)

CALLING SEQUENCE

```
 CALL     MLRSET (STAGE,SHIFT,NDAYS,DAYS,BGR,WT,
&                    Y,X1,X2,NBEFOR,NAFTER,TOTAL,
&                    SSQY,XTX,XTY)
```

INPUTS

```
    STAGE    I*4   PROCESSING STAGE
                   1 - SET OUTPUTS AND TEMPORARIES TO ZERO
                   2 - INCREMENT OUTPUTS AND TEMPORARIES
    SHIFT    I*4   CROP CALENDAR SHIFT
    NDAYS    I*4   NUMBER OF ACQUISITIONS
    DAYS     I*4   DAY OF YEAR FOR EACH ACQUISTION
                     VECTOR OF LENGTH NDAYS
    BGR      R*4   GREENNESS VALUE FOR EACH ACQUISITION
                     VECTOR OF LENGTH NDAYS
    WT       R*4   THE WEIGHT TO BE APPLIED TO EACH GREENNESS
                   VALUE (VECTOR OF LENGTH NDAYS)
```

OUTPUTS

```
    TOTAL    I*4   TOTAL NUMBER OF OBSERVATIONS USED IN
                   THE REGRESSION
    SSQY     R*4   SUM OF SQUARES OF Y
    XTX      R*4   3X3 SYMMETRICAL MATRIX (X'X) TO BE USED IN
                   MLR ANALYSIS.  THE BOTTOM LEFT HAND CORNER
                   IS NOT CALCULATED SINCE IT IS
                   THE MIRROR IMAGE OF THE UPPER RIGHT CORNER.
    XTY      R*4   3X1 MATRIX (X'Y) TO BE USED IN REGRESSION
                   ANALYSIS.
```

M L R S E T (Continued)

```
TEMPORARIES

     Y          R*4   VECTOR OF LENGTH NDAYS
                          Y=LOG(GREENNESS)
     X1,X2      R*4   VECTORS OF LENGTH NDAYS
                      (SEE COMMENTS)
     NBEFOR     I*4   NUMBER OF POINTS USED IN DETERMINING
                       PRE-PEAK CURVE (SEE COMMENTS)
     NAFTER     I*4   NUMBER OF POINTS USED IN DETERMINING
                       POST-PEAK CURVE (SEE COMMENTS)

EXTERNALS

   COMPXY     CONVERTS OBSERVATIONS TO REGRESSION VARIABLES
   FILMAT     INCREMENTS THE ELEMENTS OF XTX AND XTY

COMMENTS


   -   THE REGRESSION MODEL APPROXIMATES THE FOLLOWING
       EQUATION :

         FOR T<TMAX ;  F(T)=A*E**(B1*(T-TMAX)**2)

         FOR T > OR = TMAX ;  F(T)=A*E**(B2*(T-TMAX)**2)

       WHERE   F(T) = TASCAP GREENNESS - 25
               T    = SHIFTED DAY OF YEAR
               TMAX = SHIFTED DAY OF PEAK = 35
          A,B1,B2   = PARAMETERS TO BE ESTIMATED USING
                      LINEAR REGRESSION
       (SEE ERIM DOC. 132400-29-F2)

       THE ACTUAL REGRESSION EQUATION IS :

         Y = B0 + B1*X1 + B2*X2

         WHERE    Y = LN(F(T))
               X1 = (T-TMAX)**2 , X2 = 0       FOR T < TMAX
               X1 = 0 , X2 = (T-TMAX)**2       FOR T > OR = TMAX
               B0,B1,B2 = REGRESSION PARAMETERS

   -   GREENNESS VALUES MUST BE STANDARDIZED
        (IE. FOR TASSELED CAP DATA WITH AN OFFSET OF
             32 ONE SHOULD SUBTRACT 25)
```

M L R S E T (Continued)

- THE ELEMENTS OF XTX AND XTY ARE SUMMATIONS, OVER ALL TARGETS, OF LINEAR COMBINATIONS OF X1(I), X2(I), AND Y(I). THEREFORE, MLRSET SHOULD BE CALLED ONCE AT STAGE 1 AND THEN AT STAGE 2 FOR EACH TARGET.

