JJM SYSTEMS INC

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AN EXPERT SYSTEM SHELL FOR INFERRING VEGETATION CHARACTERISTICS - ATMOSPHERIC TECHNIQUES (TASK G)

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Prepared for:

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LIST OF ACRONYMS

KEE	Knowledge Engineering Environment
VEG	VEGetation Workbench

SECTION 1.0

INTRODUCTION

The NASA VEGetation Workbench (VEG) infers vegetation characteristics from reflectance data. For a detailed description of VEG, see references 1 and 2. A number of subgoals are available in VEG. In the previous version of VEG, the subgoals SPECTRAL.HEMISPHERICAL.REFLECTANCE, TOTAL.AND.SPECTRAL.HEMISPHERICAL.REFLECTANCE, PROPORTION.GROUND.COVER, VIEW.ANGLE.EXTENSION and LEARN.CLASS.DESCRIPTIONS were implemented.

The structure of the subgoals in VEG has been modified. Subgoals are now divided into categories. Two new subgoals in the category ATMOSPHERIC.TECHNIQUES have been added to VEG. The basic framework and interfaces for these subgoals have been implemented. No techniques for these subgoals were yet available so dummy techniques for each subgoal were included in VEG. Replacement of the dummy techniques with the real techniques when they become available should require little additional work.

This report describes the reorganization of VEG subgoals into categories and the new subgoals ATMOSPHERIC.PASSES and ATMOSPHERIC.CORRECTIONS. The code for the Lisp methods involved is included in Appendix A. A Sun cartridge tape containing these Lisp methods and the current version of VEG including the subgoal category ATMOSPHERIC.TECHNIQUES has been delivered to the NASA GSFC technical representative.

SECTION 2.0

THE SUBGOAL CATEGORY ATMOSPHERIC TECHNIQUES IN THE VEG RESEARCH MODE

The structure of the VEG subgoals has been reorganized into four categories as shown in Figure 2-1. When the user runs VEG and selects Research Mode, the Categories menu is displayed. This menu allows the user to select the required subgoal category. Selecting the category VEGETATION.PARAMETER.TECHNIQUES allows the user to select the VEG subgoals TOTAL.AND.SPECTRAL.HEMISPHERICAL.REFLECTANCE, SPECTRAL. HEMISPHERICAL.REFLECTANCE, PROPORTION.GROUND.COVER and VIEW.ANGLE. EXTENSION. Selecting the category LEARNING.SYSTEM invokes the learning system. The option NEURAL.NETWORK is included in the categories submenu although this category has not yet been implemented.

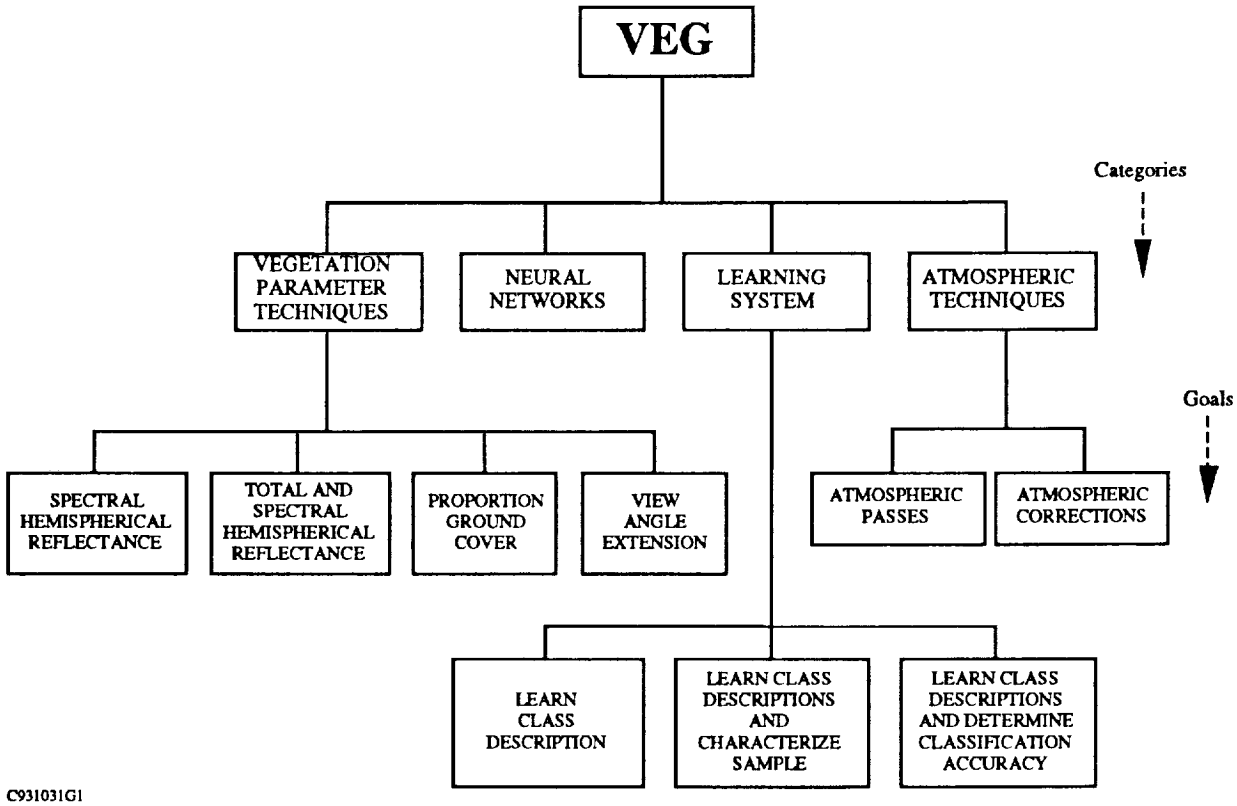

Figure 2-1
Categories of Subgoals in VEG

A new category, ATMOSPHERIC.TECHNIQUES, has been added to VEG. When this category is selected, the menu shown in Figure 2-2 is displayed. The subgoal ATMOSPHERIC.PASSES allows the scientist to take reflectance data measured at ground level and predict what the reflectance values would be if the data were measured at a different atmospheric height. The subgoal ATMOSPHERIC.CORRECTIONS allows atmospheric corrections to be made to data collected from an aircraft or by a satellite to determine what the equivalent reflectance values would be if the data were measured at ground level.

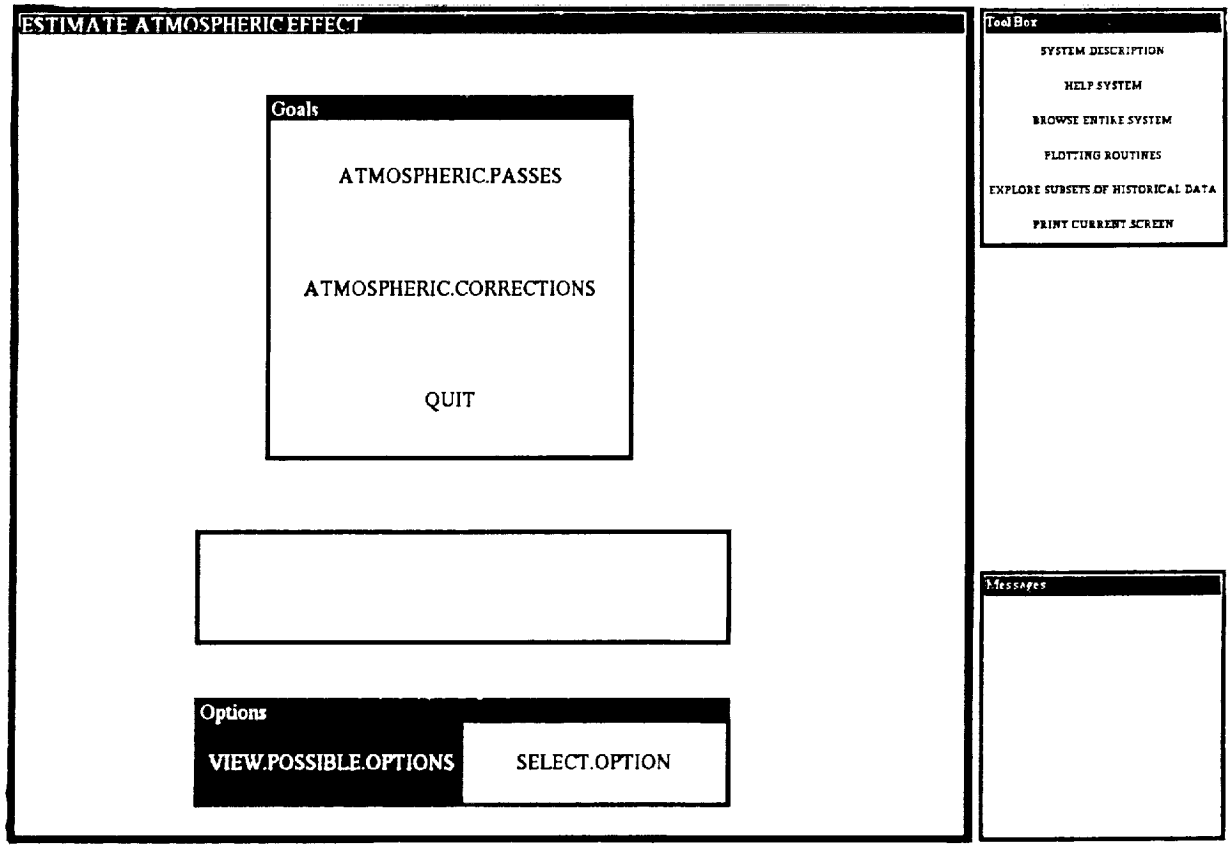

Figure 2-2
The Atmospheric Techniques Menu

When the user selects the subgoal ATMOSPHERIC.PASSES from the menu shown in Figure 2-2, the menu shown in Figure 2-3 is displayed. Selecting the subgoal ATMOSPHERIC.CORRECTIONS reveals the menu shown in Figure 2-4. The steps involved in the subgoals ATMOSPHERIC.PASSES and ATMOSPHERIC.CORRECTIONS are similar. The subgoal ATMOSPHERIC.PASSES will be described in detail in this section. Any variations for the subgoal ATMOSPHERIC.CORRECTIONS will be mentioned in the description.

The menu shown in Figure 2-3 enables the user to invoke the steps involved in processing reflectance data to estimate the reflectance values at different atmospheric heights. Before each step is carried out, a check is made to make sure that the necessary prerequisite steps have been carried out. For example, the results cannot be output before the techniques have been executed. If any prerequisite steps have not been carried out, a message is displayed and the user is prompted to complete the necessary prerequisite steps.

