MODIS Reprojection Tool User's Manual

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Introduction

The Terra Moderate Resolution Imaging Spectroradiometer (MODIS) was launched into space as part of NASA's Earth Observing System platform in December 1999. In addition, Aqua MODIS was launched in May 2002. The objective of MODIS is to provide a comprehensive series of global observations of the Earth's land, oceans, and atmosphere in the visible and infrared regions of the spectrum.[1] These observations are critical for studies of climate, vegetation, pollution, global warming, and many other important economic and environmental issues.

MODIS imagery (versions 001, 002, and 003), however, is in a new map projection called the Integerized Sinusoidal (ISIN) projection, which is not supported by most existing software packages. Native MODIS data files are stored in HDF-EOS (Hierarchical Data Format – Earth Observing System), a file format that does not currently have wide support.[2] Version 004 MODIS data has been released in the Sinusoidal projection. (The MODIS Reprojection Tool supports both versions and projections.)

The MODIS Reprojection Tool (MRT) is software designed to help individuals work with MODIS data by reprojecting MODIS images (Level-2G, Level-3, and Level-4 land data products) into more standard map projections. If desired, the user may reproject only selected portions of the image (spatial subsetting) and only selected image bands (spectral subsetting). The software outputs MODIS data in file formats that are supported by existing software packages (raw binary and GeoTIFF) as well as HDF-EOS. The MODIS Reprojection Tool runs on several platforms, including Sun Solaris workstations, SGI IRIX workstations, Linux, and Microsoft Windows. The look and feel of the software is retained across the different platforms.

The heart of the MODIS Reprojection Tool is the *resampler* and *mrtmosaic*, executable programs that may be run either from the command-line or from the MRT Graphical User Interface (GUI). The GUI is an easy, user-friendly way to run the MODIS Reprojection Tool. However, individuals with serious data processing requirements are advised to investigate the more powerful command-line interface, which allows background processing of large MODIS data files when the system load is light. This User's Manual describes how to run the *resampler* and *mrtmosaic* both from the command-line and from the GUI.

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[1] More information about MODIS may be obtained on the Web at http://modis.gsfc.nasa.gov/.
[2] More information about HDF and HDF-EOS may be obtained on the Web at http://hdf.ncsa.uiuc.edu and http://hdfeos.gsfc.nasa.gov, respectively.

MODIS Reprojection Tool Capabilities

MODIS Data Products
The MODIS Reprojection Tool currently allows the user to reproject all gridded (Level-2G, Level-3, Level-4 land products) MODIS data products. Support for swath (Level-1 and Level-2) data products is currently being implemented.

Map Projections
The MODIS Reprojection Tool allows the user to reproject to and from the following map projections:

- Albers Equal Area
- Equirectangular
- Geographic
- Hammer
- Integerized Sinusoidal
- Interrupted Goode Homolosine
- Lambert Azimuthal
- Lambert Conformal Conic
- Mercator
- Mollweide
- Polar Stereographic
- Sinusoidal
- Transverse Mercator
- Universal Transverse Mercator

ISIN-Enhanced GCTP
As part of this software, the Generalized Cartographic Transformation Package (GCTP) has been modified to incorporate the new Integerized Sinusoidal Projection.

Spectral subsetting
Any subset of the input bands may be selected for reprojection. The default is to reproject all input bands. (Note: the term "band" is used interchangeably with the HDF-EOS term "Scientific Data Set" throughout this document.)

Spatial subsetting
Two corners (upper left and lower right) of a rectangle in input/output space may be specified. These corners may be given as coordinates in input latitude and longitude, input line/sample pairs, or output projection coordinates. If specifying line/sample pairs specify as (start line, start sample) and (end line, end sample), using a zero-based coordinate system where the upper left corner is (0, 0). When specifying input lat/long or input line/sample, the other two rectangle corners (upper right and lower left) are computed automatically in input space. Then all four corners are reprojected into output space, using the specified map projection and datum. Finally, a minimum-bounding rectangle is computed that contains the four reprojected points, in output space. All points

inside this rectangle in output space are mapped back into input space for reprojection. The default is to reproject the entire input image.

When specifying output projection coordinates, specify as (start projection x, start projection y) and (end projection x, end projection y). These coordinates must be specified in the same units as is used for the projection (degrees for geographic and meters for all other projections). The upper right and lower left corners are computed from the specified upper left and lower right corners to create a rectangle in output space. Using these coordinates in output space, the corners are mapped back into input space to determine the spatial subset corners in input space. The output image corner coordinates should match the user-specified output spatial subset corners, exactly.

Resampling
Resampling may be nearest neighbor, bilinear, or cubic convolution. Background fill values are supported. If the majority of values that lie under the resampling kernel are background fill values, then a background fill value is output. Otherwise, resampling is performed only from non-background fill values, and kernel weights are adjusted accordingly. When resampling from the Integerized Sinusoidal projection, the ISIN shift is handled in the resampling process. (See the ISIN Shift section later in this User's Guide for more information.)

ISIN Shift
ISIN data has a shift between lines on a per pixel basis. This shift is linear per line. Thus, the slope of the shift can be calculated by determining the shift for the first pixel and the shift for the last pixel in a line and dividing by the number of pixels in that line. The MRT resampling processes account for this pixel shift (as of Version 3.0) in the Nearest Neighbor, Bilinear, and Cubic Convolution resampling processes. The shift for SDSs of the same resolution are the same. The shifts will be recalculated when a new resolution is encountered in the image. Shift statistics are output for the user. It is important to note that the shift handling slows down the resampling process, so the user will see a slow-down in the MRT processing times compared to previous MRT versions.