P F I T

PURPOSE

TO COMPUTE THE GOODNESS OF FIT BETWEEN A SERIES OF OBSERVATIONS AND A REFERENCE PROFILE USING THE CHI-SQUARED METHOD

CALLING SEQUENCE

```
CALL     PFIT (NACQ,DATA,PROFIL,VAR,SCALE,NUSE,FIT)
```

INPUTS

NACQ	I*4	NUMBER OF ELEMENTS IN DATA
DATA	R*4	LIST OF OBSERVATIONS TO BE FIT TO PROFILE VECTOR OF LENGTH NACQ
PROFIL	R*4	ASSOCIATED PROFILE VALUE FOR EACH ACQUISITION (VECTOR OF LENGTH NACQ)
VAR	R*4	THE CORRESPONDING VARIANCE FOR EACH POINT OF THE PROFILE. VECTOR OF LENGTH NACQ
SCALE	R*4	SCALE FACTOR

OUTPUTS

NUSE	I*4	NUMBER OF POINTS USED IN CALCULATING FIT
FIT	R*4	CHI-SQUARED FIT OF DATA TO PROFILE

LINKAGE

FITPRO

COMMENTS

FIT IS CALCULATED AS THE SUM OVER ALL ACQUISITIONS OF

(PROFIL(I) - (SCALE*DATA(I)))**2 / VAR(I) .

P S C A L E

PURPOSE

TO CALCULATE A SCALE FACTOR FOR A SET OF OBSERVATIONS THAT WILL BE USED WHEN FITTING THE OBSERVATIONS TO A REFERENCE PROFILE

CALLING SEQUENCE

```
CALL     PSCALE(NACQ,DATA,DAY,PROFIL,NDAY,SCALE,RC)
```

INPUTS

NACQ	I*4	NUMBER OF ELEMENTS IN DATA
DATA	R*4	LIST OF OBSERVATIONS TO BE FIT TO PROFILE. VECTOR OF LENGTH NACQ
DAY	I*4	THE SHIFTED DAY OF YEAR FOR EACH DATA VALUE (VECTOR OF LENGTH NACQ)
PROFIL	R*4	ASSOCIATED PROFILE VALUE FOR EACH ACQUISITION (VECTOR OF LENGTH NACQ)
NDAY	I*4	LENGTH OF PROFIL IN DAYS.

OUTPUTS

SCALE	R*4	SCALE FACTOR
RC	I*4	RETURN CODE 0 - ALL WENT WELL 1 - INSUFFICIENT NUMBER OF POINTS IN SPECIFIED RANGE

LINKAGE

FITPRO

COMMENTS

ONLY POINTS WHOSE SHIFTED DAYS ARE BETWEEN 20 AND (NDAY-20) ARE USED IN DETERMINING SCALE.
THE FOLLOWING FORMULA IS USED TO CALCULATE SCALE :

```
SCALE = SUMPRO/SUMPRD    ;
            WHERE -
        SUMPRO = SUM OF THE SQUARES OF THE PROFILE POINTS
        SUMPRD = SUM OF THE PRODUCTS OF PROFILE AND DATA
       VALUES
```

Q U F I T

PURPOSE

FITS A QUADRATIC EQUATION TO THREE POINTS.

CALLING SEQUENCE

```
CALL    QUFIT(Y,X,PEAKX,A,B)
```

INPUTS

Y	R*4	THE DEPENDANT VARIABLE VECTOR OF LENGTH 3
X	I*4	THE INDEPENDANT VARIABLE VECTOR OF LENGTH 3
PEAKX	I*4	THE DAY OF MAXIMUM GREENNESS

OUTPUTS

PEAKX	I*4	IF A QUADRATIC WAS SUCCESSFULLY FIT THEN PEAKX CONTAINS THE DAY OF THE PEAK OF THE QUADRATIC. IF NOT IT IS RETURNED UNCHANGED.
A,B	R*4	THE PARAMETERS OF THE QUADRATIC EQUATION : Y=AX**2 + BX

LINKAGE

LSHIFT

COMMENTS

IF THE MIDDLE POINT IS NOT 'ABOVE' A LINE CONNECTING THE TWO OUTSIDE POINTS THEN THE QUADRATIC FIT IS NOT DONE AND PEAKX IS UNCHANGED, A AND B ARE NOT SET.

RCORR

CALLING SEQUENCE

```
CALL    RCORR(DAT,PROF,N,CORR,RC)
```

PURPOSE

TO COMPUTE CROSS-CORRELATION BETWEEN DATA AND PROFILE

INPUTS

DAT	R*4	LIST OF DATA POINTS TO FIT
PROF	R*4	PROFILE VALUES CORRESPONDING TO DATA POINTS
N	I*4	NUMBER OF DATA POINTS

OUTPUTS

CORR	R*4	CROSS-CORRELATION
RC	I*4	RETURN CODE
		0 ALL WENT WELL
		-2,-3 UNABLE TO CALCULATE CORRELATION

R P R O B

CALLING SEQUENCE

```
CALL    RPROB(RCORR,N,PROB,RC)
```

PURPOSE

TO ASSIGN A PROBABILITY TO THE CROSS-CORRELATION OF A GIVEN NUMBER OF POINTS AND THEIR REFERENCE BRIGHTNESS PROFILE.