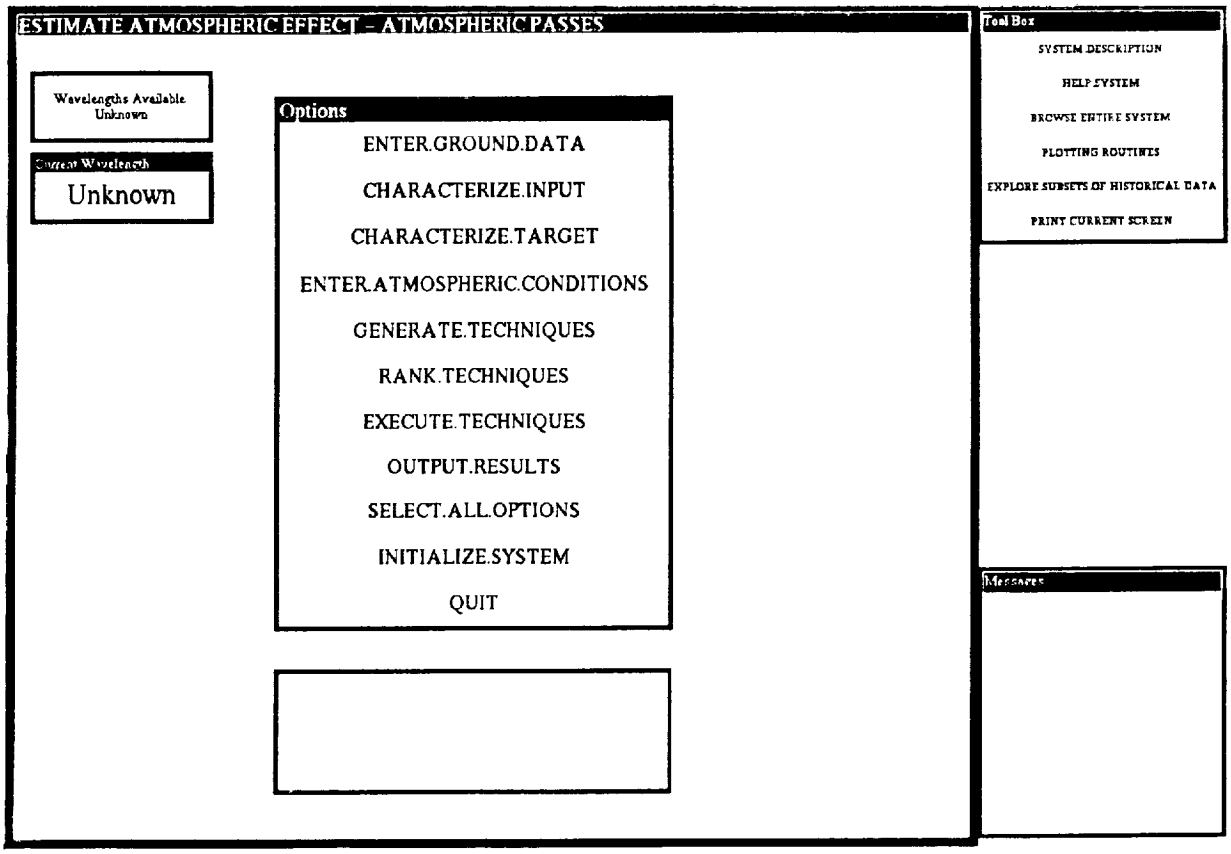

Figure 2-3
Menu for the Subgoal ATMOSPHERIC.PASSES

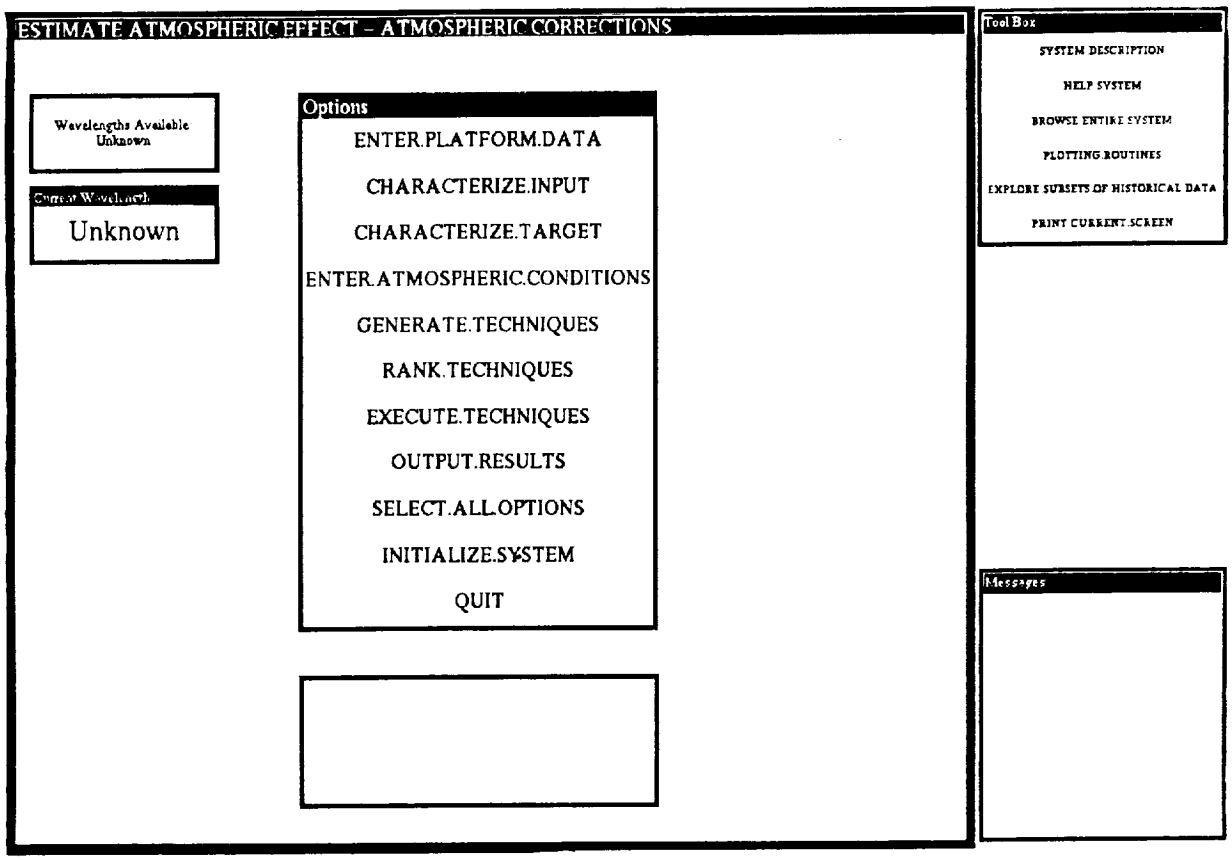

Figure 2-4
Menu for the Subgoal ATMOSPHERIC.CORRECTIONS

2.1 ENTER PLATFORM DATA

The code and interface that were originally developed for the step ENTER.DATA for the VEG subgoal SPECTRAL.HEMISPHERICAL.REFLECTANCE have been modified for re-use in this step. When the user selects the step ENTER.DATA, an interface opens. This interface allows the user to either enter a new original set of data for an unknown cover type or select one of a number of samples of cover type data stored in the VEG historical database. If the user chooses to enter original data, another interface opens as shown in Figure 2-5. This interface allows the user to enter data for the new sample. In addition to the data required for the subgoal SPECTRAL.HEMISPHERICAL.REFLECTANCE, the subgoal ATMOSPHERIC.PASSES requires the entry of the atmospheric height to which the reflectance data will be projected. A subwindow labeled "Atm Ht (m or (A)bove))" has been added to the screen. This subwindow enables the user to enter the number of meters to which the data should be projected or "A" if the data are to be projected to above the atmosphere. Each data value is checked as soon as it has been entered to make sure that it is of the correct type and is in the valid range for the data item it represents. The user can left click on the menu button "SAVE.DATA" at the bottom of the screen in Figure 2-5 to store the data. Before a set of cover type data is stored, the system checks that at a minimum the solar zenith angle, wavelength, reflectance data and atmospheric height have been entered. If any of these items is missing, the user is prompted to supply the missing items before the data are stored.

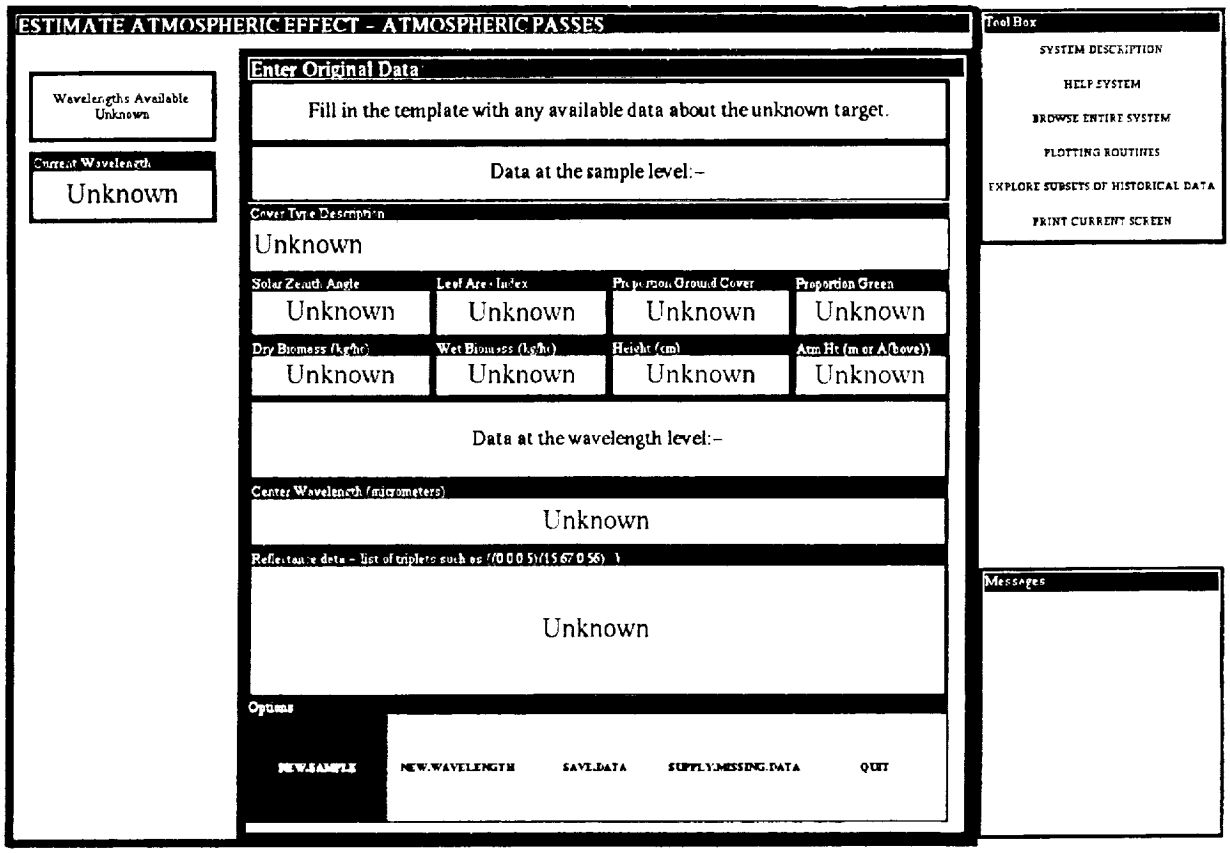

Figure 2-5
The Screen for Entering Original Platform Data

If the user elects to process a sample of cover type data from the historical cover type database, the screen shown in Figure 2-6 is opened. It is important that the user enter data into this screen in the correct order. When this screen is first opened, only the message and atmospheric height subwindows are opened. The other subwindows in this screen are automatically opened in turn, after the user has entered the necessary prerequisite data. If the user enters a data value and then subsequently changes it, the appropriate subwindows are closed to backtrack the data entry process to where the changed data value was first entered. The user is required to first enter the atmospheric height. Next the user must select the required cover type from the historical cover type database, followed by the sun angle. Figure 2-6 shows the "Select Historical Data" screen at this stage of data entry. Once the sun angle has been selected, the user is prompted to select the waveband of interest. The user is then prompted to enter the directional data. If invalid directional data is entered, the user is prompted to reenter the data in the correct format. Once valid directional data have been entered, VEG automatically interpolates and extrapolates the reflectance data for the selected historical database cover type to the specified view angles. The complete directional reflectance data, including the interpolated and extrapolated reflectance values, are displayed in the subwindow labeled "Directional Reflectance Data," as shown in Figure 2-7.