Datum Conversions
A limited number of input and output datums are supported by the MRT for datum conversions. Supported datums are NAD27, NAD83, WGS66, WGS72, and WGS84. (See the Datum Conversions section later in this User's Guide for more information.)

Output Pixel Size
An output pixel size may be specified. If specified, this output pixel size will be used for all bands. The default is to use the same input and output pixel sizes for corresponding input and output bands. For output to the Geographic projections, the pixel size must be specified in decimal degrees. For output to all other projections, the pixel size must be specified in meters.

Data Types
The MODIS Reprojection Tool supports 8-bit, 16-bit, and 32-bit integer data (both signed and unsigned), as well as 32-bit float data. The output data type is the same as the input data type for each corresponding SDS.

File Formats
HDF-EOS and raw binary files are supported on input. The MRT will only support MODIS Level-2G, Level-3, and Level-4 land data products for HDF-EOS products. Swath data products (Level-1 and Level-2) are not supported by the MRT. HDF-EOS, GeoTIFF, and raw binary files are supported on output. The raw binary file format is specified in Appendix B.

Corner Coordinates
The output corner coordinates for HDF-EOS use the HDF standard, which is the outer extent of the UL and LR corners. The output corner coordinates for the raw binary header also represent the outer extent of the pixel. The output UL corner specified for GeoTIFF format refers to the center of the pixel. And, any output corner coordinates specified by the GUI, in the status box, or by the command line, in standard output or to the log file, represent the outer extent of the pixel as well.

3-Dimensional and 4-Dimensional Data Products
Modis HDF-EOS data products are not only 2-Dimensional, but also 3-Dimensional and 4-Dimensional. The MRT supports 3D and 4D data products and currently outputs them to 2D data products for raw binary, GeoTiff, and HDF-EOS output formats.

The naming convention for the 3rd and 4th dimension slices are as follows:
$<SDS\ name>.<3^{rd}\ dimension\ name>\_\#.<4^{th}\ dimension\ name>\_\#$
where # is a two-digit value representing the data slice for the associated dimension. Obviously if the product only has three dimensions, the $<4^{th}\ dimension\ name>\_\#$ will not appear. This naming convention is used for the output filenames, the output HDF-EOS SDS names, and the band names in the GUI.

The 3D and 4D naming convention produces long names when the SDS name, 3rd dimension name, and 4th dimension name are all of substantial length themselves. Currently the HDF-EOS library for the Windows platform will only support 57 characters for SDS names, which produces problems with our naming convention on the Windows platforms. For the Windows platforms, only if the output SDS name is going to be longer than 57 characters, the naming convention is then changed to
$<SDS\ name>.3\_\#.4\_\#$
to produce smaller output SDS names.

Format Conversion
The MRT provides an option to convert an input file to a different format. The possible input and output formats are described in File Formats above. The Format Converter will support spectral and spatial subsetting. When doing format conversion, the resampling process will be skipped. The output projection type and output projection parameters are

not needed, and will be ignored if specified. In format conversion the output projection type is the same as the input projection type, and the output projection parameters are the same as the input projection parameters. The output pixel size (if specified will be ignored) remains the same as the input pixel size, as does the output data type.

Mosaic Tool
The MRT provides an option to mosaic several tiles together before reprojecting them. Mosaicking is done automatically in the MRT GUI by selecting several filenames for the input filename. The input files are mosaicked first, then reprojected. Mosaicking can also be done via the command line using the *mrtmosaic* executable. (See the mosaic section later in this User's Guide for more information.)

Platforms
The MODIS Reprojection Tool is highly portable software. It currently runs on five different platforms:

- Windows 95/98/2000/ME/XP
- Windows NT
- Linux
- Sun/Solaris
- SGI/Irix

Consult the Release Notes for platform-specific differences and caveats.

Interfaces
The MODIS Reprojection Tool may be invoked either from a user-friendly GUI or from a powerful command-line interface. The GUI allows novices and users with light processing requirements to reproject MODIS imagery. The GUI also allows easy inspection of metadata. The scriptable command-line interface, with its variety of command-line options, is likely to be the method of choice for reprojecting large numbers of files.

MODIS Reprojection Tool Installation

To obtain the MRT software, download the appropriate installation files for your specific platform from the USGS EROS Data Center MODIS Reprojection Tool Web site (http://lpdaac.usgs.gov/landdaac/tools/modis/index.asp). The installation files include a zip archive containing the MRT software, an installation script, and an executable file named unzip[3]. (On the Windows platform, there will be several other executable files that also need to be downloaded. When downloading the *install.win* and other text files, ensure your browser is saving the file as type "All Files" not "Text Document". If the type is left as "Text Document" the file will be saved as *install.win.bat* or *install.win.txt* and will need to be renamed to *install.win*.) If using the automatic installation, the MRT_<platform>.zip file should <u>not</u> be unzipped manually, since the installation script will handle the unzip.

Once you have obtained the MODIS Reprojection Tool software, it needs to be installed on your system. You can install the MRT software with either an automatic installation process or a manual installation process. The automatic installation process is recommended for most users. Instructions for both methods are outlined below.

Installation requires that the zip archive be unpacked into an appropriate directory on your system. This process will create an MRT directory containing several subdirectories (bin, data, doc, gctp, geolib, include, JavaGuiSrc, lib, src). Once the software has been unpacked, the MRT bin directory needs to be added to your path, and an environment variable named MRTDATADIR needs to be set to the MRT data directory.

In order to run the MODIS Reprojection Tool GUI, you must have a current version of Java[4] installed on your system (at least the Java 2 Runtime Environment version 1.3/1.4 or the Java 2 SDK version 1.3 or later). If you do not plan to use the MRT GUI, and only intend to use the command-line interface, then Java is not required for your installation.