INPUTS

```
RCORR  R*4  CROSS-CORRELATION
N      I*4  NUMBER OF POINTS USED IN DETERMINING RCORR
```

OUTPUTS

```
PROB   R*4  PROBABILITY ASSOCIATED WITH RCORR.
RC     I*4  RETURN CODE
                  0 - ALL WENT WELL
                > 0 - INSUFFICIENT NUMBER OF POINTS
```

COMMENTS

THE PROBABILITY IS ASSIGNED USING A CUMULATIVE DISTRIBUTION DERIVED FROM EMPIRICAL OBSERVATIONS.

S I M I N D

PURPOSE

GENERATES INDEX TO A LIST

CALLING SEQUENCE

```
CALL    SIMIND(LEN,LIST,INDEX)
```

INPUTS

```
LEN   I*4   NUMBER OF ITEMS IN LIST
LIST  I*4   LIST OF NUMBERS
```

OUTPUTS

```
INDEX I*4   INDEX TO LIST
```

COMMENTS

- INDEX(LIST(I)) = I   FOR I=1,LEN AND LIST(I) > 0 ;
  IF LIST(I) = 0, THEN INDEX(LIST(I)) = LEN.
- IT IS ASSUMED THAT THERE IS NO ENTRY IN
  LIST WITH A VALUE GREATER THAN LEN AND THAT IF
  THERE IS AN ENTRY WITH THE VALUE OF ZERO IT IS
  THE LAST ITEM IN LIST. ALSO, ALL ITEMS ARE UNIQUE.

S H P R O B

PURPOSE

TO PROVIDE A PROBABILITY, GIVEN AN OBSERVED SHIFT
AND AN EXPECTED SHIFT

CALLING SEQUENCE

```
REAL FUNCTION SHPROB(SHIFT,MEAN)
```

INPUTS

SHIFT	I*4	OBSERVED SHIFT
MEAN	I*4	EXPECTED SHIFT

OUTPUT

THE PROBABILITY IS RETURNED AS THE FUNCTION VALUE

COMMENTS

THE PROBABILITY DISTRIBUTION, DETERMINED EMPIRICALLY, IS
A MODIFIED NORMAL WITH MEAN 0 AND STANDARD DEVIATION 14.

```
                XSHIFT

PURPOSE

   DETERMINES THE SHIFT ALONG THE DAY OF YEAR AXIS WHICH
   MAXIMIZES THE CROSS-CORRELATION BETWEEN THE DATA VALUES
   AND A REFERENCE PROFILE.

CALLING SEQUENCE

    CALL     XSHIFT(NACQ,DATA,ACQS,NDAYS,PROFIL,NTAIL,
   &                    SHIFT,MAXR)

   INPUTS

     NACQ   I*4  NUMBER OF POINTS IN DATA
     DATA   R*4  LIST OF GREENESS VALUES TO BE FIT TO PROFILE
                  VECTOR OF LENGTH NACQ
     ACQS   I*4  DAY CORRESPONDING TO EACH DATA VALUE
                  VECTOR OF LENGTH NACQ
     NDAYS   I*4  NUMBER OF DAYS IN REFERENCE PROFILE
                  - INCLUDING TAILS
     PROFIL  R*4  ORDINATE VALUES FOR PROFILE
                  VECTOR OF LENGTH NDAYS
     NTAIL   I*4  NUMBER OF DAYS IN LEADING TAIL OF PROFILE
     SHIFT   I*4  INITIAL SHIFT VALUE

   OUTPUTS
     SHIFT   I*4  ADJUSTED SHIFT USING CROSS-CORRELATION
     MAXR    R*4  CROSS-CORRELATION FACTOR FOR THE
                  SELECTED SHIFT

   LINKAGE

     CSHIFT

COMMENTS

  - THE FOLLOWING FORMULA IS USED TO CALCULATE
    THE CORRELATION(R):

      R=2./(1.+SSQDAT/SUMPRD*(SSQPRO/SUMPRD))
```

X S H I F T (Continued)

```
WHERE :
  SSQDAT = SUM OVER ALL SHIFTED ACQUISITIONS OF
              THE SQUARE OF THE DATA POINT
  SSQPRO = SUM OVER ALL SHIFTED ACQUISITIONS OF
              THE SQUARE OF THE PROFILE DATA VALUE
  SUMPRD = SUM OVER ALL SHIFTED ACQUISITIONS OF THE
              PRODUCT OF THE DATA POINT AND
              THE PROFILE VALUE
- A CROSS-CORRELATION IS COMPUTED FOR ALL SHIFTS WITHIN
  + OR - THIRTY DAYS OF THE INPUTTED VALUE OF 'SHIFT'.
  TAILS OF 30 DAYS(NTAIL) SHOULD HAVE BEEN ADDED TO
  THE PROFILE SO THAT THE SAME NUMBER OF POINTS ARE
  USED IN EACH CORRELATION CALCULATION.
```