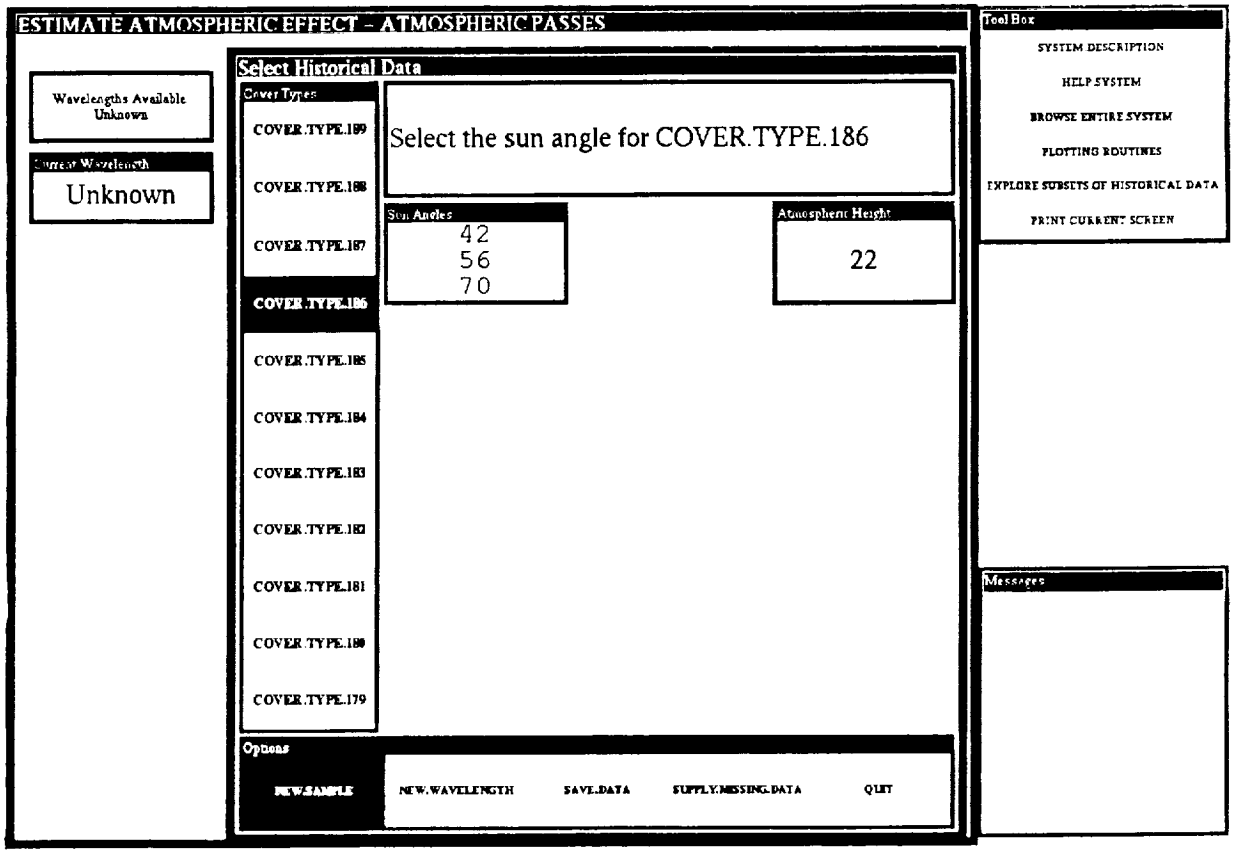

Figure 2-6
Selecting Historical Data

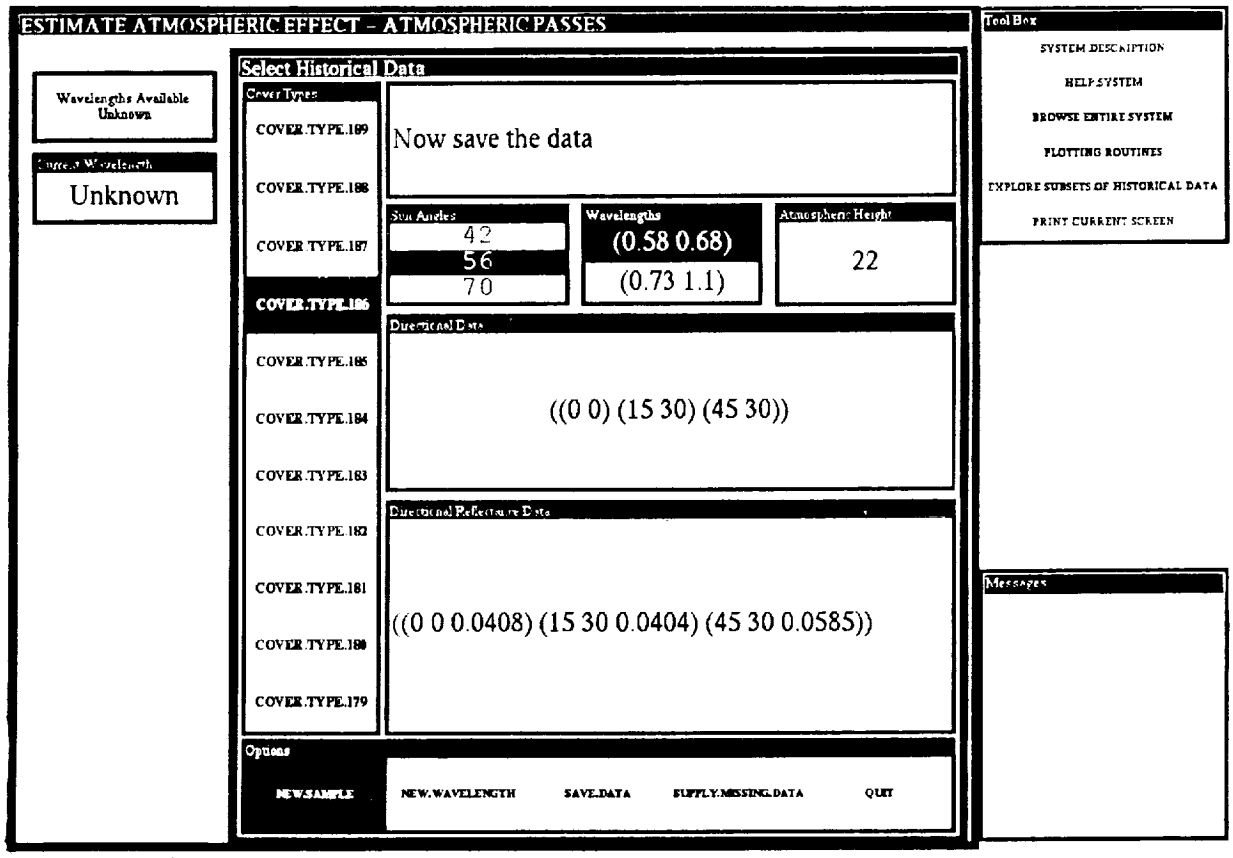

Figure 2-7
A Complete Set of Selected Historical Data

Once the data has been entered, they can be saved. If the user attempts to save an incomplete data set, the user is prompted to supply the missing data before saving them. The interface allows the user to select multiple wavebands of the same historical data sample. If the user selects "NEW.WAVELENGTH" from the "Options" at the bottom of the "Select Historical Data" screen, the "Directional Reflectance Data" subwindow is cleared and highlighting of the previously selected waveband is removed. When the user selects a different waveband, the historical cover type data for the new waveband is automatically interpolated and extrapolated to the required view angles. The set of directional reflectance data for the new waveband is automatically displayed in the "Directional Reflectance Data" subwindow. The user also has the option of entering a different set of directional view angles for the new waveband. Selecting "QUIT" returns the user to the screen shown in Figure 2-3.

When the VEG subgoal ATMOSPHERIC.CORRECTIONS is in use, platform data rather than ground data must be entered. The interface for entering platform data is the same as the interface shown in Figure 2-5, except that the atmospheric height subwindow is replaced by a subwindow for entering the platform height. All the cover type data sets in the current historical database were collected at ground level. Thus, the option of selecting data from the historical database for the ATMOSPHERIC.CORRECTIONS subgoal is not yet available.

2.2 CHARACTERIZE INPUT

The unknown cover type data at each wavelength are characterized using code that was developed for the VEG subgoal SPECTRAL.HEMISPHERICAL.REFLECTANCE. Sets of view angles in the same azimuthal plane are identified as "strings." Strings are characterized as full-strings if they contain both forwardscatter and backscatter data and half-strings if they contain either backscatter or forwardscatter data.

2.3 CHARACTERIZE TARGET

If the sample data do not contain a value for ground cover or leaf area index, an estimation of these values is made. The code developed for the VEG subgoal SPECTRAL. HEMISPHERICAL.REFLECTANCE is re-used for this purpose.