In order to install the MRT GUI, you must know the path to your Java directory. On Unix systems, you can type *which java* to determine the path to your current Java executable. This method will only work if the Java executable is on your path. You can also try typing *find / -name java*, but this will search all mounted file systems and may take a while to complete. If necessary, ask your system administrator where the Java bin directory is located.

To determine the Java bin directory on Windows, click on the Windows Start button and select Find, Files or Folders... Fill in the dialog box to search all local hard drives for a file named *java.exe*. Make note of the directory containing the most recent version of

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[3] Unzip and zip are freeware packages available from GNU. For more information, or to obtain the zip/unzip software, see the GNU Web site at http://www.gnu.org/software/software.html.
4 Java software for all platforms may be downloaded from the Sun Microsystems Web site at http://java.sun.com/j2se/.

java.exe. If *java.exe* does not appear in the Find Files listing, then Java may not be installed on your system.

If the Java executable is on your path, you can tell which version of Java is installed on your machine by typing *java –version*, which will give you an output similar to the following:

```
java version "1.3.1"
```

If the version number is older than 1.3.1, the MRT GUI is not guaranteed to work with your version of Java. In this case, you should install a newer version of Java.

Automatic Installation

For automatic installation, you must be able to supply the following information:

- The complete pathname of the directory in which you want to install the MRT. This pathname is not necessary if you want to install the MRT in a Modis subdirectory in the current directory (the default).

- The pathname of the directory containing the Java executable program (*java* or *java.exe*) on your system. This pathname is not necessary on UNIX platforms if the Java executable is on your path, in which case it will be found automatically. See the information at the start of the Installation section for hints on how to determine the Java bin directory.

Once you have this information, you can run the install script. Make sure you are in the directory containing the installation files (the zip archive, the unzip program, and the install script) that you have downloaded from the EDC Web site. On UNIX systems, type *./install*. On Windows, under Start/Programs open a Command Prompt screen. From the Command Prompt screen, navigate (using the cd command) to the directory where the files were downloaded and type *install*. This will execute the install.bat file. Follow the installation instructions carefully. The installation program will automatically unzip the zip archive into the MRT directory, and will prompt you for the information needed to set up your path and environment variables correctly.

Note that full pathnames must be provided for all directories. Wildcards (?,*) and relative pathnames will be accepted, but the MRT software may not be set up correctly. **The MRT will not run correctly if the installation uses directory names that include blank spaces, including Windows platforms.**

Automatic Installation Instructions for Unix Platforms

On Unix systems, the automatic installation process will modify the file named ModisTool in the MRT bin directory. The ModisTool shell script is used to run the MRT GUI. This file will be modified to reflect the directory paths for the install directory and the Java directory, as specified by the user in the installation process.

The automatic installation process also adds the MRT bin directory to your path, and sets the MRTDATADIR environment variable to the MRT data directory. If the current directory is not in the path (this is, oddly enough, the default on many UNIX systems), you will not be able to run the MRT even when the MRT executables are in the current directory.

Setting your path and the MRTDATADIR environment variable is accomplished by modifying the startup scripts for the most common UNIX shells (csh, tcsh, sh, and bash). For example, let us assume you have installed the MRT in the Modis subdirectory in your home directory. For csh and tcsh users, the following lines are appended to the .login file in your home directory:

```
set path = ( $path $HOME/Modis/bin )
setenv MRTDATADIR $HOME/Modis/data
```

For sh and bash users, the following lines are appended to .profile and .bash_profile files in your home directory:

```
PATH=$PATH:$HOME/Modis/bin
MRTDATADIR=$HOME/Modis/data
export MRTDATADIR
```

These changes will not take effect until you have started up a new login session. Note that each new installation keeps appending these lines to your startup files, so you may wish to remove these lines (using any text editor) prior to a new install.

Automatic Installation Instructions for Windows Platforms

On Windows platforms, the installation process is very similar to that of UNIX platforms. Note that directory pathnames must be entered into the install script with forward slashes (/) instead of backslashes (\). For instance, c:\Modis must be entered as c:/Modis. For Windows platforms, directories with blank spaces should not be used for either the MRT install directory or the Java directory. Using directories with blank spaces will cause the MRT GUI to hang when running Windows.

On Windows systems, the automatic installation process will modify the following files or user keys:

Windows 95/98/2000:
- The file ModisTool.bat in the MRT bin directory will be changed to reflect the directory paths for the install directory and the Java bin directory, as specified by the user.

- The file C:\AUTOEXEC.BAT will be changed to add the MRT bin directory to the system's path. The MRTDATADIR environmental variable will also be automatically set. The old AUTOEXEC.BAT file will be saved as AUTOEXEC.MRT. (Note that each new installation keeps adding statements to the current AUTOEXEC.BAT file.)

Windows NT/ME/XP:
- The file ModisTool.bat in the MRT bin directory will be changed to reflect the directory paths for the install directory and the Java bin directory, as specified by the user.

- The HKEY_CURRENT_USER\Environment\PATH key will be modified to add the MRT bin directory to the system's path. If the PATH key does not exist, it will be created. The MRTDATADIR user key will also be created under HKEY_CURRENT_USER\Environment.

On any platform, if automatic installation fails, try running the install script again, correcting any input errors. Alternatively, you may follow the instructions listed below to manually install the software.

Manual Installation

There are four installation steps required for manual installation of the MODIS Reprojection Tool:

- Unzip the software.
- Update your path (stored in the environmental variable PATH) to include the MRT bin directory.
- Set the environmental variable MRTDATADIR to point to the MRT data directory.
- Edit the GUI script in the MRT bin directory (ModisTool on UNIX systems, ModisTool.bat on Windows) to reflect the directory structure of your system.