S P R I N

PURPOSE

DRIVER MODULE THAT PERFORMS THE SPRING GRAIN LABELING PROCEDURE

CALLING SEQUENCE

```
 CALL      SPRIN(NCROP,NBLOB,NACQ,DIM1,
&                   GSWIT,SARRAY,SCSWIT,
&                   ACQS,SCREEN,NPIX1,GREEN,BRITE,
&                   TDAYS,GPROF,PROFPK,NTAIL,
&                   PDAYS,GPRO2,GVAR,TBR,NBR,BR1,BPROF,
&                   GTHR,XSHIFT,WEIGHT,DEFER,LLIST,PTHR,
&                   NUSE,DAYS,GR,BR,
&                   NUSE2,NUSE3,SHIFT,CCCORR,SCALE,FIT,
&                   BBEST,BCORR,PROBS,TOTPRO,LABEL,PROC)
```

INPUTS

```
(ARRAY DIMENSIONS AND CONTROL VARIABLES)
  NCROP    INT   NUMBER OF CROPS
  NBLOB    INT   NUMBER OF BLOBS
  NACQ     INT   NUMBER OF ACQUISITIONS
  DIM1     INT   LENGTH OF THE FIRST DIMENSION OF THE ARRAYS
                HOLDING THE REFERENCE PROFILES.
  GSWIT    LOG   LIST OF TEN SWITCHES DEFINED AS FOLLOWS
                  1    TRUE :CONVERT INCOMING DATA
                             FROM GRABS TO GREENNESS VALUES
                  2    TRUE :SELECT ACQUISITIONS USING THE
                             DECISION RULE THAT IF THE
                             GREENNESS VALUE FOR THAT
                             ACQUISITION IS GREATER THAN
                             GTHR INCLUDE IT IN THE SUBSET
                  3 - 10   NO FUNCTION AT PRESENT
  SARRAY   LOG   LIST OF TEN SWITCHES AS FOLLOWS
                  1 - TRUE: DETERMINE PROFILE PEAK
                             USING QUADRATIC FIT METHOD
                  2 - TRUE: PERFORM CROP CALENDAR SHIFT
                             USING CROSS-CORRELATION METHOD
                  3-10    NO FUNCTION AT PRESENT
  SCSWIT   LOG   TRUE IF SCREENING IS TO BE USED
```

S P R I N (Continued)

```
(BLOB DATA)
    - DIMENSIONED NACQ
  ACQS      INT    LIST OF ACQUISITION DAYS OF YEAR(1-366)
  SCREEN    INT    0 - INDICATES GOOD DATA
                   >0 - INDICATES BAD DATA; NOT TO BE USED
    - DIMENSIONED NACQ BY NBLOB UNLESS OTHERWISE STATED
  NPIXI     INT    NUMBER OF INTERIOR PIXELS IN A BLOB
                        VECTOR OF LENGTH NBLOB
  GREEN     REAL   GREENNESS(OR GRABS) MEANS FOR EACH BLOB
  BRITE     REAL   BRIGHTNESS MEANS FOR EACH BLOB

(PROFILE DATA)
    - DIMENSIONED NCROP UNLESS OTHERWISE STATED
  TDAYS     INT    NUMBER OF DAYS IN EACH PROFILE USED
                   FOR CROP CALENDAR SHIFT DETERMINATION,
                   EQUALS PDAYS + (2*NTAIL).
  GPROF     REAL   DIMENSIONED DIM1 BY NCROP.  LIST OF PROFILES
                   USED FOR CROP CALENDAR SHIFT
  PROFPK    INT    DAY OF PEAK GREENNESS FOR EACH CROP PROFILE
  NTAIL     INT    NUMBER OF DAYS IN A SINGLE PROFILE TAIL
  PDAYS     REAL   NUMBER OF DAYS IN EACH PROFILE USED FOR
                   GREENNESS FIT AND BRIGHTNESS CORRELATION.
  GPRO2     REAL   DIMENSIONED DIM1 BY NCROP. LIST OF
                   GREENNESS PROFILES USED FOR GOODNESS OF FIT.
  GVAR      REAL   DIMENSIONED DIM1 BY NCROP.  LIST OF VARIANCES
                   ASSOCIATED WITH EACH VALUE IN GPRO2
  TBR       INT    TOTAL NUMBER OF BRIGHTNESS PROFILES IN
                   BPROF(SCALAR)
  NBR       INT    NUMBER OF BRIGHTNESS PROFILES FOR EACH CROP
  BR1       INT    POSITION IN BPROF OF THE FIRST BRIGHTNESS
                   PROFILE FOR EACH CROP
  BPROF     REAL   DIMENSIONED DIM1 BY NBR.  LIST OF
                   BRIGHTNESS PROFILES USED FOR CORRELATION

(PROCEDURAL PARAMETERS)
  GTHR      REAL   GREENNESS VALUE BELOW WHICH AN ACQUISITION
                   WILL NOT BE INCLUDED FOR PROCESSING.  FOR
                   A BLOB TO BE PROCESSED IT MUST HAVE AT
                   LEAST THREE GOOD ACQUISITIONS, ONE WITH A
                   VALUE OF GTHR+10 OR MORE.
  XSHIFT    INT    ARRAY OF LENGTH NCROP.  EXPECTED CROP
                   CALENDAR SHIFT FOR EACH CROP.
```