2.4 ENTER ATMOSPHERIC CONDITIONS

When the user selects the option ENTER.ATMOSPHERIC.CONDITIONS from the menu shown in Figure 2-3, the screen shown in Figure 2-8 is opened. This screen allows the user to define the atmospheric conditions for the target data in each waveband. VEG automatically selects the first waveband and prompts the user to define the atmospheric conditions for that waveband. The user can select a standard atmosphere, such as "sub-arctic winter," by left clicking on the name of the standard atmosphere. The NASA GSFC technical representative was unable to provide the specifications of the standard atmospheres so dummy values were used for the development of this option. The dummy values will be replaced with the correct values when they become available. When a standard atmosphere has been selected, the user has the option to change the value of any of the atmospheric parameters as required. Alternatively, instead of selecting a standard atmosphere, the user can enter the value of each parameter independently. The type and range of each parameter value is checked after it is entered. If the user enters an invalid value, an error message is displayed, prompting the user to enter another value. Once a complete set of data has been entered, the data can be saved. If the user attempts to save an incomplete set of data he/she is prompted to supply the missing data before the data can be saved. After the data have been saved, if the target data contains more than one waveband, the prompt at the top of the screen is changed to include the next waveband. The values for the other parameters are not changed. The user has the option of changing the parameter values before saving the data for the next waveband. When atmospheric conditions have been saved for all the selected wavebands, the Enter Atmospheric Conditions Screen is automatically closed.

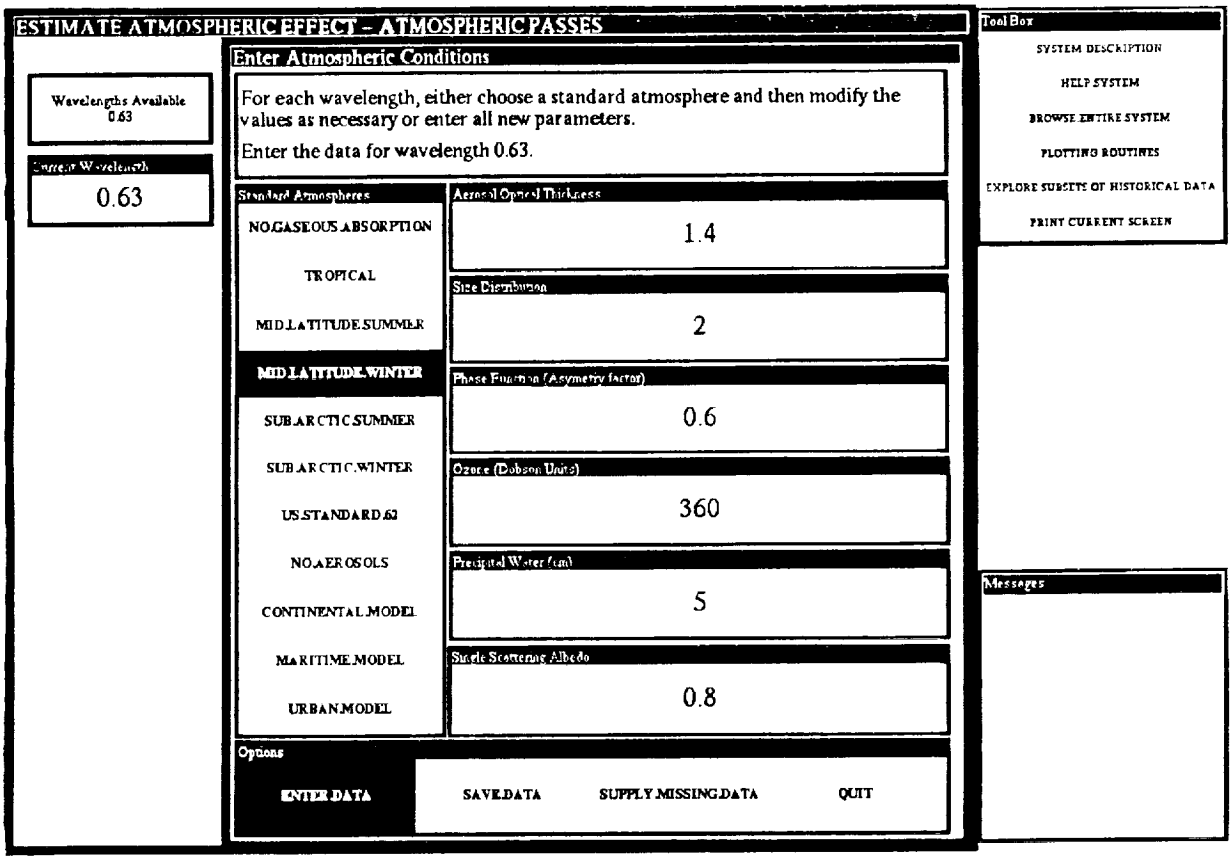

Figure 2-8
The Enter Atmospheric Conditions Screen

2.5 GENERATE TECHNIQUES

Techniques can be generated automatically by the system or selected by the user. The code for generating techniques for the VEG subgoal SPECTRAL.HEMISPHERICAL. REFLECTANCE was copied and modified for this step. A new screen was created to allow the user to select the atmospheric passes techniques, but many existing functions were used to operate this screen. The NASA GSFC technical representative advised that the atmospheric techniques were not yet available in the appropriate format for incorporation into VEG. Thus, dummy rules and technique functions were incorporated in VEG at this stage. The dummy rules and functions should be replaced with the actual atmospheric technique rules and functions when they become available.

If the user elects to have the system generate the techniques, the rules in the rulebase ATMOSPHERIC.PASSES.RULES are run. The rules operate on the unknown sample data at the wavelength level and determine the techniques that are suitable for estimating the reflectance data of a sample at a particular height. The names of the selected techniques are stored in the TECHNIQUES slot of the wavelength level unit.

If the user elects to choose the techniques manually, the Pick Techniques screen is opened. When the user left clicks on the name of a dummy technique, a brief description of the technique is displayed. A function is called to check whether the technique is suitable for the sample. If the

technique is suitable for the sample, the message "Technique is suitable for this sample" is displayed, and the technique is selected. Otherwise, an error message is displayed in the same subwindow and the technique is not selected. When the user left clicks on PICK.SELECTED.TECHNIQUES at the bottom of the screen, the selected techniques are stored in the TECHNIQUES slot of the unknown cover type unit.

Dummy rules for selecting atmospheric correction techniques were constructed in the ATMOSPHERIC.CORRECTIONS.RULES rulebase. An additional screen that allows the user to select atmospheric corrections techniques was also constructed.

Minor changes were made to the Add Techniques interface and the code for adding techniques. These changes enabled the scientist to add new techniques for the subgoals Atmospheric Passes and Atmospheric Corrections without the assistance of the developer. The Add Techniques option is described in detail in Reference 3.

2.6 RANK TECHNIQUES

The code from the same step for the subgoal SPECTRAL.HEMISPHERICAL. REFLECTANCE was re-used for this step. The techniques are ranked according to a simple weighting scheme and the ranked techniques at each wavelength are displayed on the screen. The user can select the best one, two or three techniques for each wavelength, pick all the selected techniques, or repeat the previous step and generate the techniques again.

2.7 EXECUTE TECHNIQUES

The code providing the framework for this step from the VEG subgoal SPECTRAL.HEMISPHERICAL.REFLECTANCE was re-used for this step. Dummy functions for generating the coefficients and calculating the projected reflectance data for each technique were written. When the step EXECUTE.TECHNIQUES is selected, the techniques are applied to the data in the unknown cover type sample. If a technique requires coefficients, the user is asked whether all or half the restricted data set should be used for generating the coefficients and estimating the error. The appropriate coefficient methods are applied as necessary. A hierarchy of units is set up to hold the calculated projected reflectance data for each technique.

2.8 OUTPUT RESULTS

The results are displayed on the screen shown in Figure 2-9. This screen was originally constructed for the VEG subgoal SPECTRAL.HEMISPHERICAL.REFLECTANCE. The title has been changed to "Atmospheric Passes Results." The results are displayed one wavelength at a time. The atmospheric conditions specified for the wavelength are displayed in the subwindow labeled "Wavelength Results." For each technique, the name of the technique is displayed together with the results from applying that technique to the sample of cover type data. In Figure 2-9, the dummy technique B has been applied to the sample of cover type data. The results displayed for this technique are meaningless since technique B is a dummy technique that returns the reflectance value at the first view angle. When atmospheric techniques have been added to VEG, the correct results will be displayed on the "Output Results" screen. The user can view the results for different wavebands by left clicking on "NEXT.WAVELENGTH" or "PREVIOUS. WAVELENGTH."

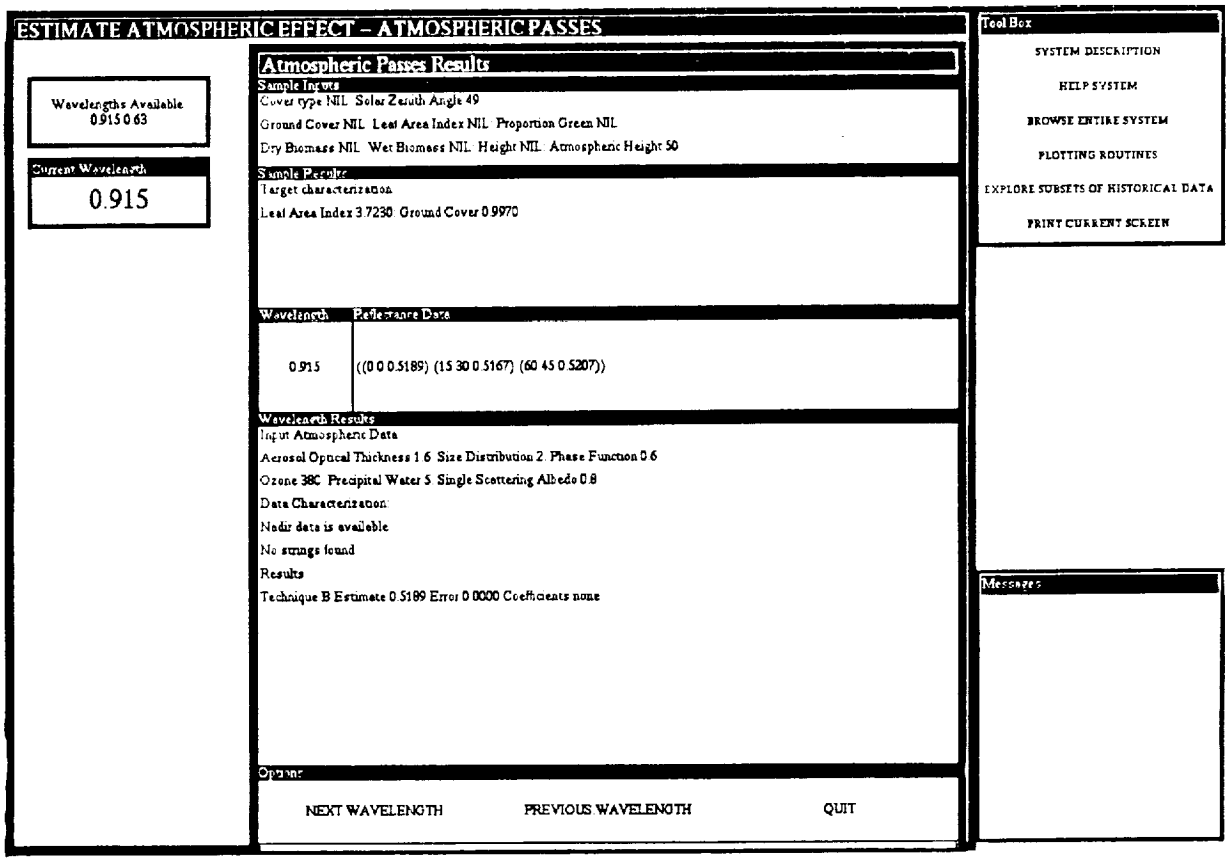

Figure 2-9
The Output Screen for the Subgoal ATMOSPHERIC.PASSES

SECTION 3.0

THE SUBGOAL CATEGORY ATMOSPHERIC TECHNIQUES IN THE VEG AUTOMATIC MODE

The menus for the VEG Automatic Mode were modified to accommodate the restructuring of VEG subgoals into the four categories described in Section 2.0. When the user selects the Automatic Mode from the Processing Mode menu, the screen shown in Figure 3-1 is opened. This screen enables the user to select the category of subgoal for automatic processing.