Manual Installation Instructions for Unix Platforms

First you must unzip the MRT software, using the following command:

```
unzip zipfile -d MRT_directory
```

where zipfile is MRT_Win.zip, MRTLinux.zip, MRT_Sun.zip, or MRT_SGI.zip, depending on your target platform, and MRT_directory is the directory in which you want to install the MRT. For example, to install the MRT in the Modis subdirectory in your home directory on a Sun workstation, type

```
unzip MRT_Sun -d $HOME/Modis
```

If you get an error message saying "unzip: command not found", try typing

```
./unzip MRT_Sun -d $HOME/Modis
```

Now you must update your path to include the Modis bin directory, and set the MRTDATADIR environmental variable to point to the Modis data directory. The best way to do this is to use any text editor to modify the startup files for the shell you are running, as described in the section entitled *Automatic Installation For UNIX Platforms*. For csh and tcsh users, edit the .login file in your home directory. For sh (bash) users, edit the .profile (.bash_profile) file in your home directory. (Don't know what shell you're using? Type *echo $0* at the command prompt.)

Next, use any text editor to edit the ModisTool shell script in the MRT bin directory. In particular, you may need to change the value of the MRTDATADIR environment variable (the path to the MRT data directory), the path to the Java executable, and the path to the ModisTool.jar file (the MRT bin directory). Nothing else should be changed! To determine the Java path, follow the instructions given at the start of the MRT Installation section.

For example, in this ModisTool shell script, the Java bin directory is /usr/java/bin, and the MRT is installed in the Modis directory in the user's home directory.

```
#!/bin/sh

MRTDATADIR=$HOME/Modis/data
export MRTDATADIR

/usr/java/bin/java -Dmrtdatadir=$HOME/Modis/data -classpath
     $HOME/Modis/bin/ModisTool.jar
     edu.sdsmt.modis.ModisTool
```

Note that the statement starting with /usr/java/bin/java … is all on one line. Do not break this statement into multiple lines!

Manual Installation Instructions for Windows Systems

First you must unzip the MRT software, using the following command:

```
      unzip MRT_Win –d MRT_directory
```

where MRT_directory is the directory in which you want to install the MRT. For example, to install the MRT in C:\Modis, type

```
      unzip MRT_Win –d c:\Modis
```

Windows 95/98/2000 users must edit the AUTOEXEC.BAT file to add the path information and set the MRTDATADIR variable. Using Notepad or some other text editor, add the following two lines to the end of your AUTOEXEC.BAT file:

```
      PATH %PATH%;c:\Modis\bin
      set MRTDATADIR=c:\Modis\data
```

where `c:\Modis` is the path to MRT directory. If you installed the MRT in some other directory, then change these directory paths accordingly.

Windows NT/ME/XP users must edit their user keys. Type *regedit* at the DOS prompt. This will bring up a GUI containing your user key information. Double-click on the HKEY_CURRENT_USER key. Click on the Environment key. Your current user key environment variables and their values should be listed on the right hand side of the GUI. If the PATH or MRTDATADIR keys already exist, you can double-click on them to modify their values. Continuing with the above example, the PATH would be modified to add c:\Modis\bin to the end of the current string. Use a semi-colon to separate directories in your path. The MRTDATADIR should be set to c:\Modis\data, removing any previous values specified for the MRTDATADIR key. If the key does not exist, the Edit/New/String Value option on the menu bar can be used to create a new user key.

On Windows platforms, it is recommended that you do not install the MRT into a directory structure containing spaces. Spaces in the directory structure cause the MRT to hang on the newer Windows platforms.

Next you need to edit the file ModisTool.bat in the MRT bin directory. You will need to update the MRT and Java bin directories to reflect the directory structure on your machine. To determine the Java bin directory on Windows, follow the instructions given at the start of the MRT Installation section. Again, it is recommended that directories with spaces in the directory name are not used.

For example, in this ModisTool.bat file, the Java bin directory is c:\winnt\jdk1.3\bin, and the MRT is installed in the c:\Modis directory.

```
set MRTDATADIR=c:\Modis\data

"c:\winnt\jdk1.3\bin\java.exe" "–Dmrtdatadir=c:\Modis\data"
      -classpath "c:\Modis\bin\ModisTool.jar"
      edu.sdsmt.modis.ModisTool
```

Note that the statement starting with `"c:\winnt...` is all on one line. Do not break this statement into multiple lines!

Adding a Shortcut Icon in Windows

The MRT has an icon file in the Windows distribution package. It is located in the Modis bin directory. You can create a shortcut icon for the MRT and use the MRT icon on the Windows platforms. To create a shortcut icon follow these steps:

- ➢ Click the right mouse button on your desktop
- ➢ Select New → Shortcut
- ➢ Type in the path and name for the ModisTool.bat file (you can also use the Browse button to find the ModisTool.bat file, which should be in your Modis bin directory)
- ➢ Select Next
- ➢ Type the name of your shortcut (i.e. ModisTool3.0, MRT3.0, etc.)
- ➢ Select Finish
- ➢ Right click on the shortcut icon that was just created
- ➢ Select Properties
- ➢ Select the Shortcut tab
- ➢ Press Change Icon
- ➢ Type in the path and name for the ModisTool.ICO file (you can also use the Browse button to find the ModisTool.ICO file, which should be in your Modis `bin` directory)
- ➢ Press OK

The MRT icon should now be available on your desktop. If you double-click on this icon, the MRT GUI should appear. Please note that the default directory when using the MRT icon, which points to the ModisTool.bat file in the Modis `bin` directory, will be the Modis `bin` directory. Thus, the log file and MRT temporary files will automatically be written to the MRT `bin` directory.

