INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

SMR.780 - 40

FOURTH AUTUMN COURSE ON MATHEMATICAL ECOLOGY

(24 October - 11 November 1994)

"Remote Sensing and G.I.S. Techniques in Ecology: A Practical Overview"

Agustin Lobo
Instituto de Ciencias de la Terra
Marti Franques S/N
08028 Barcelona
Spain

These are preliminary lecture notes, intended only for distribution to participants.

MAIN BUILDING STRADA COSTIERA, 11 TEL. 22401 TELEFAX 224163 TELEX 460392 ADRIATICO GUEST HOUSE VIA GRIGNANO, 9 TEL. 224241 TELEFAX 224531 TELEX 460449
MICROPROCESSOR LAB. VIA BEIRUT, 31 TEL. 224471 TELEFAX 224600 TELEX 460392 GALILEO GUEST HOUSE ...

REMOTE SENSING AND G.I.S. TECHNIQUES IN ECOLOGY: A PRACTICAL OVERVIEW

Appendices

From grass-lists-owner@max.cecer.army.mil Thu Jun 10 13:32:45 1993
Date: Thu, 10 Jun 93 11:23:30 MDT
From: Craig Anderson <caa@noaacrd.Colorado.EDU>
Subject: grass4.1 list of commands
Sender: lists-owner@max.cecer.army.mil
Reply-To: grassu-list@max.cecer.army.mil
To: grassu-list@max.cecer.army.mil
Content-Length: 24313

Looking through the documentation, I could not find the following so I created it.

Perhaps the following file may be of help to those of you comparing grass version X.X with 4.1. This list only includes src and src.alpha commands, a src.contrib list is forthcoming. The list was compiled from the Grass 4.1 User's Reference Manual by using the short descriptions provided on each particular command.

There are typos without a doubt.

C. Anderson
caa@noaacrd.colorado.edu

GRASS4.1 COMMANDS

GRASS DISPLAY PROGRAMS

d.3d	Displays three-dimensional images based on raster map layers.
d.ask	Prompts the user to select a GRASS data base file from among. files displayed in a menu on the graphics monitor.
d.colormode	Allows the user to establish wether a map qill be displayed using : own color table or the fixed color table of the graphics mo
d.colors	Allows the user to interactively change the color table of a raste map layer displayed on the graphics monitor.
d.colortable	To display the color table associated with a raster map layer.
d.display	A menu-driven, highly interactive progtram for vidwing final maps a and producing final map products.
d.erase	Erases the contents of the activd dispaly frame on the user's graphics monitor.
d.font	Selects the font in which text will be displayed on the user's graphics monitor.
d.frame	Manages display frames on the user's graphics noitor.
d.geodesic	Displays a geodesic line, tracing the shortest distance between two geographic points along a great circle. (lat/long data
d.graph	Program for generating and displaying simple graphics to the graphics monitor.
d.grid	Overlays a user-specified grid in the active display frame on the graphics monitor.
d.his	Produces and displays a raster map layer combining hue, intensity and saturation (HIS) values from user-specified input laye
d.histogram	Displays a histogram in the form of a pie or bar chart for a user-specified raster file.
d.icons	Displays points, as icons at user-defined locations in the active display frame on the graphics monitor.
d.label	Creates and displays text labels in the active display frame on the graphics monitor.
d.labels	To create/edit GRASS paint label files for display on the graphics monitor.
d.legend	Displays a legend for a raster map layer in the active frame on the graphics monitor.
d.mapgraph	Generates and displays simple graphics on map layers drawen in the active graphics monitor display frame.
d.measure	Measures the lengths and areas of features drawen by the user in t active display frame on the graphics monitor
d.menu	Creates and displays a menu within the active frame on the graphics monitor.
d.mon	To establish and control use of a graphics display monitor.

d.paint.labels Displays text labels formatted for use with GRASS paint 'p.labels, p.map' output to the active frame on the graph: monitor.

d.points Displays point graphics in the active frame on the graphics displa monitor.

d.profile Displays profiles of a user-specified raster map layer.

d.rast Displays and overlays raster map layers in the active display frar the graphics monitor.

d.rast.arrow Draws arrows representing cell aspect direction for a raster map layer.

d.rast.edit Program allowing users to interactively edit the cell category va: of raster map layers displayed on the graphics monitor.

d.rast.num Overlays cell category values on a raster map layer displayed to t graphics monitor.

d.rast.zoom To interactively zoom in or out of regions on a raster map display the active frame on the graphics monitor.

d.rgb Displays three user-specified raster map layers a red, green and b overlays in the active graphics frame.

d.rhumbline Displays the rhumbline joining two user-specified points, in the a frame on the user's graphics monitor.

d.save Creates a list of commands for recreating screen graphics.

d.scale Overlays a bar scale and north arror for the current geographic region at a user-defined location in the active display frame.

d.sites Displays site markders int he active display frame on the graphics monitor.

d.text Draws text in the active display frame on the graphics monitor.

d.title Outputs a title for a raster map layer in a form suitable for disp display by d.text.

d.vect Displays GRASS vector data in the active frame on the graphics mor

d.what.rast Allows the user to interactively query the category contents of mu iple raster map layers at user-specified locations within the current geographic region.

d.what.vect Allows the user to interactively query the category contents of a (binary) vector map layer at user-selected locations withi the current geographic region.

d.where Identifies the geographic coordinates associated with point locati in the active frame on the graphics monitor.

d.zoom Allows the user to change the current geographic region settings interactively, with a mouse.

exit Exits the user from the current GRASS session.

GRASS FILE MANAGEMENT PROGRAMS

g.access Controls user access to the current GRASS mapset.

g.ask Prompts the user for the names of GRASS data base files.

g.copy Copies available datat files in the user's current mapset search path and location to the appropriate element directories under the user's current mapset.

g.filename Prints GRASS data base file names.

g.findfile Searches for GRASS data base files and sets variables for the shel

g.gisenv Outputs the user's current GRASS variable settings.

g.help GRASS help facility.

g.list Lists available GRASS data base files of the user-specified data type to standard output.

g.manual Accesses GRASS User's Reference Manual entries.

g.mapsets Modifies the user's current mapset search path, affecting the user access to data existing under the other GRASS mapsets in t. current location.

g.region Program to manage the boundary definitons for the geographic regic

g.remove Removes data base element files from the user's current mapset.

g.rename To rename data base element files int he user's current mapset.

g.setproj Allows the user to create the PROJ_INFO and the PROJ_UNITS files t record the projeciton informaiton associated with a curren location.

g.tempfile Creates a temporary file and prints the file name.
g.version Outputs the GRASS version number and date.

GRASS IMAGE PROCESSING PROGRAMS

i.cca Canonical components analysis (cca) program for image processing.
i.class An imagery function that generates spectral signatures for an imag allowing the user to outline reigons of interest. The resulting signature file can be used as input for i.maxlik as a seeed signature for i.cluster.
i.cluster An imagery funciton that generates spectral signatures for land co types in an image using a cluster algorithm. The resultin signature fiel is used as input for i.maxlik to generate an unsupervised image classification.
i.colors An imagery funciton that creates colors for imagery groups.
i.composite An imagery funciton that creates a color composite image from three imagery band files specified by the user.
i.fft Fast Fourier Transform (fft) for image processing.
i.gensig Generats statistics for i.maxlik from raster map layer.
i.gensigset Generates statistics for i.smap from raster map layer.
i.gray.scale An interactive imagery function taht assigns a histogram contrast stretch grey scale color table to a raster map layer.
i.group An imagery function that creates and edits groups and subgroups of (raster) imagery files.
i.his.rgb Hue-intensity-saturation (HIS) to red-green-blue (RGB) raster map color transformation function.

i.ifft Inverse Fast Fourier Transform (IFFT) for image processing.
i.in.erdas Creates raster files from ERDAS files.
i.maxlik An imagery function that classifies the cell spectral reflectances imagery data base on the spectral signature information ge by either i.cluster, i.class, or fIi.gensig.
i.ortho.photo An interactive imagery function for the ortho-rectifiction of imag group files.
i.pca Principal components analysis (PCA) program for image processing.
i.points An imagery function that enables the user to mark coordinate syster points on an image to be rectified and then input the coor of each point for creation of a coordinate transformation matrix. The transformation matrix is needed as input for GRASS program i.rectify.
i.quantize An interactive imagery function that creates a raster map layer wh color table is based on red, gree, and blue color values p in existing user-specified imagery group files.
i.rectify An imagery function that rectifies an image by computing a coordin transformation for each cell (pixel) in the image using th transformatino coefficient matris created by the GRASS program i.points.
i.rectify2 An imagery routine that rectifies an image by computing a coordinat transformaiton for each pixel in the image based on the con points created by the GRASS programs i.points or i.vpoints.
i.rgb.his An imagery function for Red-green-blue (RGB) to hue-intensity-satu HIS).
i.smap An imagery function thaty performs contextual image classification using sequential maximum a posteriori (SMAP) estimation.
i.tape.mss An imagery function that extracts Multispectral Scanner (MSS) imag from half inch tape.
i.tape.mss.h An imagery function that extracts header information from Multispe Scanner (MSS) imagery data from half inch tape.
i.tape.other An imagery funciton that extracts scanned aerial imagery (NHAP) an satellite imagery (TM, SPOT, etc) from half-inch or 8mm ta
i.tape.spot An imagery function that extracts SPOT imagery from half-inch tape
i.tape.tm An imagery funciton that extracts LANDASAT Thematic Mapper (TM) im from half-inch tape.
i.tape.tm.fast An imagery function that extracts TM imagery from tape media.
i.target An interactive imagery function that establishes a GRASS target

location and mapset for an imagery group.

i.vpoints	Identifies coordinate pairs of points from a vector map or keyboar and corresponding points in an image.
i.zc	An image processing function for raster edge detection "Zero Cross

GRASS DATA IMPORT/PROCESSING PROGRAMS

m.datum.shift	Datum shift program.
m.dem.examine	Provides a terse description of USGS Digital Elevaion Model (DEM) files stored on half-inch tape.
m.dem.extract	Extracts USGS DEM data from half-inch tape.
m.dmaUSGSread	Extracts digital terrain elevation data (DTED) produced by Defense Mapping Agency (DMA) but supplied by the USGS (in a differ- format) on half-inch tape.
m.dted.examine	Provides a terse description of level 1 and 2 DTED files produced a distributed by DMA on half-inch tape.
m.dted.extract	Extracts DTED levels 1 and 2 supplied by DMA on half-inch tape.
m.examine.tape	Provides a description of the files on a half-inch tape.
m.flip	Flips elevation data extracted from systems that retrieve data by rows from south to north.
m.gc2ll	Converts geocentric to geographic coordinates.
m.in.pl94.db3	Imports Demographic records from Census PL94-171 dBase3 (CDROM) fi
m.in.stf1.db3	Imports Demographic records from Census STF1A dBase3 (CDROM) files
m.in.stf1.tape	Filter to extract lines from text file based on column contents, especially for Bureau of the Census STF1 files.
m.ll2gc	Converts geographic coordinates to geocentric coordinates.
m.ll2u	Converts geographic coordinates to UTM coordinates.
m.lulc.USGS	Creates raster map layers from a Composite Theme Grid (CTG) file c: by m.lulc.read which estracts the CTG data from an ASCII l· landcover (LULC) CTG format file supplied by the USGS.
m.lulc.read	Extracts landuse/landcover data in ASCII CTG data format distribut· the USGS in to a working file for m.lulc.USGS.
m.proj	Calculates conversion coordinates for geographic positions.
m.region.ll	Converts UTM coordinates falling within the current geographic reg. to geographic (lat/long) coordinates.
m.rot90	Rotates elevation data extracted by either m.dted.extract or m.dmaUSGSread.
m.tiger.region	Finds geographic regioninformation for U.S. Census Bureau Tiger in: data.
m.u2ll	Converts UTM coordinates to geographic (lat/long) coordinates.