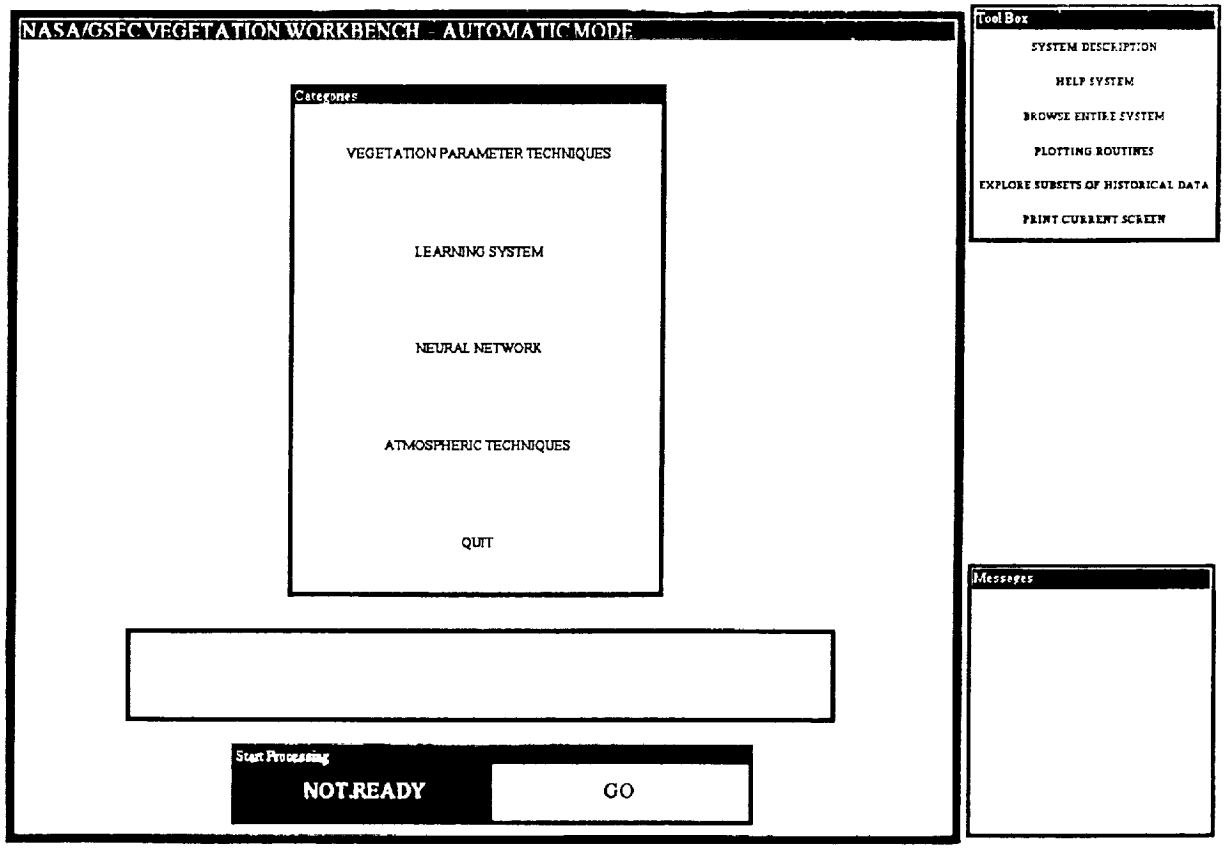

Figure 3-1
The VEG Automatic Mode Categories Menu

When the user selects the ATMOSPHERIC.TECHNIQUES option from the screen shown in Figure 3-1, the "Categories" subwindow is replaced by the "Atmospheric Techniques" subwindow. Selecting the option ATMOSPHERIC.PASSES or ATMOSPHERIC. CORRECTIONS causes additional subwindows to be opened, as shown in Figure 3-2. These subwindows enable the user to name the input and output files, select the output file format and specify how many techniques should be applied to each unknown cover type data sample.

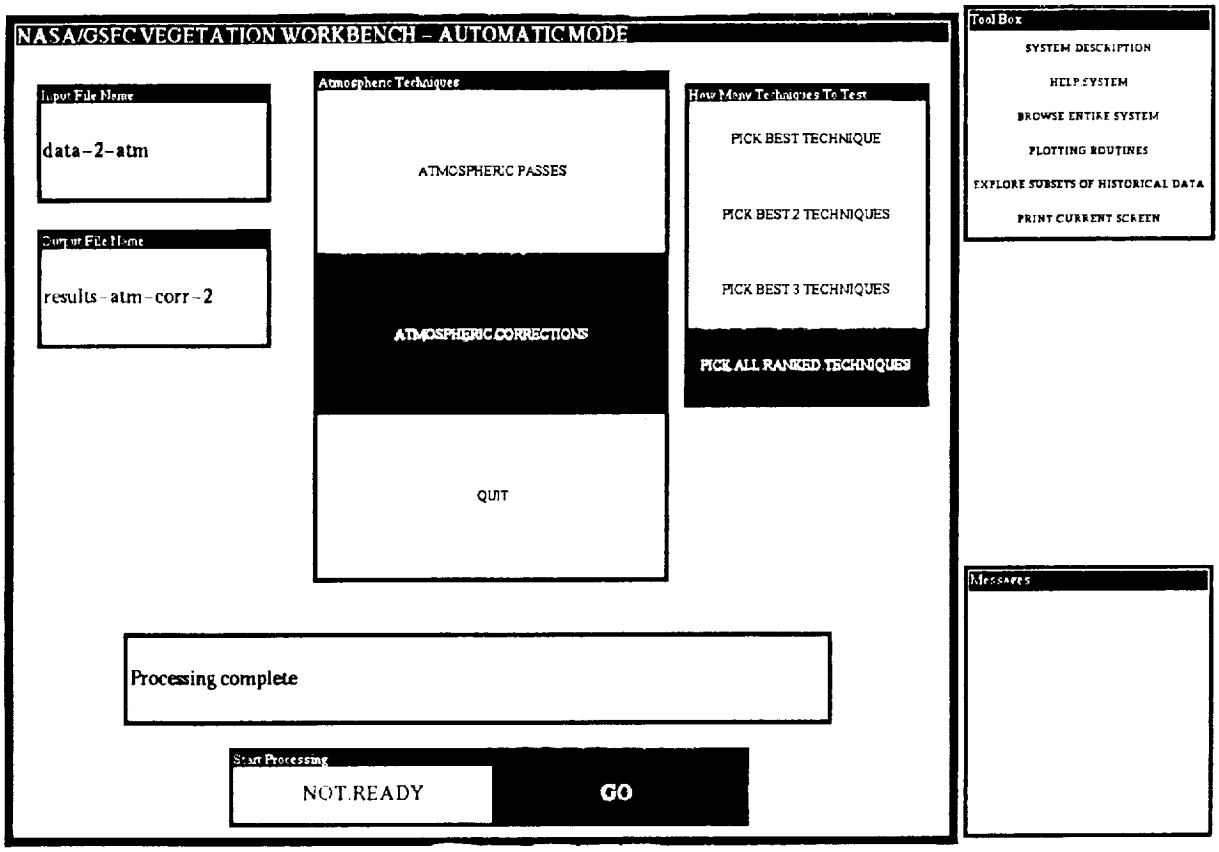

Figure 3-2
Running the Subgoal ATMOSPHERIC.CORRECTIONS in the VEG Automatic Mode

The input file for an atmospheric technique must contain atmospheric conditions data and the data platform elevation or atmospheric height as well as the cover type data that are required for subgoals in the other VEG categories. A standard file format for input files to atmospheric techniques has been defined. The file format and an example of typical values are shown in Table 3-3. Global variables *STANDARD-ATM-PASS-SAMPLE-FORMAT*, *STANDARD-ATM-CORR-SAMPLE-FORMAT* and *STANDARD-ATM-WAVELENGTH-FORMAT* have been

created in the file "veg-methods1.lisp." This file contains the methods used for inputting data from a file into VEG. The new global variables hold the list of fields in the standard format for an atmospheric techniques input file. The field names correspond to the names of slots in which the data should be stored. When the input file is named by the user, the values from the appropriate field list global variables are put in the slots AUTO.INPUT.SAMPLE.FORMAT and AUTO.INPUT.WAVELENGTH.FORMAT of the unit AUTOMATIC.PROCESS. When the file is read, these slots are referenced to determine the file format.

Table 3-1
Input File Format for Atmospheric Techniques and an Example of Typical Values

FIELD NAMES	TYPICAL VALUES
COVER.TYPE.DESCRIPTION	"Dense Vegetation Canopy"
SOLAR.ZENITH LEAF.AREA.INDEX	45 3.5
GROUND.COVER PROPORTION.GREEN	0.7 0.3
DRY.BIOMASS WET.BIOMASS HEIGHT	0.2 0.5 1000
DATA.PLATFORM.ELEVATION	30
NUMBER.WAVELENGTHS	2
WAVELENGTH	0.68
NUMBER.VIEW.ANGLES	1
REFLECTANCE.DATA	((0 0 0.043))
AEROSOL.OPTICAL.THICKNESS SIZE.DISTRIBUTION	1.6 2
PHASE.FUNCTION OZONE	0.6 360
PRECIPITAL.WATER SINGLE.SCATTERING.ALBEDO	5 0.8
WAVELENGTH	0.68
NUMBER.VIEW.ANGLES	1
REFLECTANCE.DATA	((0 0 0.043))
AEROSOL.OPTICAL.THICKNESS SIZE.DISTRIBUTION	1.8 2
PHASE.FUNCTION OZONE	0.6 400
PRECIPITAL.WATER SINGLE.SCATTERING.ALBEDO	5 0.8

When the user left clicks on "GO," the unknown cover type data are read from the file using the correct format. The input data and the target are then characterized as in the Research Mode. The rules are run, and the best techniques for the sample are selected. The selected techniques are then executed and the results are written to the named file using the specified format. The code in the file "veg-methods.lisp" that was originally written for the automatic processing of data for the vegetation parameter techniques was modified for the processing of data for atmospheric techniques.