Parameter Files

Regardless of how it is invoked (via the GUI or the command-line), a parameter file controls the MODIS Reprojection Tool. The parameter file contains all the information necessary to read MODIS data from an input data file, transform the data into a specified output projection, and write the results to an output file. The parameter file contains the file names and file types of the input and output data files, spectral and spatial subsetting information, output projection type, output projection parameters, output UTM zone, output resampling type, and output pixel size. Parameter files are ASCII text, and may be created and edited either in the MODIS Reprojection Tool GUI or by any text editor. The parameter file format is described fully in Appendix A. Parameter files should have a .prm extension.

Here is an example of a parameter file:

```
INPUT_FILENAME = MOD13A2.A2000273.h12v04.002.2000324050900.hdf

SPECTRAL_SUBSET = ( 1 0 1 0 0 0 0 0 0 0 )

SPATIAL_SUBSET_TYPE = INPUT_LAT_LONG
SPATIAL_SUBSET_UL_CORNER = ( 40.0 -130.527874 )
SPATIAL_SUBSET_LR_CORNER = ( 30.0 -103.921841 )

OUTPUT_FILENAME = MOD13LA.hdf

RESAMPLING_TYPE = BILINEAR

OUTPUT_PROJECTION_TYPE = LA

DATUM = NODATUM

OUTPUT_PROJECTION_PARAMETERS = ( 6370997.0 0.0 0.0 0.0 -100.0 45.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 )

OUTPUT_PIXEL_SIZE = 1000
```

This parameter file specifies that the input data file is MOD13A2.A2000273.h12v04.002.2000324050900.hdf, the input file type is HDF-EOS (from the input file extension), bands 1 and 3 will be reprojected to Lambert Azimuthal using bilinear resampling, the output pixel size is 1000 meters, and output will be written to the HDF-EOS file MOD13LA.hdf. The output file type is HDF-EOS (from the output file extension). Note that the term "band" refers to a Scientific Data Set (SDS) element.

Log File

The MRT writes logging and status information to the screen and also to a log file. The log file is named resample.log, and is written into the current directory (i.e., the directory in which the MRT is run). Logging information is appended to resample.log at the completion of every run. resample.log is an ASCII text file, and may be edited or printed with standard text file tools.

The command-line version of the resampler will allow the user to specify the path and name of the resample.log file, using the –g option. The options for the resampler are fully described later in the "MODIS Reprojection Tool Command-Line Interface" section.

Datum Conversions

Handling Input and Output Datums

This section will discuss the handling of datums and datum conversions in the MODIS Reprojection Tool (MRT). There are two considerations for datums: handling datums appropriately for the input data and converting to a specified datum for the output data. The MRT currently supports NAD27, NAD83, WGS66, WGS72, and WGS84 datums for both input and output. If no datum conversion is desired, then the user may use NODATUM to specify no datum conversion.

The MRT supports HDF-EOS, GeoTiff, and raw binary data formats for output. The user will now be able to specify the output datum as part of the output parameters for the MRT. Both the GUI and command-line version of the MRT allow the user to specify an output datum. The GUI uses a datum drop-down box to allow the datum to be specified. This drop-down box has "No Datum" set as the default. The user may select another value in the drop-down list, if other values are available. If the user is reprojecting to a sphere-based projection, then datum conversions are not allowed and the "No Datum" option will be the only option in the drop-down list.

If the command-line version is being used, then the datum should be specified using the DATUM parameter in the parameter file. Again, any of the datums listed above may be specified or the "NODATUM" option can be specified. If no value is provided for the DATUM in the parameter file, NODATUM will be used as the default.

If the "No Datum" option is selected, then the user must specify the spheroid information in the projection parameters. For all the MRT-supported projections, except UTM and Geographic, the first two projection parameters specify the semi-major and semi-minor axis (or the radius of the sphere for sphere-based projections) of the desired spheroid. If the "No Datum" option is selected and the semi-major and semi-minor axes are not specified in the projection parameters, then the MRT will exit with an error.

It is important for the user to understand that if the "No Datum" option is used, then the output data product will not contain any datum information. (This is required for sphere-

based projections, since technically they do not have a datum.) The data product may still be "referenced to" a datum, but that datum information will not be noted anywhere within the output product. Instead information pertaining to the spheroid will be provided in the output data product. It will be up to the user to keep track of the datum to which the data is referenced, especially for sphere-based projections. In addition, the GCTP/Geolib software prevents datum conversions when an initial datum is not known. Thus, if a product is output without a datum that product can no longer be converted to another datum using the MRT software.

Since the first two projection parameters and the datum specify the semi-major and semi-minor axes of the spheroid, only one of these may be specified. Thus, if a datum is specified and the semi-major and semi-minor axes are specified in the projection parameters, the MRT will exit with an error. It is important to note that the current GCTP package automatically uses the radius of Sphere 19 for any sphere-based projections, except for Sinusoidal and Integerized Sinusoidal. Until this is fixed in GCTP, if the user needs to specify a radius other than that used for Sphere 19, the "No Datum" option must be used. For Integerized Sinusoidal and Sinusoidal projections, the user is allowed to specify their own sphere radius values.

The datum value will be used as output to HDF-EOS, GeoTiff, and raw binary data files. The datum will be specified in HDF for the HDF-EOS files, since HDF-EOS does not support datums. (HDF-EOS files are assumed to be referenced to WGS84 according to the HDF-EOS documentation.)

The MRT supports both HDF-EOS and raw binary data formats for input. As previously mentioned, the raw binary header file will contain a DATUM parameter for input raw binary data. The MODIS Level-2G and Level-3 land products are formatted as HDF-EOS data files in the ISIN projection (using the WGS84 datum if a datum conversion is specified). Since the MRT will create HDF-EOS files with datum information in HDF, the MRT will need to support these files on input. Thus, input HDF-EOS files will be checked for the DATUM tag (previously written by the MRT) in HDF. If that tag exists, then the specified datum value will be used. Otherwise, HDF-EOS input files will, by default, be in the WGS84 datum.