GRASS HARDCOPY OUTPUT PROGRAMS

p.chart	Prints the color chart of the currently selected printer.
p.colors	Allows the suer to develop a color table that associates map categ· with user-specified printer colors.
p.icons	Creates and modifies icons for map display and output.
p.labels	Creates labels for hardcopy maps.
p.map	Hardcopy color map output utility.
p.map.new	Color map output utility.
p.ppm	Reads portable pixmap (PPM) files created by PPM utilities.
p.select	Selects a device (printer) for GRASS hardcopy output.
parser	A set of GRASS routines that standardizes GRASS commands.
photo.2image	Not a command but an option of the i.ortho.photo command.
photo.2target	Not a command but an option of the i.ortho.photo command.
photo.camera	Not a command but an option of the i.ortho.photo command.
photo.init	Not a command but an option of the i.ortho.photo command.
photo.rectify	Not a command but an option of the i.ortho.photo command.
ps.icon	Creates and modifies icons for use with ps.map.
ps.map	Hardcopy PostScript map output utility.
ps.select	Selects a PostScript device for GRASS hardcopy ouptut.

GRASS RASTER PROGRAMS

r.average	Finds the average of values in a cover map within areas assigned the same category value in a user-specified base map.
r.basins.fill	Generates a raster map layer showing watershed sub-basins.
r.binfer	Bayesian expert system development program.
r.buffer	Creates a raster map layer showing buffer zones surrounding cells contain non-zero category values.
r.cats	Prints category values and labels associated with user-specified map layers.
r.clump	Recategorizes data in a raster map layer by grouping cells that f physically discrete areas into unique categories.
r.coin	Tabulates the mutual occurrence (coincidence) of categories for t raster map layers.
r.colors	Creates/Modifies the color table associated with a raster map laye
r.combine	Allows category values from several raster map layers to be combin
r.compress	Compresses and decompresses raster files.
r.contour	Produces a GRASS binary vector map of specified contours from GRA raster map layer.
r.cost	Outputs a raster map layer showing the cumulative cost of moving different geographic locations on an input raster map lay whose cell category values represent cost.
r.covar	Outputs a covariance/correlation matrix for user-specified raster layer(s).
r.cross	Creates a cross product of the category values from multiple rast map layers.
r.describe	Prints terse list of category values found in a raster map layer.
r.digit	Interactive tool used to draw and save vector features on a graph monitor using pointing device.
r.drain	Traces a flow through an elevation model on a raster map layer.
r.grow	Generates an output raster map layer with contiguous areas grown one cell (pixel).
r.in.ascii	Convert an ASCII raster text file into a (Binary) raster map laye
r.in.ll	Converts raster data referenced using latitude and longitude coor to a UTM-referenced map layer in GRASS raster format.
r.in.poly	Creates raster maps from ASCII polygon/line data file.
r.in.sunrast	Converts a SUN raster file to a GRASS raster file.
r.infer	Outputs a raster map layer whose category values represent the app of user-specified criteria (rules statements) to other ras map layers' category values.
r.info	Outputs basic information about a user-specified raster map layer.
r.line	Creates a new binary GRASS vector (v.digit) file by extracting lin features from a thinned raster file.
r.los	Line-of-sight raster analysis program.
r.mapcalc	Raster map layer data calculator.
r.mask	Establishes or removes the current working mask.
r.mask.points	Examines and filters listsa of points constituting lines to determ if they fall within current region and mask and optionally additional raster map.
r.median	Finds the median of values in a cover map within areas assigned th same category value in a user-specified base map.
r.mfilter	Raster file matrix filter.
r.mode	Finds the mode of values in a cover map within areas assigned the category value in a user-specified base map.
r.neighbors	Makes each cell category value a function of the category values a to the cells around it, and stores anew cell values in an raster map layer.
r.out.ascii	Converts a raster map layer into an ASCII text file.
r.patch	Creates a composite raster map layer by using known category value from one (or more) map layer(s) to fill in areas of "no da in another map layer.
r.poly	Extracts area edges from a raster map layer and converts data to G vector format.
r.profile	Outputs the raster map layer values lying on user-defined line(s).
r.random	Creates a raster map layer and site list file containing randomly located sites.

r.reclass	Creates a new map layer whose category values are based upon the user's reclassification of categories in an existing raste map layer.
r.report	Reports statistics for raster map layers.
r.resample	GRASS raster map layer data resampling capability.
r.rescale	Rescales the range of category values in a raster map layer.
r.slope.aspect	Generates raster map layers of slope and aspect from a raster map of true elevation values.
r.stats	Generates area statistics for raster map layers.
r.support	Allows the user to create and/or modify raster map layer support f.
r.surf.contour	Surface generation program.
r.surf.idw	Surface interpolation utility for raster map layers.
r.surf.idw2	Surface generation program.
r.thin	Thins non-zero cells that denote linear features in a raster map l:
r.traj.data	Reviews the ammunition and weapon data base used by r.traj.
r.transect	Outputs raster map layer values lying along user defined transect line(s).
r.volume	Calculates the volume of data "clumps", and (optionally) produces GRASS site_lists file containing the calculated centroids of these clumps.
r.water.outlet	Watershed basin creation program.
r.watershed	Watershed basin analysis program.
r.watershed4.0	Watershed basin analysis program.
r.weight	Raster map overlay program.
r.weight2	Weighted overlay raster map layer analysis program.
r.what	Queries raster map layers on their category values and category la:
s.in.ascii	Converts an ASCII listing of site locations and their descriptions into a GRASS site list file.
s.menu	Accesses and manipulates GRASS site location data.
s.out.ascii	Converts a GRASS site list file into an ASCII listing of site locations and their descriptions.
s.surf.idw	Surface generation from sites data program.
s.surf.tps	Interpolates and computes topographic analysis from given site dat GRASS raster format using spline with tension.

GRASS VECTOR PROGRAMS/VECTOR DATA IMPORT PROGRAMS

v.alabel	Bulk-labels unlabeled area features in a binary GRASS vector file.
v.apply.census	Calculate/Import Demographics from Census STF1 Files.
v.area	Display GRASS area and perimeter information for GRASS vector map.
v.cadlabel	Attaches labels to (binary) vector contour lines that have been imported to GRASS from DXF format.
v.clean	Cleans out dead lins in GRASS vector files.
v.cutter	Polygon Cookie Cutter (Boolean AND Overlay)
v.digit	A menu-driven, highly interactive map development program used for vector digitizing, editing, labeling and converting vector data to raster format.
v.digit2	A menu-driven, highly interactive map development program used for vector digitizing, editing, labeling and converting vector data to raster format.
v.import	Converts ASCII Digital Line Graph (DLG) files, binary DLG files, ar ASCII vector files into binary vector files and creates the lneeded vector support files.
v.in.arc	Converts data in ARC/INFO format to GRASS's vector format and stor output in the user's current GRASS mapset.
v.in.ascii	Converts ASCII vector map layers into binary vector map layers.
v.in.dlg2	Converts an ASCII or binary USGS DLG-3 (bldg) file to a binary GRA vector (dig) file.
v.in.dxf	Converts files in DXF format to ASCII or binary GRASS vector file format.
v.in.tig.basic	Creates GRASS vector map from TIGER files.
v.in.tig.lndmk	Creates GRASS vector map from TIGER files.
v.in.tig.rim	Imports Census Bureau line data (TIGER files) to GRASS vector form
v.in.transects	Imports transect data to a GRASS vector map.
v.mkgrid	Creates a (binary) GRASS vector map of user-defined grid.

v.mkquads	Creates a GRASS vector map layer and/or sites list and/or grograph region definition file for a USGS 7.5 minute quadrangle.
v.out.arc	Converts GRASS vector files to ARC/INFO's "Generate" file format.
v.out.ascii	Converts a binary GRASS vector map layer into an ASCII GRASS vect layer.
v.out.dlg	Convers binary GRASS vector data to DLG-3 optional vector data for
v.out.dxf	Grass vector format to DXF format conversion program.
v.out.moss	Converts GRASS site, line or area data into MOSS import format.
v.patch	Creates a new binary vector map layer by combining other binary vector map layers.
v.proj	Allows projectin conversion of vector files.
v.prune	Prunes points from binary GRASS vector data files.
v.reclass	Creates a new map layer whose category values are based upon the u reclassification of categories in an existing vector map l
v.spag	Process spaghetti-digitized binary vector file.
v.stats	Prints information about a binary GRASS vector map layer.
v.support	Creates GRASS support files for (binary) GRASS vector data.
v.to.rast	Converts a binary grass vector map layer into a GRASS raster map l
v.to.sites	Converts point data in a binary GRASS vector map layer into a GRAS site_lists file.
v.transform	Transforms an ASCII vector map layer from one coordinate system in another coordinate system.
v.trim	Trims small spurs, and removes excessive nodes from a binary GRASS vector (dig) file.

UNIX SHELL SCRIPT PROGRAMS

3d.view.sh	Displays 3-d images based on raster map layers.
blend.sh	Combines the red, green and blue color components of two raster ma
bug.report.sh	A mechanism for writing, storing and e-mailing to USACERL users' b reports on GRASS 4.0 commands.
dcorrelate.sh	Graphically displays the correlation raster map layers in the acti on the graphics monitor.
grass.logo.sh	Displays a GRASS/Army Corps of Engineers logo in the active displa on the graphics monitor.
hsv.rgb.sh	Converts HSV (huyse, saturation and value) cell values to RGB (red green and blue)
old.cmd.sh	Provices the new GRASS version 4.0 program name for any program na GRASS version 3.2.
rgb.hsv.sh	Converts RGB cell values to HSV.
shade.rel.sh	Creates a shaded relief map based on current resolution settings a altitude and aximuth values entered by the user.
show.color.sh	Displays and names available primary colors usdd by GRASS programs frames on the graphics monitor.
show.fonts.sh	Displays and names available font types in the active display fram the graphics monitor.
slide.show.sh	Displays a series of raster map layers existing in the user's curr mapset search path on the graphics monitor.
split.sh	Divides the graphics monitor into two frames and then displays two in these frames.
start.man.sh	Creates the template for a manual entry in standard User's Referen Manual format for a user-specified GRASS 4.0 command.
tig.rim.sh	Generates various vector maps from a rim/TIGER data base.
tiger.info.sh	Provides tract number(s) and classification codes found within a g U.S. Census Bureau Tiger typel data file.

CONTRIBUTED PROGRAMS

IMAGE PROCESSING IN THE GRASS GIS

Hinthorne, J., Satnik, D. (1), Vali, A., and Kleeman, T. (2)

(1) GIS Lab, Central Washington Univ., Ellensburg, WA 98926.
(2) RIA Inc., 317 RR 620 South, Suite 302, Austin, TX 78734.