SECTION 4.0

TESTING AND RESULTS

The following capabilities of the VEG Atmospheric Techniques subgoal category were tested:

- Test 1 - Navigate through the category and subgoal menus in the Research Mode.
- Test 2 - Atmospheric Passes Subgoal using data entered by the user
- Test 3 - Atmospheric Passes Subgoal using historical data
- Test 4 - Atmospheric Corrections Subgoal
- Test 5 - Automatic Mode, Atmospheric Passes Subgoal
- Test 6 - Automatic Mode, Atmospheric Corrections Subgoal
- Test 7 - Add Techniques for Atmospheric Passes and Atmospheric Corrections Subgoals

All the tests were successful, showing that the system was working correctly. The tests are described in detail in this section.

4.1 TEST 1

This test was designed to test the new sequence of menus in the VEG Research Mode that was implemented as a result of the subgoals being divided into categories. After left clicking on "RUN.VEG," the user selected the Research Mode. Because no historical data were loaded, the Change Historical Database screen automatically opened. The user indicated that both the Kimes and the Deering databases should be added. After quitting the Change Historical Database screen, the user again selected the Research Mode from the Processing Mode screen. The categories screen was then opened. The user selected the VEGETATION.PARAMETER. TECHNIQUES category. The Vegetation Parameters Techniques Goals screen was opened. The user then selected and successfully ran the Estimate Spectral Hemispherical Reflectance option before navigating back to the Categories menu. Subsequently, the user successfully opened and quit the Learning System and Atmospheric Techniques goal screens. When the user selected the NEURAL.NETWORK option, a message indicating that the option was not available was displayed. This message was removed when another option was selected. The user then navigated out of the VEG system back to the KEE interface. This test showed that the new menus were operating correctly.

4.2 TEST 2

Test 2 was designed to test the Atmospheric Passes Subgoal using original data entered by the user. The user navigated to the Atmospheric Passes main menu. The data were processed by carrying out the steps in the ATMOSPHERIC.PASSES menu, as shown in Figure 2-3.

The user selected the ENTER.GROUND.DATA option, and elected to enter original data. The user entered various invalid values for the atmospheric height and the message "Atmospheric Height out of range error" was displayed in the "Messages" box. The user attempted to save an

incomplete data set. VEG prompted the user to supply the missing data before the data set could be saved. Valid data for the solar zenith angle, atmospheric height, wavelength and reflectance data were then entered and the data were saved. Next, the input data and target were characterized.

The interface for entering atmospheric conditions was thoroughly tested. The user entered invalid values for each parameter. In every case, an error message was displayed in the "Messages" box and the user was prompted to reenter the data. When attempting to save an incomplete set of atmospheric conditions data, the user was prompted to supply the missing data before the data could be saved.

The user elected to select the techniques manually. The Pick Techniques screen was opened. When the user left clicked on a technique to select it, a description of the technique was displayed. If the technique was suitable for the sample, the message "Technique is suitable for this sample" was displayed and the technique was selected. Otherwise, an error message was displayed and the technique was not selected. The test showed that the Pick Techniques screen was operating correctly.

The techniques were ranked and all the ranked techniques were selected. The techniques were then executed. The results were displayed on the screen. The atmospheric conditions were included in the results displayed in the "Wavelength Results" window. The results of applying the dummy techniques to the sample were also displayed.

Test 2 confirmed that the subgoal "Atmospheric Passes" was operating correctly when original data were entered and the techniques were generated manually.

4.3 TEST 3

In Test 3, the Atmospheric Passes Subgoal was tested using cover type data from the historical cover type database. The user selected the step ENTER.GROUND.DATA and the option SELECT.HISTORICAL.DATA. The Select Historical Data screen was opened. At this stage, only the "Message," "Option," and "Atmospheric Height" subwindows were opened. The user entered the value "300" into the "Atmospheric Height" subwindow. The "Cover Types" subwindow then opened. The user selected COVER.TYPE.7. The user then selected sun angle 59 and waveband (0.58 0.68) in successive subwindows. The user then changed the cover type selection to COVER.TYPE.11. The "Wavelengths" and "Directional Reflectance" subwindows were automatically closed and the sun angle deselected. This part of the test showed that the data entry process was correctly backtracked when previously entered data were changed. The user reselected the previous values for cover type, sun angle and waveband. The user entered the directional view angles ((0 0)(15 30)(30 45)). Directional reflectance data for these view angles were displayed in the "Directional Reflectance Data" subwindow. The user saved the data by left clicking on the "SAVE.DATA" Option at the bottom of the screen. The user then selected the waveband (0.73 1.1) with the same view angles and saved the data. This part of the test showed that the Select Historical Data Screen was operating correctly.

The data and target were then characterized. The user selected the NO.AEROSOLS standard atmosphere in both wavebands for the data. The techniques were generated automatically by running the rules. The techniques were then ranked and the best technique for each wavelength was selected. After the techniques had been executed, the results were displayed on the screen. Since the techniques were dummy, the results were not meaningful. This test showed that the select historical data step and the technique generation rules of the Atmospheric Passes Subgoal were operating correctly.

4.4 TEST 4

This test was designed to test the steps in the subgoal Atmospheric Corrections that were different from the steps in the subgoal Atmospheric Passes. The subgoal ATMOSPHERIC.CORRECTIONS was selected from the Atmospheric Techniques menu. The user selected the step ENTER.PLATFORM.DATA and then the option SELECT.HISTORICAL.DATA. The message "This option is not yet available" was displayed. The user then selected ENTER.ORIGINAL.DATA. The Enter Original Data screen opened. As expected, the screen included a subwindow for entering the Data Platform Elevation. The user entered and saved a complete set of data.

The steps Characterize Input, Characterize Target, and Enter Atmospheric Conditions were then executed. Initially, the user chose to pick the techniques manually. The Pick Techniques screen worked correctly. The user then activated the rules to generate the techniques automatically. The correct techniques were selected. The techniques were then ranked and the best technique for each wavelength was selected. The techniques were executed and the results displayed. The output screen included the Data Platform Elevation in the data at the sample level. Since the techniques were dummies, the actual values of the results were not relevant.

Test 4 confirmed that all the options in the subgoal Atmospheric Corrections were operating correctly.

4.5 TEST 5

This test was designed to test the new sequence of menus and the operation of the subgoal Atmospheric Passes in the VEG Automatic Mode. The user selected the Automatic Mode from the Processing Mode menu. The Automatic Mode screen with the Categories subwindow was opened. Tests confirmed that subgoals in the Vegetation Parameters and Learning System categories could be successfully operated via the new menu structure. When the user selected the category NEURAL.NETWORK, the message "This option is not yet available" was displayed.

The user selected the ATMOSPHERIC.TECHNIQUES Subgoal category and the ATMOSPHERIC.PASSES Subgoal. The "Atmospheric Techniques," "Input File Name," "Output File Name," and "Number of Techniques" subwindows opened. The user entered the file name DATA-2-ATM as the input file and RESULTS-ATM-PASS as the output file. Standard template number 1 was selected as the output file format. The option to test all techniques was selected. When the user left clicked on "GO," the data were processed. Inspection of the output file indicated that the data had been processed correctly.

This test showed that the new sequence of menus and the subgoal Atmospheric Passes were operating correctly in the VEG Automatic Mode.

4.6 TEST 6

In this test, Test 5 was repeated using the subgoal Atmospheric Corrections. Inspection of the output file confirmed that this subgoal was operating correctly.

4.7 TEST 7

The Add Techniques Option allows the scientist to define new techniques and add them to VEG without the assistance of the developer. Test 7 was designed to test the operation of the Add Techniques Option when the user attempted to add new techniques for the subgoals Atmospheric Passes and Atmospheric Corrections.

Using the DEFINE.NEW.TECHNIQUE option from the Add Techniques menu, the user defined a new technique for each of the Atmospheric Passes and Atmospheric Corrections Subgoals. The user then add the new techniques to VEG using the ADD.PREVIOUSLY. DEFINED.TECHNIQUES option form the Add Techniques menu. Subsequently, the user ran both the Atmospheric Passes and the Atmospheric Corrections Subgoals. It was confirmed that the new techniques had been correctly incorporated in VEG.

SECTION 5.0

CONCLUSIONS

The report described the implementation of the VEG subgoal category ATMOSPHERIC.TECHNIQUES in both the Research and Automatic Modes of VEG. It then described the testing of the new components of VEG to demonstrate their basic functionality.

The addition of Atmospheric Techniques to VEG illustrated that additional functionality can easily be added to the system without any major problems being encountered. The new subgoals Atmospheric Passes and Atmospheric Corrections were integrated into the overall VEG interface so that they worked smoothly as part of the overall system. The additional functionality provided by these new subgoals allows the scientist to take data measured at ground level and predict what the reflectance values would be if the data were measured at a different atmospheric height. It also allows atmospheric corrections to be made to data collected from an aircraft or by a satellite to determine what the equivalent reflectance values would be if the data were measured at ground level.

REFERENCES

1. Kimes, D. S., Harrison, P. R. and Ratcliffe, P. A. 1991. A Knowledge-Based Expert System for Inferring Vegetation Characteristics. International Journal of Remote Sensing: Vol 12, 10, pp. 1987-2020.

2. Kimes, D. S., Harrison, P. A. and Harrison, P. R. 1992. New Developments of a Knowledge Based System (VEG) for Inferring Vegetation Characteristics. International Geoscience and Remote Sensing Symposium, Houston, Texas, May 1992.

3. JJM Systems Inc. April 1993. An Expert System Shell For Inferring Vegetation Characteristics - Interface for the Addition of Techniques (Task H). Arlington, VA. C931021-U-2R07.