As with the output data files, a "No Datum" option will be supported for input files. If this option is specified, then the semi-major and semi-minor axes must be specified in the projection parameters. If these axes are not specified and the "No Datum" option is used, then the MRT will exit with an error.

Datum Conversions

Once the MRT knows the input and output datums and has verified that the datum/projection parameter combinations are valid, then the reprojection and datum conversion must be handled. The following are the steps that will be followed by the MRT to reproject the input ISIN data to the specified output projection and datum.

1. Project the input data to the Geographic projection, using GCTP.
2. Convert from the input datum to the output datum, in the Geographic projection.

3. Project from the Geographic projection to the output projection.

Both steps 2 and 3 are handled by the same call to Geolib. If the input data is not in the ISIN projection, then a single call to Geolib will handle the reprojection and datum conversion.

Bounding ISIN Tiles

Bounding ISIN tiles have provided some difficulties for the MRT. These tiles are the tiles on the outer edge of the following diagram of the ISIN projection.
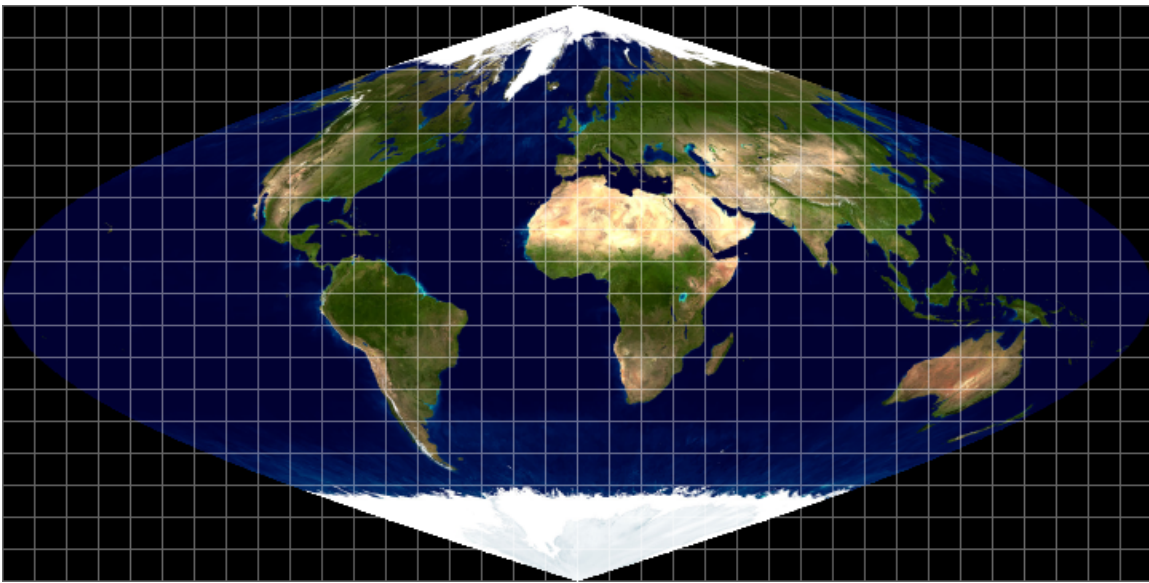
The tiles in the ISIN projection are labeled from top to bottom and from left to right starting at 00. The horizontal tiles range from h00 to h35, and the vertical tiles range from v00 to v17. Oftentimes a MODIS HDF-EOS filename will contain `.h##v##.` This specifies the horizontal and vertical location of the tile. For example, the tile which contains the state of Florida, USA, is h10v06, and the tile which contains the southern tip of Africa is h19v12.

The ISIN bounding tiles are unique in that they contain corner points with projection coordinates that do not map to a valid latitude/longitude. In this case, the MRT will issue a warning to the user to notify that a certain corner point does not have a valid latitude/longitude. To work around this issue, the MRT uses the bounding rectangular coordinates from the metadata as the corner points for the tile. Different products put these bounding rectangular coordinates in different metadata structures, so the StructMetadata, CoreMetadata, and ArchiveMetadata are all read and searched for the bounding rectangular coordinates. Once they are found, the other structures are not searched.

For example, the MOD09A1 products store their bounding rectangular coordinates in the ArchiveMetadata structure, but the MOD12Q1 data products store their bounding rectangular coordinates in the CoreMetadata structure.

It is important for the user to note that using these bounding rectangular coordinates often times adds extra data (mostly fill data) to the output image. These coordinates are not the exact coordinates of the original tile, thus the output image will not exactly match the input image. The bounding rectangular coordinates are used to create a rectangle in input latitude/longitude space, which is then output to the output projection space. This is opposed to using the exact latitude/longitude corners of the image to create a rectangle in input space. The bounding rectangular coordinates rectangle will be much larger than the rectangle based on the exact corner points. This will also be the case when implementing a format conversion on a bounding tile.

Crossing the International Dateline

The only time a tile should "cross the international dateline" is for bounding ISIN tiles, unless the user inputs erroneous subset values. In some cases for the bounding ISIN tiles, the bounding rectangular coordinates are reported such that they cross the international dateline. For example, the bounding rectangular coordinates reported for the file MOD09A1.A2001001.h30v13.001.2001088044433 are

NORTHBOUNDINGCOORDINATE = -40.000000
SOUTHBOUNDINGCOORDINATE = -48.189583
EASTBOUNDINGCOORDINATE = -180.000000
WESTBOUNDINGCOORDINATE = 156.651809

In the case of coordinates crossing the international dateline, the MRT will find the longitude value that is closest to the dateline and change its sign. In this case, the EASTBOUNDINGCOORDINATE would be changed from −180.0 degrees to +180.0 degrees. This information will also be printed as a warning to the user.