ABSTRACT

The UNIX-based public domain raster GIS named GRASS has some excellent user friendly programs for the import and export of data, and several kinds of image processing for band files and/or maps including: spatial filtering; arithmetic combination (band ratios, etc.); Fast Fourier transformation, band space transformations (principle components, canonical components, etc.); classification (supervised and unsupervised); and rectification or georeferencing. All raster processing programs can be applied to all raster images and maps in GRASS data bases; all use the low level GRASS library to insure portability and future compatibility; and all are executed by commands using standard GRASS and UNIX syntax.

image processing, GRASS, geographic information systems, GIS

GENERAL DESCRIPTION OF GRASS

Since 1983 the UNIX-based GRASS (Geographic Resources Analysis Support System) geographic information system, developed and maintained by the Construction Engineering Research Laboratory (CERL) of the U. S. Army, has evolved into a very powerful, public domain, raster based GIS with a full range of single-layer and multi-layer map analysis tools. It also contains a number of import/export and map drawing functions which accommodate vector and point data types, as well as raster type. Recently, several programs have been added to integrate the GRASS user's environment with a relational data base management system for point and vector data types.

IMAGE PROCESSING

Some image processing functions have been available to GRASS users since the development of version 1 in 1984, however these were contained in an external "GRASS-IMAGERY" software module for data from satellite and photographic sources only; data layers developed in the main "GRASS-GRID" module could not be processed with the image enhancement and classification routines. Today, in versions 3 and 4, all raster analysis functions, including those traditionally viewed as "image processing," are contained in a single comprehensive set of software tools which use the same low-level library functions for file access and graphics display and are executed by commands with consistent user interfaces.

GRASS image processing functions can be grouped into seven categories: import / export, spatial domain transformations, frequency domain transformations, band/color space transformations, classification and rectification. All functions can be used on any raster image or map in any logical order, e.g., classification can be used either before or after rectification. In addition, any non-"image processing" analysis function can be used on image bands when appropriate. Individual cell values may be up to 4 byte integers in most current workstation imple- mentations of GRASS, and disk storage is automatically reduced by a run length encoding algorithm.

Program names are marked by italics and programs marked with the † symbol have been recently added to GRASS by us

IMPORT / EXPORT

GRASS has routines to automatically read Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) data. TM distribution tapes may be in either band sequential or band interleaved formats. SPOT Imagery, NHAP (National High Altitude Photography) and other "raw raster" data formats are all imported from tape or CD-ROM by a routine which queries the user for necessary information such as tape block size and the number of bytes per cell. UNIX utility programs are used to accomplish functions such as byte swapping and removal of unnecessary end of line characters. Raster images can also be input from text files (ASCII) where each row of an image is a string of space separated numbers with new-line characters marking the end of each row. Vector data in a number of standard formats can be imported into GRASS and converted raster maps.

Because the data compression routine in GRASS can be processor dependent, for export the *decompress* function is normally run to produce a binary file of the size rows*cols*bpc bytes (where bpc is the number of bytes per cell required by the largest cell value in the image). The resulting file can then be exported via tape, modem, etc., using UNIX tools to transfer the data to another GRASS site or other image processing/GIS system. Supporting information such as color tables, descriptions of cell values, histograms and geographic location data are stored in GRASS as text files and may be transferred directly to other sites or printed. GRASS also has routines to convert rast 'mages to vector maps and these can be exported in a variety of formats, e.g., DLG-3, ARC/INFO, AUTOCAD-DFX.

SPATIAL DOMAIN TRANSFORMATIONS

Normal image filtering for smoothing, feature enhancement, etc., can be accomplished by several functions in GRASS. *Gmfilter* performs the standard function of convolving an odd sized square matrix of user-defined factors to an image or cell map, summing the products and dividing by a user-defined value to calculate a new value for each cell in an output image. A choice between sequential or parallel processing of cells is given. The *neighbors* program also works on the basis of a matrix-like neighborhood around each cell, but offers a choice of several filter algorithms, some of which cannot be accomplished with *Gmfilter*, e.g., mode, interspersion, maximum, minimum, or diversity.

General purpose arithmetic computations can be done on all GRASS raster maps and images with *Gmapcalc*. This function provides a combination of arithmetic (addition, sub-traction, multiplication, division and modulus) operators, logical (and, or, not, and if-then-else) operators and transcendental functions (trigonometric, exponential and logarithmic). Operands for the calculations can be constants (integer or floating point), cell values from the image or map, or logical constants (true is 1 and false is 0). Up to 15 maps and/or images can be used in a single *Gmapcalc* expression to produce a new image or map. Each cell, row by row, is calculated in turn. Two examples will indicate the power of *Gmapcalc*.

To compute a new image which is the average of three band file images:

Gmapcalc aver.123=(band1+band2+band3)/3

Or, to produce an elevation model in feet from one in meters:

Gmapcalc elev.ft=elev.meters * 39.4 / 12.0

Recent additions to *Gmapcalc* provide for the optional specification of a cell on each input map relative to the current one being computed (offset by a number of rows and/or columns) to be used as an operand. This makes it possible to calculate slope and aspect maps from digital elevation models or perform the image filtering like *Gmfilter* with greater flexibility (exponential or logarithmic scaling for example). Very complex modeling calcu-lations can be implemented using *Gmapcalc*.

Gmapcalc is commonly used to calculate band ratios to enhance some features of interest in an image. And can be used to perform many other types of image enhancement.

FREQUENCY DOMAIN TRANSFORMATIONS

Many image defects such as bad or missing scan lines or periodic noise are difficult to remove with filters in the spatial domain, but are dealt with more easily in the frequency domain.

A Fast Fourier Transform (FFT) program, *Gfft*† and its inverse *Gifft*†, have recently been added to GRASS by us. The precision required to perform the inverse FFT is maintained by saving double precision floating point copies of the real and imaginary components of the FFT as well as creating scaled integer real and imaginary component images for viewing, masking, etc., by the user. Rectangular images can be processed by *Gfft* and *Gifft*; they are zero-filled in each direction to create a rectangle whose sides are an even power of two. The transformation is computationally intensive, but our implementation uses an algorithm of order $N \log_2 N$ originally devised by N. Brenner of Lincoln Laboratories.

Using the FFT routines, a zero-crossing edge detection filter has been implemented, *Gzc*†, based on the Laplacian of the gaussian function. The user can control the width and threshold of the gaussian filter as well as the number of directional (azimuthal) categories in the product image.

High and low pass frequency filters can be performed on an image band by using *Gfft* to transform the image into the frequency domain, then using the standard GIS masking function to mask out the high or low frequency components and finally using *Gifft* to transform the masked frequency domain image back into the spatial domain.

BAND/COLOR SPACE TRANSFORMATIONS

The following band and color space transformations have been recently added to GRASS by us. The first two band space transforms, *Gpca*† and *Gcca*†, depend on statistical information taken from the image to determine the parameters of the transformation. The third transformation, *Grgb.to.his*†, treats the image bands as color components and performs a color space transformation.

The program *Gpca* has been developed to compute N (where 2 ≤ N ≤ 8) principle component image bands from N input image bands. Principal components analysis uses a linear combination of the bands to transform a set of correlated bands into a set of uncorrelated bands. This process condenses the information content of the multiple input image bands in the first few output image bands, typically leaving noise-like data in the last few output bands.

The *Gcca* program performs a canonical components transformation on N (where 2 ≤ N ≤ 8) input image bands and a set of training regions to compute N output image bands. Canonical components analysis uses a linear combination of the input image bands that maximize the separability of the training regions to generate the set of output image bands.

The *Grgb.to.his* program (and its inverse *Ghis.to.rgb*†) perform color space transformations on the image bands. Each of these programs take three input image bands and generate three output image bands. *Grgb.to.his* treats the three input bands as the red, green and blue components of the image and produces the three output bands as hue, intensity and saturation.

IMAGE CLASSIFICATION

The GRASS programs *i.cluster* and *i.class*† provide for the generation of sets of class (category) signatures from up to 8 input bands. In *i.class* the user graphically selects the training area (supervised classification) to define each class and is then shown all the regions of the image that match the signature using a parallelapiped classification method. *i.cluster* generates a set of signatures by an "unsupervised" method; the user can specify the maximum number of classes and the percent convergence in the iterative assignment of cells to classes. Seed signatures for *i.cluster* can be taken from *i.class*, previous *i.cluster* results or entered by hand.

A single "classifier" program, *i.maxlik*, processes the signatures and the image band files to create a final classified image using a maximum likelihood method. Other classifier algorithms could be added to GRASS by users with C programming experience. (The complete source code of GRASS is distributed to all users.)

RECTIFICATION

The conversion of raw images into geographic coordinate systems, known as rectification or georeferencing, combines translation, rotation, scaling and differential stretching. Three GRASS programs are used to accomplish this. The first is *i.target* in which the user identifies the data base into which the rectification will be done; this "target" data base is typically one with maps in the UTM coordinate system. Second, the *i.points* program is used to associate "true" ground coordinates with a number of specific cells or points on the image(s) to rectify; typically 15 to 30 points are desired for superior results. Then the *i.rectify* program is run which rectifies designated image bands and/or processed image band products into the target data base.

CONCLUSIONS

Image processing using the GRASS GIS offers many possibilities for enhancement and transformation of image bands. The versatility of programs like *Gmapcalc* and *neighbors* coupled with the special purpose commands like *Gpca* and *Gcca* provide a rich set of tools for the user. In addition, because of the UNIX operating environment underneath GRASS the user and/or programmer can readily build shell scripts (batch files) that allow a series of the image processing commands to be executed as a single command. This leads to an extendible and user customizable environment which is quite powerful.

Spatial Statistics and Interpolation Procedures for GRASS*

James Darrell McCauley
USDA Graduate Fellow
mccauley@ecn.purdue.edu

Bernie Engel
Associate Professor
engelb@ecn.purdue.edu

Department of Agricultural Engineering
Purdue University
West Lafayette, Indiana 47907-1146, USA

Abstract

Especially important to GRASS users whose work originates with punctual data is the ability to perform statistical analyses and to interpolate/contour their data. Many users rely on other software for some analyses of geographic data since GRASS marginally supports the types of operations required. An overview of spatial statistics calculations and interpolation methods for punctual data currently available in GRASS is presented. Recommendations for tools needed in spatial statistics and contouring toolboxes, based upon expert opinion, are presented.

1 GIS and Spatial Statistics

Many statisticians have all of the tools that they deem necessary readily accessible for whatever type of analysis they face. GIS users, who may only *occassionally* need to do various statistical analyses, must usually search to find the computer programs they need. In most instances, their needs are limited and they cannot justify the purchase of comprehensive statistical analysis packages. Additionally, if a statistical package is available, data transfer between it and the GIS may not be a straightforward task. Even if the data transfer is possible, the statistical package may not do exactly what the GIS user has in mind, such as account for spatial dependence. Therefore, it seems appropriate that GIS systems have tools for calculating commonly used statistics and doing spatial analysis with statistics.