S P R I N (Continued)

```
WEIGHT   REAL   ARRAY OF LENGTH 3.  WEIGHT TO BE APPLIED
                TO THE PROBABILITIES ASSOCIATED WITH
                CROP CALENDAR SHIFT, GREENNESS GOODNESS
                OF FIT, AND BRIGHTNESS CORRELATION.
DEFER    LOG    ARRAY OF LENGTH NCROP.  TRUE IF CROP
                IS NOT TO BE CONSIDERED FOR LABELING.
LLIST    CHAR   LIST OF 12-CHARACTER LABELS ASSOCIATED
                WITH EACH CROP.
                ARRAY DIMENSIONED 12 BY NCROP.
PTHR     REAL   PROBABILITY THRESHOLD BELOW WHICH A CROP
                IS NOT CONSIDERED A CANDIDATE

OUTPUTS

NUSE     INT    NUMBER OF ACQUISITIONS INCLUDED FOR
                PROCESSING (VECTOR OF LENGTH NBLOB)
  - DIMENSIONED NACQ BY NBLOB
DAYS     INT    ACQUSITIONS INCLUDED FOR PROCESSING
GR       REAL   GREENNESS VALUES(-GTHR) OF ACQUISITIONS
                INCLUDED FOR PROCESSING.
BR       REAL   BRIGHTNESS VALUES OF ACQUISITIONS
                INCLUDED FOR PROCESSING.
  - DIMENSIONED NCROP BY NBLOB (UNLESS OTHERWISE STATED)
NUSE2    INT    NUMBER OF ACQUISITIONS USED IN DETERMINING
                GOODNESS OF FIT STATISTIC
NUSE3    INT    NUMBER OF ACQUISITIONS IN PROFILE RANGE
                AFTER SHIFT IS APPLIED TO ACQUISITION DAY
SHIFT    INT    COMPUTED SHIFT FOR EACH BLOB TO EACH PROFILE
CCCORR   REAL   CORRELATION ASSOCIATED WITH COMPUTED SHIFT
SCALE    REAL    SCALE FACTOR USED IN FITTING BLOB MEANS
                 TO GREENNESS PROFILE
FIT      REAL    CHI-SQUARED GOODNESS OF FIT STATISTIC
                 (GREENESS FIT)
BBEST    INT     INDICATES WHICH BRIGHTNESS PROFILE
                 ASSOCIATED WITH THE CROP WAS USED TO OBTAIN
                 CORRELATION(IE. 1 OR 2 OR 3 ...)
BCORR    REAL   CORRELATION BETWEEN A BLOB'S BRIGHTNESS
                MEANS AND A CROP'S BRIGHTNESS PROFILE
PROBS    REAL   ARRAY OF CALCULATED PROBABILITIES (I,J,K)
                DIMENSIONED 3 BY NCROP BY NBLOB.
                (1,I,J):THE PROBABILITY ASSOCIATED
                WITH THE CROP CALENDAR SHIFT.
```

S P R I N (Continued)

		(2,I,J):THE PROBABILITY ASSOCIATED WITH THE GOODNESS OF FIT STATISTIC FOR THE GREENNESS VALUES.
		(3,I,J):THE PROBABILITY ASSOCIATED WITH THE BRIGHTNESS CORRELATION.

S.