APPENDIX A

LISP CODE FOR THE VEG SUBGOAL CATEGORY ATMOSPHERIC TECHNIQUES

```
;;; veg-methods6.lisp
;;;
;;; Code for VEG Atmospheric Techniques
;;;
;;; Created April 27, 1993
;;; Last Modified October 18, 1993

(in-package 'kee)

(defun open-atmospheric-screen ()
"Opens the screen that allows the user to select the atmospheric technique
goal."
  (remove.all.values 'atmospheric 'goals)
  (put.value 'atmospheric 'message "")
  (put.value 'atmospheric 'options 'view.possible.options)
  (unitmsg 'viewport-atmospheric.1 'open-panel!))

;;;-------------------------------------------------------------------------
;;; Methods for Atmospheric Passes
;;;-------------------------------------------------------------------------

(defun atm.pass.p ()
"Returns t if the current goal is atmospheric passes and nil otherwise."
  (eq (get.value 'atmospheric 'goals) 'atmospheric.passes))

(defun initialize-atmospheric-screen-research ()
"Initializes the main atmospheric category screen in the VEG research mode."
 (remove.all.values 'atmospheric 'goals)
 (put.value 'atmospheric 'error.message ""))

(defun open-atmospheric-passes-interface ()
"Opens the interface for the atmospheric passes main menu."
 (remove.all.values 'atmospheric.passes 'ap.menu)
 (unitmsg 'viewport-atmospheric.passes.1 'open-panel!))

;;;-------------------------------------------------------------------------
;;; Methods for Atmospheric Correction
;;;-------------------------------------------------------------------------

(defun atm.corr.p ()
"Returns t if the current goal is atmospheric corrections and nil otherwise."
  (eq (get.value 'atmospheric 'goals) 'atmospheric.corrections))

(defun open-atmospheric-corrections-interface ()
"Opens the interface for the atmospheric corrections main menu."
 (remove.all.values 'atmospheric.corrections 'ac.menu)
 (unitmsg 'viewport-atmospheric.corrections.1 'open-panel!))
```

```
;;;-----------------------------------------------------------------------
;;; Methods for Entering Original Ground Data
;;;-----------------------------------------------------------------------

(defun open-enter-ground-data-interface ()
"Opens the interface that allows the user to select between entering original
ground data and selecting historical data."
  (put.value 'atmospheric 'error.message
     "Reinitializing the system")
  (unitmsg 'initialize.system 'initialize.system)
  (put.value 'atmospheric 'error.message "")
  (remove.all.values 'atmospheric.passes 'options)
  (remove.all.values 'estimate.hemispherical.reflectance 'current.sample)
  (remove.all.values 'estimate.hemispherical.reflectance
          'current.sample.wavelengths)
  (unitmsg 'viewport-atmospheric.passes.2 'open-panel!))

(defun enter-original-ground-data ()
"Opens the enter data interface, including the atmospheric height subwindow."
  (enter-original-data)
  (unitmsg 'windowpane-atmospheric.height-of-atmospheric.passes.1 'open!))

;;;-----------------------------------------------------------------------
;;; Methods for Entering Original Platform Data
;;;-----------------------------------------------------------------------

(defun open-enter-platform-data-interface ()
"Opens the interface that allows the user to select between entering original
platform data and selecting historical data."
  (put.value 'atmospheric 'error.message
     "Reinitializing the system")
  (unitmsg 'initialize.system 'initialize.system)
  (put.value 'atmospheric 'error.message "")
  (remove.all.values 'atmospheric.corrections 'options)
  (remove.all.values 'estimate.hemispherical.reflectance 'current.sample)
  (remove.all.values 'estimate.hemispherical.reflectance
          'current.sample.wavelengths)
  (unitmsg 'viewport-atmospheric.corrections.2 'open-panel!))

(defun enter-original-platform-data ()
"Opens the enter data interface, including the platform elevation subwindow."
  (enter-original-data)
  (unitmsg 'windowpane-data.platform.elevation-of-atmospheric.corrections.2
           'open!))
```

```
;;;-----------------------------------------------------------------------
;;; Methods for Selecting Historical Ground Data
;;;-----------------------------------------------------------------------

(defun update-cover-type-window ()
"Update the cover types subwindow of the select historical ground data screen."
  (remove.all.values 'atmospheric.passes 'historical.cover.types)
  (put.facet.value 'atmospheric.passes 'historical.cover.types 'valueclass
     (cons 'one.of (get.value 'historical.cover.types 'current.cover.types)))
  (slot-image-toggle-enable
   (unit
    'windowpane-historical.cover.types-of-atmospheric.passes.2))
  (slot-image-toggle-enable
   (unit
    'windowpane-historical.cover.types-of-atmospheric.passes.2)))

(defun select-historical-ground-data ()
"Opens the select historical ground data screen."
  (remove.all.values 'atmospheric.passes 'directional.data)
  (put.value 'atmospheric.passes 'historical.data.options 'new.sample)
  (put.value 'atmospheric.passes 'error.message
     "Enter the atmospheric height")
  (unitmsg 'viewport-atmospheric.passes.3 `open-panel!))

(defun valid-directional-data (data)
"Returns t if the directional data is valid and nil otherwise."
   (and (consp data)
      (dolist (point data t)
         (unless (and (listp point)
                      (= (length point) 2))
                 (return-from valid-directional-data nil))
         (let ((z (zenith point))
               (a (azimuth-360 point)))
           (unless (and (numberp z)(>= z 0)(<= z 90)
                        (numberp a)(>= a 0)(< a 360))
             (return-from valid-directional-data nil))))))

(defun get-appropriate-cover-type ()
"Returns the name of the cover type unit at the wavelength level that has been
selected. i.e. The descendant of the selected cover type with the selected sun
angle and waveband."
  (let* ((this-sun (get.value 'atmospheric.passes 'sun.angles))
         (this-waves (get.value 'atmospheric.passes 'wavelengths))
         (this-wave-max (second this-waves))
         (this-wave-min (first this-waves)))
    (dolist (sun (unit.children
                    (get.value 'atmospheric.passes 'historical.cover.types)
                    'subclass))
      (when (= (get.value sun 'solar.zenith.angle) this-sun)
         (dolist (wave (unit.children sun 'member))
           (when (and (= (get.value wave 'wavelength.max) this-wave-max)
                      (= (get.value wave 'wavelength.min) this-wave-min))
             (return-from get-appropriate-cover-type wave)))))))
```

```
(defun find-matching-reflectance-values (view-angles)
"Interpolates and extrapolates the cover type data to match the entered
directional view angles and returns a list of points, each having zenith,
azimuth and reflectance values."
 (put.value 'atmospheric.passes 'directional.reflectance
   (match-unaltered-target-data view-angles
                                (get-appropriate-cover-type))))

(defun reset-hct-sample-data ()
"Initializes all the select historical data screen."
  (remove.all.values 'atmospheric.passes 'cover.types)
  (remove.all.values 'atmospheric.passes 'sun.angles)
  (remove.all.values 'atmospheric.passes 'wavelengths)
  (remove.all.values 'atmospheric.passes 'directional.reflectance)
  (remove.all.values 'atmospheric.passes 'atmospheric.height))

(defun reset-hct-wavelength-data ()
"Initializes the wavelength and directional reflectance data in preparation for
 selection of a different wavelength in the select historical data screen."
  (remove.all.values 'atmospheric.passes 'wavelengths)
  (remove.all.values 'atmospheric.passes 'directional.reflectance)
  (put.value '1.enter.data 'successful.save t))

(defun insufficient-data-hct-sample ()
"Displays an error message because the data at the sample level is incomplete
and hence cannot be saved."
 (my-documentation-print
  "DATA NOT SAVED - Insufficient data - minimum data required is solar zenith, wavelength,
directional data and atmospheric height")
  (put.value '1.enter.data 'successful.save nil)
  (put.value '1.enter.data 'sample.flag 'sample))

(defun insufficient-data-hct-wavelength ()
"Displays an error message because the data at the wavelength level is
incomplete and hence cannot be saved."
 (my-documentation-print "DATA NOT SAVED - Insufficient data - minimum data required is
wavelength and directional data")
  (put.value '1.enter.data 'successful.save nil)
  (put.value '1.enter.data 'sample.flag 'wave))

(defun save-hct-sample-data ()
"If sufficient data is present, calls a function to save the data at the sample
level."
  (let ((solar-zenith (get.value 'atmospheric.passes 'sun.angles))
        (wavelength (get.value 'atmospheric.passes 'wavelengths))
        (reflectance-data (get.value 'atmospheric.passes
                                     'directional.reflectance))
          (atmospheric-height (get.value 'atmospheric.passes
                                         'atmospheric.height)))
      (if (and solar-zenith wavelength reflectance-data atmospheric-height)
          (save-hct-sample-data-aux solar-zenith wavelength reflectance-data
                                    atmospheric-height)
          (insufficient-data-hct-sample))))
```

```
(defun save-hct-sample-data-aux (solar-zenith wavelength reflectance-data
                                              atmospheric-height)
"Saves the data at the sample level."
  (let ((new-sample
          (create.unit (gentemp "SAMPLE-UNKNOWN-TARGET")
                  'veg 'target.data nil)))
    (put.value new-sample 'solar.zenith solar-zenith)
    (put.value new-sample 'atmospheric.height atmospheric-height)
    (put.value 'estimate.hemispherical.reflectance 'current.sample
         new-sample)
    (save-hct-wavelength-data-aux wavelength reflectance-data)))

(defun save-hct-wavelength-data ()
"If sufficient data is present, calls a function to save the data at the
wavelength level."
  (let ((wavelengths (get.value 'atmospheric.passes 'wavelengths))
       (reflectance-data (get.value 'atmospheric.passes
                                    'directional.reflectance)))
      (if (and wavelengths reflectance-data)
        (save-hct-wavelength-data-aux wavelengths reflectance-data)
        (insufficient-data-hct-wavelength))))

(defun save-hct-wavelength-data-aux (wavelengths reflectance-data)
"Saves the data at the wavelength level."
  (let* ((parent-sample
           (get.value 'estimate.hemispherical.reflectance 'current.sample))
       (new-wavelength (create.unit (gentemp "W") 'veg nil parent-sample)))
       (put.value new-wavelength 'wavelength
            (/ (+ (first wavelengths)(second wavelengths)) 2))
       (put.value new-wavelength 'reflectance.data reflectance-data)
          (put.value 'atmospheric.passes 'error.message "Data saved")
       (put.value '1.enter.data 'successful.save t)))

;;;---------------------------------------------------------------------------
;;; Methods for Entering Atmospheric Data
;;;---------------------------------------------------------------------------

(defun open-enter-atmospheric-conditions-interface ()
"Opens the interface for entering the atmospheric conditions."
 (initialize-enter-atmospheric-data)
 (put.values 'atmospheric 'wavelengths.left
    (get.values 'estimate.hemispherical.reflectance
          'current.sample.wavelengths))
 (next-wavelength)
 (unitmsg 'viewport-atmospheric.2 'open-panel!))
```

```
(defun initialize-enter-atmospheric-data ()
"Initializes the enter atmospheric conditions interface."
  (remove.all.values 'atmospheric 'standard.atmospheres)
  (remove.all.values 'atmospheric 'aerosol.optical.thickness)
  (remove.all.values 'atmospheric 'size.distribution)
  (remove.all.values 'atmospheric 'phase.function)
  (remove.all.values 'atmospheric 'ozone)
  (remove.all.values 'atmospheric 'precipital.water)