The movement to incorporate statistical programs into GIS software has been gaining momentum over the past few years as GIS conferences and workshops have begun to focus on this need. For example, the U.K. Economic and Social Research Council (ESRC) funded an "experts" workshop on this theme in 1991 (attended by quantitative geographers and statisticians), and the International Geographical Union (IGU) hosted another workshop on the same theme. Griffith [5] expresses that the key concern of these experts is software integration. He lists a core set of algorithms that should be included in spatial statistics toolboxes of a GIS:

- a standard ordinary least squares multiple regression procedure,
- a test for spatial autocorrelation in regression residuals, and
- a nonlinear regression procedure designed specifically for estimating spatial autoregression parameters.

Several other recommendations were made in Griffith's exposition [5]. Probably the most visible evidence of this trend is Research Initiative 14 of the National Center for Geographic Information and Analysis (NCGIA) [3] funded by the National Science Foundation, which "will focus upon impediments to the accurate use of spatial analytic modules in a GIS environment."

This paper surveys the types of spatial statistics (for punctual data) and interpolation procedures currently available in GRASS, whether part of the normal distribution or freely available from other sources, and recommends development of other types of related procedures.

2 What is Available?

The following section describes programs that are currently available. Most are available in GRASS 4.1β, but some are still under development (see the appended "Software Index"). Other statistical procedures for image data (*i.e.*, texture analysis, principle components, cluster analysis) are not discussed—attention here is focused on procedures that operate *on* punctual (point) data.

2.1 Point Pattern Analysis

MacLennan reports [7] on a program called *Gstat* (written for GRASS 3.1) that calculates statistics for determining clustering tendency in point patterns, but the status of this program is unknown. Despite the name, this program reported has an entirely different function that the *Gstats* GRASS 3.1 (which later became *r.stats*).

2.2 Spatial Autocorrelation

Spatial autocorrelation refers to the spatial ordering of a single variable and to the relationship between pairs of observations of this variable [4]. The ordering of n observed values of some variable X is usually described with the aid of a connectivity matrix, **C**. Non-zero c_{ij} entries in the $n \times n$ matrix indicate that the corresponding row and column units (polygons) are juxtaposed. The connectivity matrix is used for calculating common indices of spatial autocorrelation, such as the Geary Ratio (GR) and the Moran Coefficient (MC). In order for this connectivity matrix to be expressed, triangulation must be done.

Delauney triangulation and Voronoi diagram construction (also known as Dirichlet tesselation and Thiessen polygon construction [6]) have recently been made possible by the *s.delauney* and *s.voronoi* programs, respectively (see appended Software Index). Figure 1 shows vector output and the connectivity matrix obtained from a GRASS sites list by these programs.

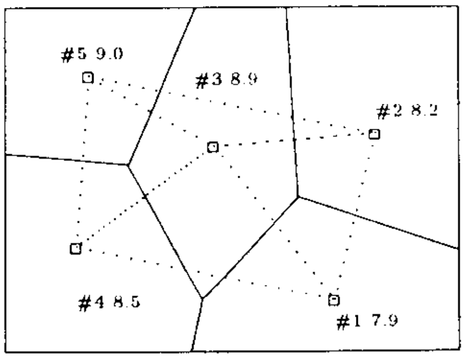
Calculation of GR and MC are accomplished in GRASS through the use of *v.autocorr*. By using the output of *s.voronoi*, the connectivity matrix is built, these indices and their standard errors are calculated, and the appropriate z statistics are calculated so that a user may determine if non-zero autocorrelation exists.

The presence of non-zero spatial autocorrelation may be important for a number of reasons. It's existence may affect the next step in an analysis, particularly if the task or method assumes either spatial dependence or independence. Interpolation is an example.

2.3 Interpolation/Contouring

Methods of surface approximation usually focus on interpolation with punctual data (as does this section). However, for completeness, the following two paragraphs describe methods of surface estimation which either do not involve interpolation or do not begin with punctual data.

* Written for presentation at the 8th Annual GRASS GIS Users' Conference and Exhibition, 14-18 March 1993, Reston, Virginia.



$$\mathbf{C} = \begin{array}{c} \\ \#1 \\ \#2 \\ \#3 \\ \#4 \\ \#5 \end{array} \begin{array}{c} \begin{array}{ccccc} \#1 & \#2 & \#3 & \#4 & \#5 \end{array} \\ \left(\begin{array}{ccccc} 0 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 \end{array} \right) \end{array}$$

Figure 1: Delaunay triangulation, a Voronoi diagram, and a connectivity matrix from sites data.

Already mentioned in the previous section was *s.voronoi*, which produces a vector representation of a surface. This type of map, where values are homogeneous within the boundaries of regions, is called an *isochor* map (see fig. 1). Another method of producing an isochor map is through the site to raster conversion in *s.menu*. Isochor maps, though appropriate in some instances, are one of the crudest types of surface estimation. No interpolation ne.

An intuitive method of creating a surface would be to use some type of linear interpolation. If a set of contours were already available (probably in vector form), linear interpolation could be done between contours. This is the function of *r.surf.contour*.

For GRASS database developers who collect their data in the field using a global positioning system (GPS) or conventional surveying methods (instead of buying/importing their data or digitizing printed maps), the method described above is of no use. Unless they are willing to employ paper-cartographers or drafting experts to do contouring manually, they must use computer methods which operate on punctual data. Four general methods of approximating surfaces from this type of data in GRASS are described below.

Inverse distance-based interpolation is the most intuitive method of interpolation. Inverse distance weighting, according to Watson [12], may have been the first computer interpolation method for spatial data. Three GRASS programs are currently available for inverse distance-squared weighting: *r.surf.idw*, *r.surf.idw2*, and *s.surf.idw*. The first two programs, which work with raster input, differ only in how memory is managed. The latter uses site lists as input.

Relaxation surfaces, or Laplacian surfaces, are constructed by iteratively minimizing local curvature differences [12]. With a raster map to supply initial values, *r.surf.sor* systematically improves z estimates by comparing both the sign and magnitude of slope differences in different directions.

A thin-plate spline method is available in a program called *s.surf.tps*. A regularized spline with tension is used for interpolation [8, 9]. Topographic parameters such slope, aspect, profile curvature, tangential curvature, and mean are optionally computed and saved as raster files. This program is the most advanced interpolation facility available to all GRASS users, though another "rival" method, kriging, is available for testing.[1]

Kriging, perhaps because of its popularity in the literature, has been the most sought-after interpolation facility for GRASS over the past 2-3 years. Since kriging is not a simple one step process, more than one program is necessary.

The first general step in producing a kriged map from punctual data is semivariogram modeling. This may be handled in GRASS by a program called *s.semivar*. This software is still under development but is available for testing (see the appended Software Index). It currently only builds isotropic semivariogram models of one form (no nested models).

An integral part of modeling semivariance is examination of plots. This was primary purpose in development of *g.gnuplot*, a general purpose plotting package capable of plotting either functions or data as xy or xyz graphs. It was adapted from the popular GNUPLOT scientific plotting package and is easily extended to work with GRASS data structures (*e.g.*, fig. 1 was produced with *g.gnuplot* using two vector files and a sites list).

The next general step, which utilizes the semivariogram, is the actual interpolation. The program *s.surf.krig*, which implements ordinary kriging, is available for testing (but not yet for distribution).

A related program, *s.medp*, performs a median polish trend removal. Sometimes the overall trend is first removed from data and a semivariogram is fit to the residuals. After kriging, the trend is added back to the data. All of these kriging methods are described in detail by Cressie [2].

3 What is Needed?

GRASS, which has benefited from several enhancements for spatial statistics and interpolation, needs further development in this area if it is to gain the respect of those interested in the analytical/statistical aspects of GIS.

3.1 Spatial Statistics

Among the spatial statisticians' "wish list" presented earlier [5] are ordinary least squares (OLS) and nonlinear regression modules. Several public domain implementations are available for immediate adaptation for GRASS. For example, Ajay Shah of the University of Southern California has written an OLS program that is easily accessible on INTERnet[2] and Carsten Grammes[3] of Saarbruecken University in Germany has implemented Marquardt's (nonlinear) method for GNUPLOT (which could be incorporated into *g.gnuplot*). There are several other sources for quick implementation—these are given only as examples. It would behoove the potential programmer to examine other sources of code before adapting these programs or starting from scratch.

Other "fertile ground" for spatial statistics development in GRASS, besides that related to kriging, is *spatial point patterns*.

[1] There is a formal connection between these two methods but its description is beyond the scope of this paper—see [2].

[2] ftp.uu.net:usenet/comp.sources.reviewed/volume01/ols

[3] Carsten Grammes' email address is ph12hucg@rz.uni-sb.de

In some cases, it may be sensible to model the geographic location of objects (or in the statistical sense, events) as completely random. A completely random set of locations can be modeled as a Poisson process. Quadrat and distance methods and K-functions [2] can be used to reject (and measure) a departure from a Poisson distribution. With the exception of the program described in §2.1, no work is know to have been done in this area. Chapter 8 of Cressie's book [2] would be an excellent resource to enable the potential programmer to make significant contributions to GRASS development.

3.2 Contouring/Interpolation

Triangle-based methods use triplets of data as subsets for interpolation. In the simplest case, linear interpolation may be done using *barycentric coordinates* as weights. In figure 2, sites 1-3 are vertices of a triangle created by *s.delauney*. The weight of each site for interpolation at point A is equal to the area of the opposite sub-triangle divided by the area of the larger triangle (thus the sum of weights for each triplet is equal to one). Though this is a simplistic method, it does have useful applications. Its implementation would be straightforward using the output of *s.delauney*.

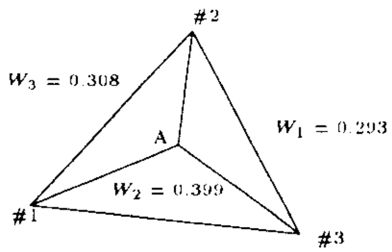


Figure 2: Barycentric coordinates.

The least satisfactory aspect of this method, noted by Watson [12], is the jagged appearance of contours. If an estimation of the gradient is available at each site, then several nonlinear methods can be used which smooth the transition from triangle to triangle. Watson [12] lists a large number of these—his book may be a good source for GRASS program development.

Triangle-based methods are plentiful and have existed for a long time. For some applications though, they may not be suitable. Other methods, including geostatistical, should be developed.

The next popular **kriging** method that should be developed for GRASS is *universal kriging*. This method differs from ordinary kriging in that different assumptions are made regarding the error of the spatial process—the mean is not assumed constant. With the enhancement of *s.semivar* to do robust semivariogram estimation [1, 2], *robust kriging* methods could be developed.

Natural neighbor interpolation, introduced by Sibson [10], is claimed to be the most general interpolation method available [12]. Natural neighbor coordinates differ from nearest neighbor coordinates. They are defined as: "all the data that share empty circumcircles with the datum and such that no data lie within any circle. The Voronoi polygons of these data have at least one point of contact with the Voronoi polygon of the datum [12]." The weight of the neighbor is based on area computations (see fig. 3). Linear and nonlinear (*e.g.*, gradient) interpolations are then possible.

Linear interpolation with natural neighbor coordinates is accomplished in the same manner as linear triangular planes using barycentric coordinates. In this case, though, the resulting surface is smooth, but has abrupt changes in slope at each datum [12].