TOTPRO	REAL	PROBABILITY ASSOCIATED WITH A CUMULATIVE TEST STATISTIC OBTAINED VIA FISHER'S OMNIBUS PROCEDURE.
LABEL	CHAR	CHARACTER*12 LABEL ASSOCIATED WITH EACH BLOB (ARRAY DIMENSIONED 12 BY NBLOB)
PROC	LOG	ARRAY DIMENSIONED NBLOB. TRUE IF THERE WERE AT LEAST THREE ACQUISITIONS WITH GREENNESS GREATER THAN GTHR.

R E G R E S

PURPOSE

COMPRISES PART OF THE WHEAT/BARLEY LABELING PROCEDURE. COMPUTES THE SEGMENT SPECIFIC PROFILE BY FITTING THE MEANS OF ALL SPRING SMALL GRAIN 'BIG BLOBS' TO A PROFILE MODEL USING REGRESSION ANALYSIS. GENERATES AN ANOVA TABLE FOR THE REGRESSION.

CALLING SEQUENCE

```
   CALL        REGRES(N,NACQ,ACQS,WT,BRITE,GREEN,NPIXI,LABEL,
  &                  SGPREP,SARRAY,SCSWIT,SCREEN,GTHR,
  &                  TDAYS,GPROF,PROFPK,NTAIL,
  &                  NUSE1,DAYS,GR,BR,SHIFT,GFIT,
  &                  NSBR,SOILBR,TOTAL,SSQY,XTX,XTY,PROC,
  &                  BETA,ANOVA,PEAK,RC)
```

INPUTS

```
    N        I*4   NUMBER OF BLOBS
    NACQ     I*4   NUMBER OF ACQUISITIONS PER BLOB
    ACQS     I*4   THE DAY OF THE YEAR ASSOCIATED
                   WITH EACH ACQUISTION
                       VECTOR OF LENGTH NACQ
    WT       R*4   THE WEIGHT TO BE APPLIED TO EACH GREENNESS
                   VALUE (VECTOR OF LENGTH NACQ)
    BRITE    R*4   BRIGHTNESS VALUES
                       ARRAY DIMENSIONED NACQ BY N
    GREEN    R*4   GREENNESS VALUES
                       ARRAY DIMENSIONED NACQ BY N
    NPIXI    I*4   NUMBER OF INTERIOR PIXELS IN BLOB
                       VECTOR OF LENGTH N
    LABEL    CHAR  12-CHARACTER LABEL FOR EACH BLOB
                       ARRAY DIMENSIONED 12 BY N
    SGPREP   L*4   LIST OF SWITCHES INDICATING WHETHER A
                   PARTICULAR FUNCTION SHOULD BE PERFORMED:
                     (VECTOR OF LENGTH 10)
                   SGPREP(1) - IF TRUE, THEN
                       CONVERT GRABS TO GREENNESS
                   SGPREP(2) - IF TRUE, THEN
                       SELECT ACQUISITIONS TO BE PROCESSED
                   SGPREP(3)...(10) - UNDEFINED
```

R E G R E S (Continued)

```
    SARRAY    L*4   LIST OF SWITCHES TURNING OFF VARIOUS
                    MODULES OF THE PROGRAM
                     SARRAY(1) - IF TRUE, DO QUADRATIC FIT
                     SARRAY(2) - IF TRUE, DO CROSS-CORRELATION
                                 SHIFT DETERMINATION
                     SARRAY(3)...(10) - UNDEFINED
    SCSWIT    L*4   .TRUE. IF SCREEN IS TO USED
    SCREEN    I*4   ARRAY OF LENGTH NACQ
                       0 = GOOD VALUE
                    > 0 = BAD VALUE
    GTHR      R*4   GREENNESS VALUE BELOW WHICH
                    ACQUISITION SHOULD BE EXCLUDED
    TDAYS     I*4   NUMBER OF DAYS IN PROFILE INCLUDING TAILS
    GPROF     R*4   CONTAINS REFERENCE CROP PROFILE
                          VECTOR OF LENGTH TDAYS
    PROFPK    I*4   DAY OF PROFILE PEAK GREENNESS
    NTAIL     I*4   NUMBER OF POINTS IN THE LEADING TAIL
                    OF THE PROFILE

TEMPORARIES

    NUSE1     I*4   SCALAR
    DAYS      I*4   VECTOR OF LENGTH NACQ
    GR        R*4   VECTOR OF LENGTH NACQ
    BR        R*4   VECTOR OF LENGTH NACQ

OUTPUTS

    SHIFT     I*4   THE DIFFERENCE BETWEEN THE DAY OF PEAK
                    GREENNESS AS CALCULATED FROM THE
                    OBSERVATIONS, AND THE DAY OF PEAK
                    GREENNESS OF THE PROFILE
                          VECTOR OF LENGTH N
    GFIT      R*4   CORRELATION ASSOCIATED WITH SHIFT VALUE
                          VECTOR OF LENGTH N
    NSBR      I*4   NUMBER OF BRIGHTNESS OBSERVATIONS USED IN
                    CUMULATIVE SOIL BRIGHTNESS VALUE (SOILBR)
    SOILBR    R*4   CUMULATIVE SOIL BRIGHTNESS VALUE
                    FOR SEGMENT
    TOTAL     I*4   TOTAL NUMBER OF OBSERVATIONS USED
                    IN THE REGRESSION
    SSQY      R*4   SUM OF SQUARES OF Y
    XTX       R*4   3X3 SYMMETRICAL MATRIX (X'X) USED IN
                    MLR ANALYSIS.  THE BOTTOM LEFT HAND CORNER
                    IS NOT CALCULATED AS IT IS
                    THE MIRROR IMAGE OF THE UPPER RIGHT CORNER.
```