  (remove.all.values 'atmospheric 'single.scattering.albedo)
  (put.value 'atmospheric 'enter.atmospheric.data.options 'enter.data))

(defun save-atmospheric-data ()
"If sufficient data has been entered, calls a function to save the atmospheric
data.  Otherwise displays an error message."
  (let ((current-wavelength
          (get.value 'estimate.hemispherical.reflectance
            'current.wavelength))
        (aero (get.value 'atmospheric 'aerosol.optical.thickness))
        (size-dist (get.value 'atmospheric 'size.distribution))
        (phase-function (get.value 'atmospheric 'phase.function))
        (ozone (get.value 'atmospheric 'ozone))
        (precipital-water (get.value 'atmospheric 'precipital.water))
        (single-scattering-albedo (get.value 'atmospheric
                                    'single.scattering.albedo)))
    (if (and aero size-dist phase-function ozone precipital-water
             single-scattering-albedo)
        (save-atmospheric-data-aux current-wavelength aero size-dist
                                   phase-function ozone
                                   precipital-water single-scattering-albedo)
        (insufficient-atmospheric-data))))

(defun save-atmospheric-data-aux (current-wavelength aero size-dist
    phase-function ozone
    precipital-water single-scattering-albedo)
"Save the atmospheric data in the currently selected wavelength level unit."
   (put.value current-wavelength 'aerosol.optical.thickness aero)
   (put.value current-wavelength 'size.distribution size-dist)
   (put.value current-wavelength 'phase.function phase-function)
   (put.value current-wavelength 'ozone ozone)
   (put.value current-wavelength 'precipital.water precipital-water)
   (put.value current-wavelength 'single.scattering.albedo
        single-scattering-albedo)
  (put.value 'atmospheric 'successful.save t)
  (next-wavelength))
```

```
(defun next-wavelength ()
"Prompts the user to enter atmospheric data at the next wavelength or closes
the screen is all wavelengths have been processed."
 (let ((new-wavelength (get.value 'atmospheric 'wavelengths.left)))
  (cond ((null new-wavelength)
         (quit-enter-atmospheric-conditions-interface))
        (t (remove.value 'atmospheric 'wavelengths.left new-wavelength)
          (put.value 'estimate.hemispherical.reflectance 'current.wavelength
              new-wavelength)
          (put.value 'atmospheric 'error.message (format ()
"For each wavelength, either choose a standard atmosphere and then modify the values as
necessary or enter all new parameters.  Enter the data for wavelength ~S."
          (get.value new-wavelength 'wavelength)))))))

(defun quit-enter-atmospheric-conditions-interface ()
"Closes the enter atmospheric conditions interface."
 (put.value 'atmospheric 'error.message "")
 (unitmsg 'viewport-atmospheric.2 'close-panel!)
 (put.value 'atmospheric 'done.enter.atmospheric.conditions.p t)
 (when (get.value 'estimate.hemispherical.reflectance 'select.all)
  (open-generate-techniques-interface)))

(defun insufficient-atmospheric-data ()
"Displays an error message if insufficient atmospheric data has been entered."
 (my-documentation-print
  "DATA NOT SAVED - Insufficient data - all boxes must be filled before data can be saved")
  (put.value 'atmospheric 'successful.save nil))

(defun set-up-standard-atmosphere (name)
"Sets up the correct arguments and calls a function to assign the correct slot
values for a standard atmosphere. This function is a dummy at present.  It should
be replaced by the correct descriptions of standard atmospheres when they are
available."
 (case name
  (no.gaseous.absorption (set-up-standard-atmosphere-aux 1 2 0.5 300 5 0.8))
  (tropical (set-up-standard-atmosphere-aux 1.2 2 0.6 350 5 0.8))
  (mid.latitude.summer (set-up-standard-atmosphere-aux 1.3 2 0.6 350 5 0.8))
  (mid.latitude.winter (set-up-standard-atmosphere-aux 1.4 2 0.6 360 5 0.8))
  (sub.arctic.summer (set-up-standard-atmosphere-aux 1.5 2 0.6 370 5 0.8))
  (sub.arctic.winter (set-up-standard-atmosphere-aux 1.6 2 0.6 380 5 0.8))
  (us.standard.62 (set-up-standard-atmosphere-aux 1.7 2 0.6 390 5 0.8))
  (no.aerosols (set-up-standard-atmosphere-aux 1.8 2 0.6 400 5 0.8))
  (continental.model (set-up-standard-atmosphere-aux 1.9 2 0.6 250 5 0.8))
  (maritime.model (set-up-standard-atmosphere-aux 2 2 0.6 260 5 0.8))
  (urban.model (set-up-standard-atmosphere-aux 2.1 2 0.6 270 5 0.8))))
```

```
(defun set-up-standard-atmosphere-aux (aero size-dist phase-function ozone
                                       precipital-water
                                       single-scattering-albedo)
"Assigns the appropriate slot values for a standard atmosphere."
  (put.value 'atmospheric 'aerosol.optical.thickness aero)
  (put.value 'atmospheric 'size.distribution size-dist)
  (put.value 'atmospheric 'phase.function phase-function)
  (put.value 'atmospheric 'ozone ozone)
  (put.value 'atmospheric 'precipital.water precipital-water)
  (put.value 'atmospheric 'single.scattering.albedo single-scattering-albedo))

;;;-------------------------------------------------------------------------
;;; Methods for Generating Atmospheric Passes Techniques
;;;-------------------------------------------------------------------------

(defun user-pick-atm-pass-techniques ()
"Opens the interface that selects each wavelength in turn to allow the user to
select atmospheric passes techniques."
  (unitmsg 'viewport-6.generate.techniques.3 'open-panel!)
  (dolist (thisunit (get.values 'estimate.hemispherical.reflectance
                                'current.sample.wavelengths)
            (all-generate-techniques-finished-message))
    (put.value 'estimate.hemispherical.reflectance 'current.wavelength
          thisunit)
    (user-pick-atm-pass-techniques-aux)
    (remove.all.values '6.generate.techniques 'push.button)
    (wait-for-mouse-gt)))

(defun user-pick-atm-pass-techniques-aux ()
"Opens the interface to allow the user to select atmospheric passes
techniques."
  (reset-initial-values-pick-atm-pass-techniques)
  (unitmsg 'viewport-atmospheric.passes.4 'open-panel!))

(defun reset-initial-values-pick-atm-pass-techniques ()
"Initializes the user pick atmospheric passes techniques screen."
  (remove.all.values 'atmospheric.passes 'selected.techniques)
  (put.value '6.generate.techniques 'error.message "")
  (put.value '6.generate.techniques 'description.of.technique "")
  (put.value 'atmospheric.passes 'action.on.selecting.techniques
     'select.techniques))

(defun pick-selected-values-atm-pass ()
"Stores the selected atmospheric passes techniques in the correct wavelength
level unit and displays a list of the selected techniques."
  (let ((techs (get.values 'atmospheric.passes 'selected.techniques))
        (current-wave (get.value 'estimate.hemispherical.reflectance
                                 'current.wavelength)))
    (unless (null current-wave)
      (put.values current-wave 'techniques techs))
    (tech-message (format ()
          "Techniques selected for the sample at wavelength ~S are:-~{ ~S~}"
                          (wav current-wave) (get-unit-names techs)))))
```

```
;;;-----------------------------------------------------------------------
;;; Methods for Generating Atmospheric Corrections Techniques
;;;-----------------------------------------------------------------------

(defun user-pick-atm-corr-techniques ()
"Opens the interface that selects each wavelength in turn to allow the user to
select atmospheric corrections techniques."
  (unitmsg 'viewport-6.generate.techniques.3 'open-panel!)
  (dolist (thisunit (get.values 'estimate.hemispherical.reflectance
                                'current.sample.wavelengths)
            (all-generate-techniques-finished-message))
    (put.value 'estimate.hemispherical.reflectance 'current.wavelength
          thisunit)
    (user-pick-atm-corr-techniques-aux)
    (remove.all.values '6.generate.techniques 'push.button)
    (wait-for-mouse-gt)))

(defun user-pick-atm-corr-techniques-aux ()
"Opens the interface to allow the user to select atmospheric corrections
techniques."
  (reset-initial-values-pick-atm-corr-techniques)
  (unitmsg 'viewport-atmospheric.corrections.3 'open-panel!))

(defun reset-initial-values-pick-atm-corr-techniques ()
"Initializes the user pick atmospheric corrections techniques screen."
  (remove.all.values 'atmospheric.corrections 'selected.techniques)
  (put.value '6.generate.techniques 'error.message "")
  (put.value '6.generate.techniques 'description.of.technique "")
  (put.value 'atmospheric.corrections 'action.on.selecting.techniques
     'select.techniques))

(defun pick-selected-values-atm-corr ()
"Stores the selected atmospheric corrections techniques in the correct
wavelength level unit and displays a list of the selected techniques."
  (let ((techs (get.values 'atmospheric.corrections 'selected.techniques))
        (current-wave (get.value 'estimate.hemispherical.reflectance
                                 'current.wavelength)))
    (unless (null current-wave)
      (put.values current-wave 'techniques techs))
    (tech-message (format ()
          "Techniques selected for the sample at wavelength ~S are:-~{ ~S~}"
                          (wav current-wave) (get-unit-names techs)))))
;;;-----------------------------------------------------------------------
;;; Select all options for atmospheric techniques
;;;-----------------------------------------------------------------------

(defun select-all-atm-options ()
   (determine-atm-starting-point-and-start)
   (put.value 'estimate.hemispherical.reflectance 'select.all t))
```

```
(defun determine-atm-starting-point-and-start ()
  (cond ((not (get.value 'estimate.hemispherical.reflectance
                  'done.enter.data.p))
         (if (atm.pass.p)
           (open-enter-ground-data-interface)
           (open-enter-platform-data-interface)))
        ((not (get.value 'estimate.hemispherical.reflectance
                  'done.characterize.input.p))
         (open-characterize-input-interface))
        ((not (get.value 'estimate.hemispherical.reflectance
                  'done.characterize.target.p))
         (open-characterize-target-interface))
          ((not (get.value 'atmospheric 'done.enter.atmospheric.conditions.p))
           (open-enter-atmospheric-conditions-interface))
        ((not (get.value 'estimate.hemispherical.reflectance
                  'done.generate.techniques.p))
         (open-generate-techniques-interface))
        ((not (get.value 'estimate.hemispherical.reflectance
                  'done.rank.techniques.p))
         (open-rank-techniques-interface))
        ((not (get.value 'estimate.hemispherical.reflectance
                  'done.execute.techniques.p))
         (open-execute-techniques-interface))
        (t (open-output-results-interface))))
```

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16. Abstract

The NASA VEGetation Workbench (VEG) is a knowledge based system that infers vegetation characteristics from reflectance data. The VEG Subgoals have been reorganized into categories. A new subgoal category "Atmospheric Techniques" containing two new subgoals has been implemented. The subgoal Atmospheric Passes allows the scientist to take reflectance data measured at ground level and predict what the reflectance values would be if the data were measured at a different atmospheric height. The subgoal Atmospheric Corrections allows atmospheric corrections to be made to data collected from an aircraft or by a satellite to determine what the equivalent reflectance values would be if the data were measured at ground level. The report describes the implementation and testing of the basic framework and interface for the Atmospheric Techniques Subgoals.

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