Now that the MRT also supports mosaicking several tiles together, crossing the international dateline will be more common. Even for mosaicked tiles, it will still be the case that the MRT cannot support crossing the dateline and will change the sign on the longitude value closest to the dateline.

Metadata

Metadata (the embedded metadata in the .hdf file itself) can be browsed within the GUI. Output file metadata support is currently limited to HDF-EOS files only. The output HDF-EOS file contains the output metadata, followed by the original input file metadata. The input structure, core, and archive metadata information is stored under the HDF attributes OldStructMetadata, OldCoreMetadata, and OldArchiveMetadata, respectively.

When mosaicking tiles, the MRT will output the structure, core, and archive metadata for each of the input tiles. The metadata is renamed to add the tile location in the overall mosaic. Thus the tile which resides in row 0 and column 3 of the output image will specify that information in the output structure, core, and archive metadata names.

MODIS Reprojection Tool Command-Line Interface

This section of the User's Manual describes how to run the MRT from the command-line. The command-line version of the MRT is invoked by running the *resample* program.

Typing *resample* at the command prompt results in a brief usage message, listing various command-line options to the resampler:

```
MODIS Reprojection Tool v3.2 April, 2004

Usage: RESAMPLE -p parameter_file [options]

Options that override parameter file specifications:
   -i input_file_name
   -o output_file_name
   -r resampling_type [NN BI CC NONE]
   -t projection_type [GEO HAM IGH ISIN LA LCC MOL PS SIN TM UTM]
   -j projection_parameter_list ["p1 p2 ... p15"]
   -s spectral_subset ["b1 b2 ... bN"]
   -a spatial_subset_type [INPUT_LAT_LONG INPUT_LINE_SAMPLE
                           OUTPUT_PROJ_COORDS]
   -l spatial_subset ["ULlat ULlong LRlat LRlong"]
               -or-  ["ULline ULsample LRline LRsample"]
               -or-  ["ULprojx ULprojy LRprojx LRprojy"]
   -u UTM_zone
   -x pixel_size
   -g filename for the log file

Usage: RESAMPLE -h file.hdf
       creates raw binary header file TmpHdr.hdr
```

The only required command-line argument is the parameter file name. To run the resampler from the command-line, type:

```
resample -p parameter_file5
```

The command-line MRT is designed to be fully scriptable for batch processing of MODIS data. For example, given a number of MODIS files in HDF-EOS format, you might create a parameter file for each one, with the same name as the input file but with the .prm extension appended to the input file name. Then a script/batch file could be used to run the resampler on each input data file, containing the following lines:

```
resample -p file1.prm
resample -p file2.prm
resample -p file3.prm
     . . .
```

---

[5] See Appendix A for more information about the parameter file.

An alternative would be to use iteration such as the following Unix Bourne shell for loop:

```
for i in *.hdf
do
        resample -p $i.prm
done
```

Since for and foreach are not available in DOS, Windows users must create a batch file (.bat file) containing the resample commands. For example, if the following are contained in a file called *modisproc.bat*, then the Windows user would type '*runme*' at the DOS prompt to execute the batch file. (NOTE: the last command in this example should be contained all on one line in the batch file. Since the page is not wide enough to show the command on one line, it wraps to the second line.)

```
resample -p TmpParam.prm
resample -p TmpParam2.prm
resample -p TmpParam.prm -i
MOD10A1.A2001077.h12v04.003.2001192020807.hdf -o out.hdf
```

Command-Line Options

In addition to the required parameter file argument, there are a number of optional arguments to the command-line MRT. These optional arguments provide no additional functionality, but do make it easier to control the resampler. In particular, they may greatly reduce the number of parameter files that are needed for batch processing of MODIS data.

The optional arguments are designed to override fields in the parameter file. Consider a scenario in which you wish to process a number of MODIS input data files, performing essentially the same operations (transformation to a different output projection, spectral subsetting, spatial subsetting, etc.) on each data set. Rather than creating a different parameter file for each input data product (a tedious and error-prone process at best), you may generate a single parameter file, and then override the input and output filename fields via command-line arguments.

Consider the following shell iteration:

```
for i in *.hdf
do
        resample -p prmfile.prm -i $i -o `basename $i hdf`tif
done
```

This example reprojects every HDF-EOS file in the current directory using the single parameter file *prmfile.prm*, writing output to GeoTIFF files with the same base filename as the input file.

The optional command-line arguments to the resampler are the following:

-i input_filename
This option overrides the input filename field in the parameter file. The input file type is determined from the extension (either .hdr or .hdf).

-o output_filename
This option overrides the output filename field in the parameter file. The output file type is determined from the extension (.hdr, .hdf, or .tif).

-r resampling_type
This option overrides the resampling type field in the parameter file. Values for *resampling_type* are NN, BI, CC (nearest neighbor, bilinear, cubic convolution).

-t output_projection_type
This option overrides the output projection type field in the parameter file. Values for *output_projection_type* are AEA, ER, GEO, HAM, ISIN, IGH, LA, LCC, MERCAT, MOL, PS, SIN, UTM (Albers Equal Area, Equirectangular, Geographic, Hammer, Integerized Sinusoidal, Interrupted Goode Homolosine, Lambert Azimuthal, Lambert Conformal Conic, Mercator, Polar Stereographic, Sinusoidal, Universal Transverse Mercator).