R E G R E S (Continued)

```
XTY      R*4   3X1 MATRIX (X'Y) USED IN MLR ANALYSIS
PROC     L*4   LOGICAL VECTOR OF LENGTH N.  PROC(I) IS
               .TRUE. IF BLOB WAS SUCCESSFULLY PROCESSED
               AND DATA USED IN REGRESSION MODEL
BETA     R*4   VECTOR OF LENGTH 3, CONTAINING THE
               REGRESSION PARAMETERS
ANOVA    R*4   VECTOR OF LENGTH 10, CONTAINING THE
               ENTRIES TO THE ANOVA TABLE AS FOLLOWS :
                 1 - SUM SQUARES REGRESSION
                 2 - SUM SQUARES ERROR
                 3 - SUM SQUARES TOTAL
                 4 - MEAN SQUARE REGRESSION
                 5 - MEAN SQUARE ERROR
                 6 - F-STATISTIC = ANOVA(4)/ANOVA(5)
                 7 - R**2 = ANOVA(1)/ANOVA(3)
                 8 - DEGREES OF FREEDOM REGRESSION
                 9 - DEGREES OF FREEDOM ERROR
                10 - DEGREES OF FREEDOM TOTAL
PEAK     R*4   PEAK OF PROFILE AS DETERMINED BY REGRESSION
RC       I*4   RETURN CODE
                 0 = ALLS WELL
                 1 = XTX IS SINGULAR
                 2 = UNABLE TO SOLVE SYSTEM OF LINEAR EQ.
```

```
COMMENTS

 THE REGRESSION MODEL APPROXIMATES THE FOLLOWING EQUATION :

      FOR T<TMAX ;  F(T)=A*E**(B1*(T-TMAX)**2)
      FOR T > OR = TMAX ;  F(T)=A*E**(B2*(T-TMAX)**2)

    WHERE  F(T) = TASCAP GREENNESS - 25
           T    = SHIFTED DAY OF YEAR
           TMAX = SHIFTED DAY OF PEAK = 35
       A,B1,B2  = PARAMETERS TO BE ESTIMATED USING
                  LINEAR REGRESSION
    (SEE ERIM DOC. 132400-29-F2)

    THE ACTUAL REGRESSION EQUATION IS :

      Y = B0 + B1(X1-TMAX)**2 + B2(X2-TMAX)**2

      WHERE   Y = LN(F(T))
             X1 = T, X2 = 0      FOR T < TMAX
             X1 = 0, X2 = T      FOR T > OR = TMAX
             B0,B1,B2 = REGRESSION PARAMETERS
```

W B L A B

PURPOSE

LABELS EACH PIXEL IN A SCAN LINE BY ASSIGNING A VALUE OF 0, 1, 2, OR 3 AS FOLLOWS:
0 - NOT THE INTERIOR PIXEL OF A SPRING GRAIN BLOB,
1 - WHEAT, 2 - BARLEY, OR
3 - UNKNOWN SPRING GRAIN.

CALLING SEQUENCE

```
 CALL       WBLAB(
&                   NBLOB,NACQ,ACQS,SCSWIT,GTHR,
&                   BINDEX,LABEL,BPROC,
&                   SARRAY,SGPREP,TDAY,NTAIL,GPROF,PROFPK,
&                   SHIFT,DAY1,LINE,NPIX,TNCHAN,
&                   BLOB,STRIP,TASCAP,SCREEN,
&                   CODE,NGOODP,TOT)
```