Implementation of natural neighbor methods have been planned by the authors for the third or fourth quarter of 1993.

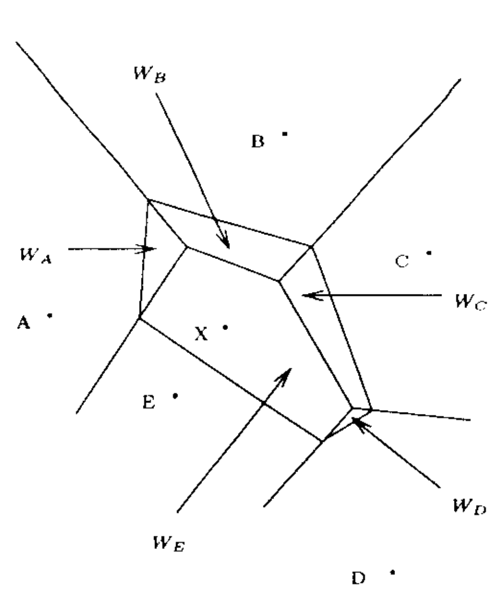


Figure 3: Natural neighbor local coordinates.

3.3 Real-valued Raster Files

Many GRASS programs make calculations on integer *category* values or eventually round output values when mapping to categories. Because of this, many GRASS users have expressed dissatisfaction regarding the lack of floating-point support. The usual *kludge* is to map categories to a constant multiple determined from the precision of the data. While this may be acceptable for most applications, it increases the burden on the user (*e.g.*, the user must document or remember that *actual* values are the category value ÷ 100). Another method used by some is to determine the number of unique floating-point values used in a data set, map each of these to a category, and use the category *label* to store the floating-point value (*e.g.*, *v.autocorr*). An alternative solution to this problem is the use of real-valued raster files. Models of real-valued images have been discussed by some [11] and could be introduced into GRASS as a fourth data format (in addition to raster, vector, and sites lists). Implementation of real-valued raster files would be especially helpful for the storing the output of interpolation procedures, which must currently implement one of the above kludgy fixes.

3.4 A Note about Documentation

With the call for development of many new and complex GRASS programs is a similar request for documentation. GRASS programmers should educate GRASS users regarding their work. The mode of knowledge transfer already in place for this is *GRASS Tutorials*. Whereas manual pages should give the syntax, author, and literature reference to the algorithm of a program, GRASS Tutorials should explain, in detail, the usage of *and* the theory employed by GRASS programs. The importance of these documents should not be overlooked by program developers. Because of the diverse background of the GRASS user base and the nature of the literature describing various analysis techniques, care should be taken to exactly define which variant of a theory or algorithm is implemented. Understanding and correct usage of new tools can avoid spurious, misleading, or even disastrous results.

4 Conclusion

GRASS has made some positive steps toward improving it's spatial statistics and interpolation toolboxes within the past year and a half. Important developments include spatial autocorrelation, thin plate spline interpolation, and kriging-related programs. Most needed are regression procedures and additional interpolation programs. Continued effort by programmers can only help GRASS as potential users begin to see the additional functionality. An important part of this development should emphasize education of the GIS user regarding the methods employed in the software.

Acknowledgments

The authors acknowledge the financial support of the United States Department of Agriculture through the USDA National Needs Fellowship Program.

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[12] David F. Watson. *Contouring: A Guide to the Analysis and Display of Spatial Data*. Pergamon Press, 1992.

Software Index

The following index lists the GRASS programs mentioned in this article. A dagger (†) is placed by those that are not part of the normal GRASS distribution or have been updated since the 4.1,3 release.

Software by the Authors

The following software was all written by James Darrell McCauley under the guidance of Bernie Engel at Purdue University. The most recent versions of each can be obtained via anonymous ftp from pasture.ecn.purdue.edu (128.46.161.85, 128.46.133.85, 128.46.129.85) in the directory pub/mccauley/grass.

†*g.gnuplot*. Scientific plotting program which uses the GRASS graphics monitor.[4]

†*s.delauney*. Produces a vector map from a sites list using Delauney triangulation.

†*s.medp*. Performs a median polish on a sites list.

†*s.semivar*. Semivariogram modeling using a sites list.

†*s.voronoi*. Produces a vector map from a sites list creating a Voronoi diagram.

v.autocorr. Tests for spatial autocorrelation using the Geary Ratio and the Moran Coefficient.

Software by Others

r.surf.contour. Produces a raster map by linear interpolation between contour lines using a raster contour map as input. Chuck Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory.

r.surf.idw. Produces a raster map from an existing raster map using inverse distance squared weighting. Greg Koerper, Oregon State University, USA.

r.surf.idw2. Produces a raster map from an existing raster map using inverse distance squared weighting. Michael Shapiro, U.S. Army Construction Engineering Research Laboratory.

r.surf.sor. Produces a raster map from an existing raster map using simultaneous over-relaxation. Michael Shapiro, U.S. Army Construction Engineering Research Laboratory.

s.surf.idw. Produces a raster map from a sites list using inverse distance squared weighting. Michael Shapiro, U.S. Army Construction Engineering Research Laboratory.

†*s.surf.krig*. Produces a raster map from a sites list using ordinary kriging. Chris Skelly, Macquarie University, NSW Australia. (mqmet.cic.mq.edu.au, 137.111.91.14).[5]

s.surf.tps. Produces a raster map from a sites list using thin-plate splines with smoothing. Helena Mitášová, Illinois Natural History Survey and US Army Construction Engineering Research Laboratory; Lubos Mitáš, Department of Physics, University of Illinois at Urbana Champaign, Illinois.

[4] The GRASS terminal driver has been included in the 3.3 beta version (patchlevel 10) of GNUPLOT and should be available to all GRASS/GNUPLOT users when version 3.3 is released.

[5] This program contains proprietary source code and is only available for testing by research organizations.

From: Jim Westervelt (3/31/92)
To: Agustin Lobo
GatorMail-Q Re: grass
Received: by qmrelay.mail.cornell.edu (2.01/GatorMail-Q); 31 Mar 92 12:10:19 U
Received: by marla.urban.uiuc.edu id AA24393
(5.65c/IDA-1.4.3 for agustin_lobo@qmrelay.mail.cornell.edu); Tue, 31 Mar 1992
11:05:41 -0600
Date: Tue, 31 Mar 1992 11:05:41 -0600
From: Jim Westervelt <westerve@marla.urban.uiuc.edu>
Message-Id: <199203311705.AA24393@marla.urban.uiuc.edu>
To: agustin_lobo@qmrelay.mail.cornell.edu
Subject: Re: grass

Some information about getting involved with GRASS:

##

GRASS Information Office
Melanie Mayfield
USA-CERL
phone: 1-800-USA-CERL extension 220
email: mayfield@zorro.cecer.army.mil

The following items are available from this office. Most are without cost.
- GRASSclippings (newsletter)
- Bibliography
- Lots of papers regarding various aspects of GRASS
- User manual (there is a cost for this)
- Index of commercial offerings
- Schedule for GRASWS classes and conferences world wide
- Commercial GRASS distributors

##

GRASS SOURCE AVAILABLE VIA FTP

About the OGI FTP server

Rob Knauerhase
Office of Grass Integration
rob@amber.cecer.army.mil

December 16, 1991

The Office of GRASS Integration (OGI) is pleased to introduce a new FTP server for use by the GRASS community. This location will be the new "canonical" source for GRASS software, as well as bug fixes, contributed sources, documentation, and other files. Not all the files planned for the server are there at the time of this writing, but they will be made available as time and local resources permit.

FTP (for "file transfer protocol") allows users to access files on remote machines through the Internet; the FTP server that OGI is using is an especially user-friendly variant of the standard FTP software. In order to use this service, you must have access to an Internet-connected machine at your site; unfortunately, BITnet and UUCP sites are not equipped to use the Internet for file transfer.

The site of the service is [moon.cecer.army.mil]; the IP address of this site (for those sites who do not use the Domain Naming Service) is 129.229.1.16. The location of the machine at CERL is subject to change, in which case the IP address will change, but the server will always be reachable as "moon.cecer.army.mil". Connections are only allowed during off-peak hours (weekends and weekdays before 8:00 A.M. and after 5:00 P.M. Central Standard time).

To connect to this site, simply type [ftp moon.cecer.army.mil] from your computer. You'll be prompted for a name and a password --- for the name, type "ftp" (without the quotes), and for password, type your E-mail address. A sample session will look like this (things you type are in bold):

```
% ftp moon.cecer.army.mil
Connected to moon.cecer.army.mil.
220 moon FTP server (Version 6.27 Tue Nov 19 16:16:06 CST 1991) ready.
Name (pegasus:knauer): ftp
331 Guest login ok, *please type e-mail address as password*.
Password:  type your E-mail address here
230-
230-
230-Welcome to the GRASS FTP server.
230-It is now Tue Nov 26 16:27:57 1991 in Champaign, Illinois.
230-
```

This will be followed by an introductory text that offers up-to-the-minute news about the system and helpfiles for system use.

Once you're connected and you see the "ftp>" prompt, you can type many Unix commands just as you would on a local machine. For example, to see what files are available, type [ls] and the server will return the contents of the current directory. The [cd] command allows you to enter subdirectories of the current directory, and [cd ..] will take you back up one level when you have entered a subdirectory. If you become lost, typing [cd /] will return you to where you began.

Additionally, as you navigate the system, you will be presented with informative messages about the area you're in and so forth. For example, when you change to the GRASS distribution directory, you will see a message similar to:

```
230-
230-This directory contains the for-distribution release of GRASS 4.0.
230-It is available in "tar" or "cpio" format.
230-
ftp>
```

The "230-" is a code that instructs your local FTP program to show you the message. It is entirely superfluous and may be ignored.

Occasionally there will be a file titled README in the directory; it will contain more in-depth information than the message you get when you enter that directory. You will see messages like:

```
230-
```

```
230-Please read the file /README (use "get README" or "get README |more")
230-  it was last modified on Tue Nov 12 21:15:20 1991 - 14 days ago
230-
ftp>
```

If you are interested in the file, you can bring it to your local machine with the

    get README

command. Alternately, your machine might support a construct such as

    get README |more

(with a vertical bar before more, and no space between it and the word "more") which will display the file on your monitor (but not copy it to your disk) and pause if the file is greater than one screen-height long.

The [get] command will copy files from the server to your machine; simply typing

    get <<filename>>

will retrieve <<filename>> for you. This FTP server also supports dynamic compression and uncompression and "tar" archiving of files. For example, if you see that there is a file called "newprogram.c" in the current directory, you can append a ".Z" (which is the suffix [compress] adds to compressed files) to the filename, and the server will compress the file before sending it to you. For example, if the result of the [ls] command says:

```
ftp> ls
200 PORT command successful.
150 Opening ASCII mode data connection for file list.
README
newprogram.c
oldprogram.c
226 Transfer complete.
(end courier monospace)
```

then you can type

    get newprogram.c.Z

and the server will server will compress the file and save it as <<newprogram.c.Z>> on your local disk. This is handy when disk space is at a premium (or network bandwidth is costly for your site).

Some files will already be compressed on the server, and therefore will have the name <<filename.Z>>. If you don't have the uncompress program, or if you want an already-uncompressed version, you can type [get <<filename>>] (note the lack of ".Z") and the server will dynamically uncompress the file and send you that version.

If you would like all the files in a given directory (let's use the example <<neatprogs>>), you can type [get <<neatprogs.tar>>] and the server will create a tar (for "tape archive"; tar is a common Unix archiving utility) file and send it to you. You can then un-tar this file on your local computer and put the files from it wherever you wish. Be forewarned that many of the files on the server (such as the GRASS distribution directory) are very large, and tarfiles of these directories will require copious amounts of free disk space on your local computer (albeit temporarily).

This article is meant as an introduction to the server, which we hope will prove to be a convenient way of acquiring GRASS software, on-line manuals, and other related files (much of which will be available at a later date). We encourage interested parties to explore the server, see what is available, and take advantage of its resources. The contents of the FTP server will be somewhat dynamic, as new bug-fixes and releases become available. Updates to the files on the server will be made on a periodic basis, and further information on this will be made available in files on the server, in {\it GRASS Clippings}, and through OGI's E-mail lists. If you encounter problems or have questions about the server, feel free to send mail to ftp-admin@moon.cecer.army.mil.

##

GRASS E-MAIL LISTS

grassu-list - for GRASS users; application-level questions, support concerns, miscellaneous questions, etc.

grassp-list - for GRASS programmers; system-level questions and tips, tricks, and techniques of design and implementation of GRASS applications

About the OGI GRASS Mailing Lists

Rob Knauerhase
Office of Grass Integration
rob@amber.cecer.army.mil

December 16, 1991

The Office of GRASS Integration would like to introduce a new service that will be of interest especially to those GRASS users who have access to electronic mail. We have set up two e-mail lists to foster communication between GRASS users and GRASS programmers. Through the lists, people interested in user or programmer issues can exchange ideas and solutions in a dialogue-style format.

The lists work on the principle of "mail exploding" --- a user mails a note to one address, and the computer at that address "explodes" the letter, re-mailing it to everyone who subscribes to the list. So, for example, a user with a question about one of the GRASS programs can mail his request to the list; other participants in the list will then see the question and (according to their expertise) can reply. These replies can then be sent back to the list, where all subscribers will see the answer. This way, everyone is presented with the questions and answers of others, reading and contributing as their interests permit. Frequently, several people will propose answers, which can foster discussion on the list about which methods are better for various circumstances. Both lists will automatically be preserved in an archive, so a "knowledge base" of questions, replies, and discussion will be built, and users can request these archive files at any time.

The list for GRASS users and friends is called "grassu" (short for "GRASS users"), while the list for programmers and system-level users is called "grassp" (short for "GRASS programmers"). Topics for discussion on the |grassu-list| may include questions about how to use certain GRASS applications, sources of (or reviews of) third-party support, and various and sundry other experiences with GRASS. On the |grassp-list|, topics will include discussion of the algorithms and intricacies of current GRASS programs, programming hints and ideas for new GRASS applications, and other programmer-oriented issues. Note that the grassp-list is |not| the best (nor even an appropriate) place to report suspected bugs in GRASS code; the current <bug.report.sh> program and correspondence with OGI are the preferred problem-report procedures.

Many CERL employees will participate in the lists, but on an informal basis. The list will be maintained and stored on CERL computers; however, CERL will not officially monitor the content, intent, or accuracy of any messages that pass through the list.

Both lists will reside on a CERL machine called <amber.cecer.army.mil>. This machine should be reachable from Internet, BITnet, and UUCP sites. Users will
interact with the list through electronic mail; contributions are sent and received in normal E-mail messages. Likewise, commands to the list and the replies it generates are contained in regular E-mail.

To join the user's or programmer's list, send a message to

<grassu-request@amber.cecer.army.mil> (for user's list)
<grassp-request@amber.cecer.army.mil> (for programmer's list).

You will need to issue the "subscribe" command; the listserver software will then extract your E-mail address from your message and add it to the recipient list. The command may be in the subject or body of your message, and may be abbreviated "sub" if you like. Following the command should be your real name.

For example, using the standard Unix mail program, the exchange would look like this (bold type indicates the computer's responses):

```
% mail grassu-request@amber.cecer.army.mil
Subject: <return>

subscribe John Doe
.
%
```

The list server will mail back a confirmation message, and you are now able to participate in the list.

To remove yourself from the list, send mail to

<grassu-request@amber.cecer.army.mil> (for user's list)

<grassp-request@amber.cecer.army.mil> (for programmer's list)

and issue the "unsubscribe" command. The command must be at the beginning of a line, and may be either in the subject or body of your mail message. The list server will send you a confirmation message when your name has been deleted from the list.

To contribute to the list, send mail to

<grassu-list@amber.cecer.army.mil> (for user's list)
<grassp-list@amber.cecer.army.mil> (for programmer's list).

If your mail program asks for a subject, type something appropriate, and then fill in the body of your message. Your note will be forwarded exactly as received to everyone on the list. If you are replying to a message from the list, and your mailer has a "reply" command, you can use that command to answer other people's notes.

The list server also understands many other commands; send a message to either of the "-request" addresses with "help" on a line by itself to request a file detailing all the commands.

If you have questions or problems with the list server, or require a human response to something, send mail to

lists-owner@amber.cecer.army.mil

and CERL personnel will reply.

===

1.1 Pathfinder Data Sets

There are four types of Pathfinder AVHRR Land data sets:

- Daily Data Set - daily, global, 8 km, terrestrial data
- Composite Data Set - 10-day, global, 8 km composites
- Climate Data Set - 1-degree NDVI product for climate modeling
- Browse Images - images for Daily and Composite Data Set selection

In addition, the Pathfinder project is generating a data set for AVHRR calibration researc which contains calibration data records extracted from the AVHRR orbital data. An ancillar data file with elevation and geolocation information is also provided for use with the Daily an Composite Data Sets.

Table 1-1 presents a summary of the size, structure, and format of the Pathfinder dat products. Many of the Pathfinder data sets contain multiple geophysical parameters i each file. These parameters are organized as "stacked" two dimensional arrays which ar referred to in this document as **data layers** .

Also mentioned in Table 1-1 is the product format. All Pathfinder data, with th exception of the Calibration Extraction product, are stored in the Hierarchical Dat Format (HDF) (Brown, et al. 1993) which is the standard data format for the early Eart Observing System Data and Information System (EOSDIS). HDF is discussed in detai in Section 4, "Reading the Data" and Appendix E, "HDF Basics."

Table 1-1 Product Summary

Data Product	Data Layers per file	Dimensions (columns x rows)	Format	Compressed / Uncomp. size
Daily Data Set	12	5004 x 2168	HDF (SDS)	35 MB / 228 MB
Composite Data Set	12	5004 x 2168	HDF (SDS)	35 MB / 228 MB
Ancillary Data File	4	5004 x 2168	HDF (SDS)	18 MB / 50 MB
Climate Data Set	1	360 x 180	HDF (SDS)	12 KB / 66 KB
Browse Images	2	625 x 271	HDF (RIS8)	95 KB / 342 KB
Calibration Extracts	n/a	n/a	NOAA 1b	5 MB

1.1.1 Daily Data Set

The Daily Data Set contains global, 8 km, terrestrial data mapped to an equal area projection. Geophysical parameters contained in the data set include: Normalized Difference Vegetation Index (NDVI) (Goward, et al. 1991), cloud and quality control flags, solar and scan geometry, reflectances derived from the AVHRR channels 1 and 2, brightness temperatures derived from the AVHRR channels 3, 4, and 5, and date and hour of observation. Data over oceans, large inland water bodies, and in areas of twilight have been masked out.

These data are derived directly from the AVHRR level 1b orbital data using the procedures described in Appendix B. There is one file per day for the entire Pathfinder processing period (June 25, 1981 to present).

The Daily Data Set is useful for studies of many terrestrial variables (e.g., vegetation, temperature, snow cover) as well as for producing a variety of composite data sets, but each day a significant portion of the Earth's surface is covered by clouds.

1.1.2 Composite Data Set

The Composite Data Set is similar to the daily data in structure and is derived from the Daily Data Set, however the process of compositing removes the much of the cloud cover present in the Daily Data Set (Holben, 1986). To generate the Composite Data Set, 8 to 11 consecutive days of data are combined, taking the observation for each 8 km bin from the date with the fewest clouds and atmospheric contaminants as identified by the highest NDVI value. Only data from the Daily Data Set which are within 42 degrees of nadir are considered in generating the composite.

The Composite Data Set contains the same geophysical parameters as the Daily Data Set, and these data are mapped to the same global, 8 km, equal area projection as the daily data. There are three composites per month for each year of data. The first composite of each month is for days 1 to 10, the second composite is for days 11 to 20 and the third composite is for the remaining days.

The Composite Data Set is particularly useful for studies of temporal and interannual behavior of surface vegetation and for developing surface background characteristics for use in climate modeling, however if a completely cloud free background is required, further compositing may be necessary.

1.1.3 Climate Data Set

This data set contains global, mean, cloud free, NDVI data at 1-degree resolution for each 8- to 11-day composite period. This data set is derived from the Composite Data Set, and there are 36 climate data files for each year.

The Climate Data Set is intended primarily for use in General Circulation Models (GCM), simple biosphere models (Sellers, et al. 1986), and other global time series studies.

1.1.4 Browse Images

Browse Images are generated from the Daily and Composite Data Set to aid in scene selection. The Browse Images are produced by subsampling every eighth pixel of every eighth line of the full resolution daily and composite data files. A daily Browse Image consists of two data layers, Channel 2 reflectance and Channel 4 brightness temperature, and is useful in determining cloud extent and areas of missing data. Each 10-day composite Browse Image consists of an NDVI and a Channel 4 brightness temperature layer and is useful for identifying areas of residual cloud contamination.

Due to their rescaling and subsampling, these images are for data selection only and are not recommended for data analysis.

1.1.5 Ancillary Data File

The Pathfinder Ancillary File contains land and sea flags, elevation, and bin center latitude and longitude, for global, 8 km, bins which have all been coregistered to the same 8 km equal area projection as the daily and composite data.

There is a single, invariant ancillary data file for the entire Pathfinder time period and it is primarily used to assist in interpreting the daily and composite data. The land/sea mask and elevation in this file are the same used in the generation of the Daily Data Set, however this file should not be confused with the ancillary data sets which are part of the processing inputs.

1.1.6 Extracted Calibration Data

To support AVHRR Calibration research, selected information is extracted from the satellite orbital data. This includes calibration coefficients, gains and offsets, blackbody/deep space view information, and instrument (baseplate) temperature.

Calibration data are extracted from approximately 6 GAC orbits per month. The orbit which passes over the equator at 0° longitude every 5-7 days is chosen. This results in data over different surface types (ocean and desert) within each orbit and different solar and scan geometry among orbits. These data are in the NOAA 1b 10-bit packed format as described in the *NOAA Polar Orbiter Data User's Guide* (Kidwell 1991), and are roughly 5 MB each.

1.2 Data Set Origins

The input to the Pathfinder data processing is more than 70,000 orbits of AVHRR GAC 1b data from the NOAA polar orbiting satellites with the afternoon ascending node equator crossing times. With current definitions of satellite data processing levels, these data would be referred to level **1a**, however the GAC orbital data from the NOAA Polar Orbiters are referred as **1b** for historical reasons.