INPUTS

```
  NBLOB    I*4   NUMBER OF BLOBS IN SEGMENT
  NACQ     I*4   NUMBER OF ACQUISITIONS
  ACQS     I*4   DAY OF YEAR FOR EACH ACQUISITION
                 VECTOR OF LENGTH NACQ
  SCSWIT   L*4   .TRUE. IF SCREEN IS TO USED
  SCREEN   I*4   VECTOR OF LENGTH NACQ
                  0 = GOOD VALUE
                 >0 = BAD VALUE
  GTHR     R*4   GREENNESS VALUE BELOW WHICH
                 ACQUISITION SHOULD BE EXCLUDED
  BINDEX   I*4   ARRAY DIMENSIONED NBLOB.  INDEX INTO BLOB
                 STATISTICS WHERE THE POSITION IN BINDEX
                 IS THE BLOB NUMBER AND ITS VALUE IS THE
                 CORRESPONDING POSITION IN THE STATISTICAL
                 ARRAYS.
  LABEL    CHAR   ARRAY DIMENSIONED 12 BY NBLOB. CONTAINS
                  THE CHARACTER*12 LABEL FOR EACH BLOB.
  BPROC    L*4   VECTOR OF LENGTH NBLOB
                 TRUE IF BLOB HAS AN ASSOCIATED SHIFT
  SARRAY   L*4   LIST OF SWITCHES TURNING OFF VARIOUS
                 MODULES OF THE PROGRAM
                 SARRAY(1) - IF TRUE, DO QUADRATIC FIT
                 SARRAY(2) - IF TRUE, DO CROSS-CORRELATION
                             SHIFT DETERMINATION
                 SARRAY(3)...(10) - UNDEFINED
```

W B L A B (Continued)

```
SGPREP   L*4   LOGICAL VECTOR OF LENGTH 10, INDICATING
               WHETHER A PARTICULAR SUBROUTINE SHOULD
               BE RUN:
                   SGPREP(1) - IF TRUE, THEN
                     CONVERT GRABS TO GREENNESS
                   SGPREP(2) - IF TRUE, THEN
                     SELECT ACQUISITIONS TO BE PROCESSED
                   SGPREP(3)...(10) - UNDEFINED
TDAY     I*4   NUMBER OF DAYS IN PROFILE INCLUDING TAILS
NTAIL    I*4   NUMBER OF POINTS IN THE LEADING TAIL
               OF THE PROFILE
GPROF    R*4   CONTAINS REFERENCE CROP PROFILE
                     VECTOR OF LENGTH TDAY
PROFPK   I*4   DAY OF PROFILE PEAK GREENNESS
SHIFT    I*4   THE DIFFERENCE BETWEEN THE DAY OF PEAK
               GREENNESS AS CALCULATED FROM THE
               OBSERVATIONS, AND THE DAY OF PEAK
               GREENNESS OF THE PROFILE.
               VECTOR OF LENGTH NBLOB
DAY1     I*4   DAY OF YEAR CORRESPONDING TO FIRST POINT
               IN VECTOR 'LINE'
LINE     R*4   18 VALUES OF THE DECISION LINE STARTING
               AT DAY1

  - IMAGES:  ONE SCAN LINE OF DATA AT A TIME.
TASCAP - TASSELED CAP DATA, 4 CHANNELS PER ACQUISITION
         IN THE FOLLOWING ORDER :
             BRIGHTNESS, GREENNESS, YELLOW, NONESUCH
         DIMENSIONED INCHAN BY NPIX
SCREEN - ONE CHANNEL PER PIXEL CONTAINING AN INTEGER
             0 = GOOD DATA
           > 0 = BAD DATA
         DIMENSIONED NACQ BY NPIX
STRIP  - ONE CHANNEL PER PIXEL CONTAINING AN INTEGER
             0 = INTERIOR PIXEL OF A BLOB
             1 = BOUNDARY PIXEL OF A BLOB
         DIMENSIONED 1 BY NPIX
BLOB   - ONE CHANNEL PER PIXEL CONTAINING THE BLOB
         NUMBER (DIMENSIONED 1 BY NPIX)
```

W B L A B (Continued)

OUTPUTS

```
    CODE       - IMAGE LINE CONTAINING THE FOLLOWING INTEGER
                      LABELS     (DIMENSIONED 1 BY NPIX):
                      0 = PIXEL IS NOT THE INTERIOR PIXEL OF A
                          SMALL GRAIN BLOB,
                      1 = WHEAT ,
                      2 = BARLEY ,
                      3 = UNKNOWN SPRING GRAIN.
    NGOODP    I*4  FOR EACH BLOB, THE NUMBER OF INTERIOR
                   PIXELS WHICH RECEIVED A LABEL OF 1,2 OR 3.
                   VECTOR OF LENGTH NBLOB
    TOT       I*4  NUMBER OF PIXELS IN EACH BLOB LABELED
                   1,2 AND 3. (ARRAY DIMENSIONED 3 BY NBLOB)
```

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