The AVHRR instrument onboard the NOAA-series satellites (TIROS–N/NOAA 6–12) provides daily coverage of the Earth in 4 or 5 spectral bands at a nominal resolution of 1 km. Because the 1 km resolution data are too voluminous to be captured daily, the data are subsampled and averaged onboard and then transmitted to central receiving stations as Global Area Coverage (GAC) data with a nominal resolution of 4 km providing full global coverage.

Pathfinder input data commence with NOAA–7 which was launched in June 1981. This was the first AVHRR instrument with five channels, and it is the five channel AVHRR instruments which are used in producing the Pathfinder data sets. The additional channel provides better cloud discrimination and is useful for determining Sea Surface Temperature which will be produced in a separate Pathfinder effort.

The AVHRR instrument's 110.8° cross-track scan equates to a swath of about 2700 km. The orbital period is about 102 minutes and there are 14 orbits per day with a repeat cycle of approximately 14 days.

A more detailed, comprehensive description of the NOAA series satellites, the AVHRR instrument, and the AVHRR GAC 1b data can be found in the *NOAA Polar Orbiter Data User's Guide* (Kidwell 1991), which can be obtained from NOAA's National Environmental Satellite Data and Information Service (NESDIS) at:

NOAA/NESDIS
Satellite Data Services Division
Room 100
Princeton Executive square
5267 Allentown Road
Camp Springs, MD 20746

Phone: (301) 763-8402
Fax: (301) 763-8443

Internet: sdsdreq@pes.sdsd.ncdc.noaa.gov

The input ancillary data are described in Section 5, "Frequently Asked Questions."

25

5. Frequently Asked Questions

5.1 About Data

1. What is the schedule for Pathfinder processing?

It is estimated that 5 years of data will have been processed by December 1994. The full historical record from 1981 through 1993 will be completed by the end of December 1995.

2. Is there any charge for large amounts of Pathfinder data?

Currently, there is no charge for any quantity of data. The DAAC encourages orders via FTP, but will also fill orders on tape. If an extremely large data order is requested on tape, the recipient may be required to provide blank tapes.

3. How does the Pathfinder data set relate to other AVHRR Vegetation Index Data Sets?

Higher resolution 1 km Local Area Coverage (LAC) and High Resolution Picture Transmission (HRPT) data have been used for a variety of terrestrial remote sensing applications. Other related data products are the Global Area Coverage (GAC) 1b, NOAA's Global Vegetation Index (GVI) product (Kidwell 1990, Goward et al. 1993), Global Inventory Monitoring and Modeling (GIMMS) product, and the European Community's Joint Research Centre (JRC) Monitoring of Tropical Vegetation (MTV) product. These data sets are discussed in Report 20 of the International Geosphere Biosphere Programme (Townshend, 1992).

The Pathfinder builds on the techniques used to produce these data sets. The significant differences between the Pathfinder data and these precursors are that the Pathfinder data provides many data layers, provides daily as well as composite data, and provides global, mapped data at a higher resolution.

4. What is the Pathfinder Program and what are the other Pathfinder data sets?

Recognizing the need for improved, long time series data sets for global change research, NOAA and NASA initiated the "Early-EOS Pathfinder Data Set Activity" (aka The Pathfinder Program) in 1990. Candidate data sets were identified based on available coverage (temporal and spatial) and importance of the data for global change research. Four data sets were identified for the initial Pathfinder processing effort

- Advanced Very High Resolution Radiometer (AVHRR) data from the polar orbiting TIROS NOAA satellites.

- TIROS Operational Vertical Sounder (TOVS) data from the polar orbiting TIROS/NOAA satellites,
- Data from the Geostationary Operational Environmental Satellite (GOES), and
- Special Sensor Microwave / Imager (SSM/I) data from the Defense Meteorological Satellites (DMSP).

In addition, NASA, through it's Mission to Planet Earth Program initiated Pathfinder projects for

- Scanning Multichannel Microwave Radiometer (SMMR) from the Nimbus-7 satellite, and
- selected time periods of Landsat data for land cover classification and change detection of several periods and regions.

In some cases there are multiple processing sites for these Pathfinders.

The TOVS pathfinder data are also available for ordering at the Goddard DAAC both via the online IMS and through the User Services Office.

5. *Where can I obtain AVHRR GAC data?*

NOAA/National Environmental Satellite Data and Information
Service National Climatic Data Center
Satellite Data Services Division
Room 100
Princeton Executive square
5267 Allentown Road
Camp Springs, MD 20746

Phone: (301) 763-8402
Fax: (301) 763-8443

Internet: sdsdreq@pes.sdsd.ncdc.noaa.gov

6. *What ancillary data are required to produce Pathfinder data and where can I acquire these data?*

The input ancillary data are described in Table 5-1.

The input ancillary files (ephemeris, clock resets, metadata, ozone, and topolandsea) can be obtained from the Pathfinder Processing Team. Files containing a list of orbits to be processed and a process control file are generated by users at the time of the run. NOAA 1b data are available from NOAA/NESDIS; however, at present users would have to provide some simple reformatting of the 1b data or rewrite the Pathfinder software to ingest standard NOAA 1b format data.

Table 5-1
Ancillary Data Sets

Ancillary Data	Description
Topography data	Land surface elevation from the Earth Topographic 5-Minute Grid (ETOPO5) data set (NGDC 1993).
Ozone data	Daily 1° ozone data from the Total Ozone Mapping Spectrometer (TOMS) (Bowman and Krueger 1985).
Metadata ancillary files	ASCII files containing both metadata (units, layer names, etc.) and DAAC metadata (listing general product information).
Land/sea mask	The NOAA operational land sea mask (Stowe et al. 1991).
Ephemeris file	Files containing orbital elements for each satellite available from NORAD.
Clock reset file	One ASCII file for the full processing period—contains correction information for the NOAA onboard clock.

7. How can I obtain NOAA ephemeris data?

The most current orbital elements from the North American Air Defense Command (NORAD) two-line element sets file are carried on the Celestial Bulletin Board Service, 513–253–9767, and are updated several times a week. Documentation and tracking software are also available on this system. Element sets (updated weekly) and some documentation and software are also available via anonymous FTP from archive.afit.af.mil (129.92.1.66) in the directory pub/space.

5.2 About Software

8. What is the Pathfinder AVHRR Land processing system?

The Pathfinder system produces 8 km, terrestrial global data from the GAC data from the NOAA–7, –9, and –11 AVHRRs. The system reads Pathfinder format GAC orbits (the Pathfinder format is essentially a reblocked GAC orbit with a special header), renavigates each pixel, calibrates the five channels, corrects Channels 1 and 2 for Rayleigh scattering and ozone absorption, converts Channels 1 and 2 to surface reflectance and Channels 3,4, and 5 to brightness temperature. The software then generates cloud flags and NDVI, and creates a 12-layer output HDF file with Goddard DAAC specified metadata. Software documentation (overview, data flow, data dictionary, and program description) is available from the Pathfinder Processing Team.

9. Can I obtain the Pathfinder processing software?

Yes. The Pathfinder processing software is part of the public domain and all source code is available to users. However, the software is "use at your own risk." NASA will not implement changes on request. At this time, NASA does not have the resources to provide support beyond collegial email consultations.

10. How large is the Pathfinder Processing source code?

The Pathfinder source code consists of 26,900 lines of ANSI C code. HDF and Common Data Format (CDF) software are also required to run the Pathfinder.

11. What hardware s required to run the Pathfinder processing software?

Pathfinder software has compiled and run successfully on the following UNIX workstations: SGI, HP, Sun, and IBM. However, recent operating system upgrades may or may not have introduced problems in compiling or running the code. The minimum recommended hardware configuration is

- 64 MB memory
- 1GB storage for input and ancillary files (assuming 14 NOAA GAC orbits will be processed on any given run)
- 600 MB storage for output files
- 300 MB for all sources, libraries, and configuration control files (optional).

12. Where can I get HDF and CDF?

HDF is available from NCSA via anonymous FTP at **ftp.ncsa.uiuc.edu.** The operational Pathfinder uses version 3.2r4. It is availabl... the HDF/prev_releases directory. The Pathfinder processing system has been tested successfully with more recent versions of this software.

CDF is available from NASA via anonymous FTP at ncgl.gsfc.nasa.gov. The operational Pathfinder uses version 2.2, which is available in the **pub/cdf/cdf22-dist** directory. The Pathfinder processing system has been tested successfully with more recent versions of this software.

Documentation and support for both format software packages are available from NCSA and NASA at the sites listed above. Neither the Pathfinder team nor the Goddard DAAC is responsible for maintaining or supporting either package.

13. How can I re-project the Pathfinder Data to other map projections?

The General Cartographic Transformation Package (GCTP) may be used to reproject the Pathfinder data. A C programming language version (GCTPc) which contains several new projections which were not in earlier versions of GCTP is now available from the EROS Data Center (EDC) via anonymous FTP. Communications concerning GCTPc may be directed to

gctpc@edcserver1.cr.usgs.gov

Periodic updates and corrections will be put in this directory for access by the science community. Descriptions of these updates will be added to the Read Me file in the main directory.

The package has been tar'd and compressed under the directory name gctpc. To access it, retrieve the file gctpc.tar.Z by anonymous FTP to

edcftp.cr.usgs.gov

This file can be retrieved by following these steps.

ftp **cd pub/software/gctpc**

ftp **get gctpc.tar.Z**

Then on a UNIX system, type

% **uncompress gctpc.tar**

% **tar -xvf gctpc.tar**

The **gctpc.tar** file is 40 MB in size. A GCTPc directory will be created and the files copied into it. The installation will require 80 MB of disk space. The gctpc.tar file is not automatically deleted.

In order to re-project the Pathfinder data you may need to know the projection parameters for the global data set. These are listed in Table 5-2.

Table 5-2
Goode Interrupted Homolosine Global 8 km Projection Parameters

Number Output Lines 2168
Number Output Pixels 5004
Upper Left Y Coordinate 8669500.0
Upper Left X Coordinate −20011500.0
Output Pixel Size 8000
Earth's Radius (R) = 6370887.0 meters

Central meridians for each of the 12 regions			False eastings for each of the 12 regions	
lon_center[0]	−1.74532925199	−100.0 degrees	feast[0]	R * −1.74532925199
lon_center[1]	−1.74532925199	−100.0 degrees	feast[1]	R * −1.74532925199
lon_center[2]	0.523598775598	30.0 degrees	feast[2]	R * 0.523598775598
lon_center[3]	0.523598775598	30.0 degrees	feast[3]	R * 0.523598775598
lon_center[4]	−2.79252680319	−160.0 degrees	feast[4]	R * −2.79252680319
lon_center[5]	−1.0471975512	−60.0 degrees	feast[5]	R * −1.0471975512
lon_center[6]	−2.79252680319	−160.0 degrees	feast[6]	R * −2.79252680319
lon–center[7]	−1.0471975512	−60.0 degrees	feast[7]	R * −1.0471975512
lon_center[8]	0.349065850399	20.0 degrees	feast[8]	R * 0.349065850399
lon_center[9]	2.44346095279	140.0 degrees	feast[9]	R * 2.44346095279
lon_center[10]	0.349065850399	20.0 degrees	feast[10]	R * 0.349065850399
lon_center[11]	2.44346095279	140.0 degrees	feast[11]	R * 2.44346095279

14. Whom can I ask for limited Pathfinder science and processing information?

Mary E. James
Code 902.3
Global Change Data Center,
NASA Goddard Space Flight Center
Greenbelt, MD 20771

fax: 301–286–1775
email: mary.james@gsfc.nasa.gov
phone: 301–286–2432

Ecoregions of the Continents
R.G. Bailey Supp. Env. Conservation V 16, 4 1989

GLOBAL GRASS™ 1, 2, 3, 4, & 5
DIGITAL DATA SETS
on CD-ROM

Developed by USACERL & Rutgers University
Available from the Center for Remote Sensing and Spatial Analysis, Cook College, Rutgers University

Greetings,

The following is a description of the data contained on the Global GRASS™ 1, 2, 3, 4, and 5 CD-ROM digital datasets. We have also enclosed ordering information for your convenience.

The data was developed by the US Army Corps of Engineers by their Spatial Analysis Systems Team and the Center for Remote Sensing and Spatial Analysis, Cook College, Rutgers University. Rutgers is responsible for bringing this data to you.

The files on the CD-ROM are stored in uncompressed, flat format and can be accessed directly using GRASS software. The files can be imported fairly easily for those of you who are not GRASS users. As a side note, GRASS 4.1.2 is now available on CD-ROM as well. For GRASS 4.1.2 distribution information contact Pamela Cashman at The Open GIS Foundation (Phone: 617-621-7025; FAX: 617-621-7174).

For something more detailed than the following list contact the individuals below for information on the data or about ordering the CDs:

Scott Madry, Associate Director
Center for Remote Sensing and Spatial Analysis, Cook College
Box 231, College Farm Road
Rutgers University
New Brunswick, NJ 08903
Phone: 908-932-1582
FAX: 908-932-8746
email: madry@ocean.rutgers.edu

OR

Carine O'Neil
Global Dataset Project Coordinator
same address
same Phone and FAX
email: coneil@ocean.rutgers.edu

To Order Global GRASS CD-ROM Datasets, please fill out and return this form:

Name: ____________________

Address: ____________________

____

____

____

Phone: ____________________

Employer: ____________________

Please send me:

☐ CD1 ($375) ☐ CD4 ($225)

☐ CD2 ($300) ☐ CD5 ($225)

☐ CD3 ($250) ☐ all 5 ($1,125)

Please add me to your mailing list: ☐

Applications for this data (optional): ____________________

Amount Enclosed/Mode of payment: ____________________

Overseas shipping and handling is US $10. US government agencies receive a 25% discount.

CONTENTS OF Global GRASS™ CD 1

FILE:	SOURCE:
Surface Albedo fo January, April, July & October	- Matthews, E. 1983. "Global Vegetation and Land Use: New High Resolution Data Bases for Climate Studies," J. Climate Appl. Meteor (22):474-487.
Aspect	- ETOPO5, NOAA Geophysical Data Center
Continents	- ETOPO5, World Data Base II
Continental Shelf	- ETOPO5
Coral Reef Distribution	- Times Atlas of the Oceans, 1983
Primary Cover/Vegetation Types	- NOAA National Center for Atmospheric Research, University of Liverpool
Reliability of Land Cover Data	- As above
Secondary Cover/Vegetation Types	- As above
Intensity of Agricultural Cultivation	- Matthews 1983 (see above)
Major World Ecosystem Complexes	- NOAA/Oak Ridge National Laboratory, Martin Marietta Energy Systems, the CDIC Numeric Data Collection
Highest Biomass Production (Kg C/sq m.)	- as above
Medium Biomass Production (Kg C/sq m.)	- as above
Lowest Biomass Production (Kg C/sq m.)	- as above
Major World Fisheries Areas	- FAO Atlas of the Living Resources of the Seas, 1977
Fisheries Productivity	- as above
Greenturtle Distribution and Characteristics	- Atlas of Animal Migrations 1972
Land (Elevation greater than 0)	- ETOPO5
Nations - Political Boundaries	- paper map dated Jan. 1, 1982. 1:40,000,000 scale
Ocean Bio-Geographic Zones based on Surface Temp.	- Times Atlas of the Oceans. 1983
Biological Ocean Zones based on Bathymetry	- map based on ETOPO5, with info. from Rand McNally - Atlas of the Oceans. 1977
Ocean Floor Biomass Production	- Times Atlas of the Oceans. 1983
Marine Conservation Projects	- Times Atlas of the Oceans. 1983
General Range of Sea Otter	- Times Atlas of the Oceans. 1983
Ocean Productivity in mg/m3	- Coastal Zone Color Scanner (CZCS)
Phytoplankton Productivity	- FAO Atlas of the Living Resources of the Seas 1977
Soil Map	- FAO 1974 Soil Map of the World and Matthews 1983 vegetation dataset
World Soil Slope Groups	- as above
Soil Texture Groups	- as above
Reliability of Soils	- as above
Detailed Soil Types	- as above
Soils for GMC	- NOAA National Center for Atmospheric Research, University of Liverpool
Shaded Relief Map	- ETOPO5
World Topographic Elevation Ranges	- ETOPO5
Natural Vegetation (Pre-Agriculture)	- based on UNESCO classification system and Matthews 1983
Abundance of Zooplankton	- FAO Atlas of the Living Resources of the Seas 1977
Average Vegetation Production for Each Month of the Year 1984-88 (12 files)	- AVHRR data from April 1984 - December 1988

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CONTENTS OF Global GRASS™CD 2

FILE:	SOURCE:
12 monthly Cloud Cover (percentage) files	- International Institute for Applied Systems Analysis (IIASA) datbase for mean monthly values of temp., precipitation and cloudiness (Leemans and Cramer 1990)
12 monthly Precipitation (inches) files	- as above
12 monthly Temperature (degrees F) files	- as above
5 Watersheds of the World files	- Created at CERL, based on ETOPO5
Bathymetry file	- ETOPO5
Visual Earth - shaded image	- Eyes on the Earth, Inc. Santa Monica, CA and CERL
Major Mountains of the World	- USA-CERL
Ridges of the World	- Created at CERL
Rivers of the World	- Created at CERL, based on World Data Base II
Soil Elements	- UNESCO/FAO Soil Map of the World 1973
Soil Formations	- as above
Shaded Relief Map	- CERL (Improved from CD1)
Percent of Urban Cover	- Corrected by CERL from US Navy (NCAR) 1984
Vegetation Production	- NOAA Geophysical Data Center

CONTENTS OF Global GRASS™CD 3

FILE:	SOURCE:
53 Weekly Vegetation Productivity Files	- Each file is a composition of approximately 7 AVHRR NVI Images

CONTENTS OF Global GRASS™CD 4

FILE:	SOURCE:
6.2 *Million* (approximately) global sites files in over 630 different category types	- Foreign data: Defense Mapping Agency - Hydrographic/Topographic Center (Geographic Names Branch) - U.S. data: United States Geological Survey - Geographical Names Information System - National Geographic Names Branch
High resolution World Data Base II global vector data	- World Data Base II
High resolution (1.5 min.) shaded relief map	- Created at CERL
High resolution (21 sec.) land/water map	- Created at CERL - based on World Data Base II

CONTENTS OF Global GRASS™ CD 5

FILE:	SOURCE:
Gross National Product	- WWF Atlas of the Environment 1992
Acid Rain	- as above
Spreading Deserts	- as above
Safe Drinking Water Availability	- as above
Daily Calorie Intake /Person	- as above
Physicians/Person	- as above
Tropical Forest Destruction	- as above
Bovines/sq. Km	- National Center for Atmospheric Research
Buffalo/sq. Km	- as above
Camels/sq. Km	- as above
Caribou/sq. Km	- as above
Non-Dairy Cattle/sq. Km	- as above
Dairy Cattle/sq. Km	- as above
Goats/sq. Km	- as above
Horses/sq. Km	- as above
Pigs/sq. Km	- as above
Methane production/sq. Km	- as above
Albacore - Distribution, Spawning & Fisheries	International Tropical Tuna Commission 1988 Tuna and Billfish: Fish Without a Country
Albacore - Migration	- as above
Bluefin- Distribution, Spawning & Fisheries	- as above
Bluefin - Migration	- as above
Marlin - Distribution, Spawning & Fisheries	- as above
Marlin - Migration	- as above
Skipjack - Distribution, Spawning & Fisheries	- as above
Skipjack - Migration	- as above
Yellowfin - Distribution, Spawning & Fisheries	- as above
Yellowfin - Migration	- as above
Manatee and Dugon Distributions	- Ridgeway & Harris 1981. Handbook of Marine Mammals.
Inundated Land	- NASA, Goddard Space Flight Center, Institute for Space Studies
Fog	- Times Atlas of the Oceans. 1983
Icebergs	- as above
Casualty Risk Areas at Sea	- as above
Tropical Storms	- as above
Winter Gales	- as above
Ridge Direction	National Center for Atmospheric Research (NCAR);1984 and U.S. Navy
Numbers of Ridges	- as above
Primary Terrain	- as above, corrected by Rutgers University
Secondary Terrain	- as above
12 Seasurface Temperature (degrees C) interpolated files (5 year average for days 48, 76, 104, 132, 160, 188, 215, 244, 272, 300, 335 and 363 of the year)	Physical Oceanography DAAC @ Jet Propulsion Lab. & California Institute of Technology

1.1 Pathfinder Data Sets

There are four types of Pathfinder AVHRR Land data sets:

- Daily Data Set - daily, global, 8 km, terrestrial data
- Composite Data Set - 10-day, global, 8 km composites
- Climate Data Set - 1-degree NDVI product for climate modeling
- Browse Images - images for Daily and Composite Data Set selection

In addition, the Pathfinder project is generating a data set for AVHRR calibration research which contains calibration data records extracted from the AVHRR orbital data. An ancillary data file with elevation and geolocation information is also provided for use with the Daily and Composite Data Sets.

Table 1-1 presents a summary of the size, structure, and format of the Pathfinder data products. Many of the Pathfinder data sets contain multiple geophysical parameters in each file. These parameters are organized as "stacked" two dimensional arrays which are referred to in this document as **data layers** .

Also mentioned in Table 1-1 is the product format. ‘ll Pathfinder data, with the exception of the Calibration Extraction product, are stored in the Hierarchical Data Format (HDF) (Brown, et al. 1993) which is the standard data format for the early Earth Observing System Data and Information System (EOSDIS). HDF is discussed in detail in Section 4, "Reading the Data" and Appendix E, "HDF Basics."

Table 1-1
Product Summary

Data Product	Data Layers per file	Dimensions (columns x rows)	Format	Compressed / Uncomp. size
Daily Data Set	12	5004 x 2168	HDF (SDS)	35 MB / 228 MB
Composite Data Set	12	5004 x 2168	HDF (SDS)	35 MB / 228 MB
Ancillary Data File	4	5004 x 2168	HDF (SDS)	18 MB / 50 MB
Climate Data Set	1	360 x 180	HDF (SDS)	12 KB / 66 KB
Browse Images	2	625 x 271	HDF (RIS8)	95 KB / 342 KB
Calibration Extracts	n/a	n/a	NOAA 1b	5 MB