-j projection_parameter_list
This option overrides the projection parameter field in the parameter file. The *projection_parameter_list* is a quoted floating-point list of 15 projection parameters[6], with each value separated by white space ("p1 p2 ... p15"). If there are fewer than 15 values specified in the list, the remaining values will be set to zero. Integer values will automatically be converted to floating point.

-s spectral_subset_list
This option overrides the spectral subsetting field in the parameter file. The *spectral_subset_list* is a quoted binary list, with each value separated by white space ("1 0 1 0 …0"). In this list, 0 means **"don't select the corresponding band"** and 1 means "select the corresponding band". If there are fewer values in the list than input bands, the remaining bands will *not* be selected (i.e., will default to 0).

-a spatial_subset_type
This option overrides the spatial subset type field in the parameter file. Values for the *spatial_subset_type* are INPUT_LAT_LONG, INPUT_LINE_SAMPLE, and OUTPUT_PROJ_COORDS. The value specified for this field must match the type of values specified in the *spatial_subset_list*.

-l spatial_subset_list   [note: lower case L]
This option overrides the spatial subsetting fields in the parameter file. The *spatial_subset_list* is a quoted floating-point list consisting of the UL corner latitude, UL corner longitude, LR corner latitude, LR corner longitude. Alternatively, it may be a quoted integer list consisting of the start (UL corner) line, start (UL corner) sample, end

---

[6] See Appendix C for more information about projection parameters.

(LR corner) line, end (LR corner) sample. The third option is to specify the output projection coordinates of the UL and LR corners. Thus it may be a quoted floating-point list consisting of the UL projection x, UL projection y, LR projection x, and LR projection y values. Values must appear in the specified order, separated by white space.

-x pixel_size
This option overrides the output pixel size field in the parameter file.

-u UTM_zone
This option overrides the output UTM zone field in the parameter file.

-g log_filename
This option allows the user to specify the path and name of the log file. The default log filename is "resample.log".

-h HDF_filename
This creates a raw binary header file from the input HDF file. The name of the output header file is TmpHdr.hdr.

-f
This switch causes the resampler to implement format conversion. The input file format is converted to the specified output file format (based on the input and output filename extensions). No resampling is done in the format conversion. If the output projection type or projection parameters are specified, they will be ignored. The output projection type and output projection parameters are the same as the input projection type and input projection parameters. The output pixel sizes and data types remain the same as the input pixel sizes and data types. The format converter will support spectral and spatial subsetting. INPUT_FILENAME, OUTPUT_FILENAME, and OUTPUT_PROJECTION_TYPE are all required parameters in the parameter file (.prm). Even though the OUTPUT_PROJECTION_TYPE is not used in the Format Converter, it is required in the parameter file. Any valid option may be specified for this parameter. The Format Converter will ignore it during processing.

Note: All command-line options are lower case characters. These options are case sensitive.

MODIS Mosaic Tool Command-Line Interface

The MRT provides a mosaic tool (*mrtmosaic*) for mosaicking tiles together prior to resampling. The mosaic tool requires that all input files are of the same product type and they must contain the same SDS names, SDS sizes (number of lines and samples), SDS projection types and projection information, SDS pixel size, etc. If the SDS characteristics for each input tile do not match, then the mosaic tool will exit with an error.

The mosaic tool requires an input parameter file which lists the full path and filename of each input file to be mosaicked. The intput files can be listed in any order and the mosaic tool will determine how they fit together in the mosaic. The mosaic tool also requires an output filename. The file type of the output file must match that of the input files. Thus, if the input files are HDF-EOS then the output file extension must be .hdf. If the input files are raw binary then the output file extension must be .hdr.

The user may get the usage information for the mosaic tool by typing *mrtmosaic* at the command prompt.

```
Usage: mrtmosaic -i input_filenames_file -t -h -o output_filename
                 -s spectral_subset ["b1 b2 ... bN"]
                 -g filename for the log file
   where input_filenames_file is a text file which contains the
   names of the files to be mosaicked.
   If -t is specified then the tile locations of the input
   filenames are output to tile.txt (-o, -s, and -h are not needed).
   Raw binary files must specify the tile locations in the filename
   to be used with the -t switch (i.e mod09ghk_h02v16.hdr).
   If -h is specified then the mosaicked header information will
   be output to TmpHdr.hdr (-o, -s, and -t are not needed).
   NOTE: Only input Sinusoidal and Integerized Sinusoidal
   projections are supported for mosaicking.
```

Spectral subsetting is allowed when mosaicking by using the –s command-line switch. The –h switch will provide the user with header information for output mosaic. The –t switch will output the h##v## tile information for all the input files. The MODIS HDF-EOS files provide the horizontal and vertical tile information in the embedded metadata, and the mosaic tool will read the embedded metadata for that information. For raw binary files, the tile information must be specified in the filename itself. Thus if the user wants to use the –t switch with mosaic tool, the input filenames must contain "_h##v##" somewhere in the filename. The mosaic tool will exit with an error if the horizontal tile information is not available.

The status information from the mosaic tool will specify the order of the input files in the output mosaic. In the following example, `file[0]` refers to the first file listed in the parameter file. `file[1]` refers to the second file, and so on. When the input files do not provide a rectuangular output mosaic, then sections of the mosaic are filled using the Background Fill Value. `file[-9]` specifies that background fill is being used for that tile of the mosaic.

```
MODIS Mosaic Tool (v3.2 April 2004)
Start Time:  Mon Dec 16 11:18:58 2004


----------------------------------------------------------------------


Input filenames (4):
   D:\ModisSave\testdata\MOD12Q1.A2000289.h24v02.002.2001103225932.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h25v02.002.2001103225927.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h26v03.002.2001103225927.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h27v03.002.2001103231505.hdf
Output filename: D:\ModisSave\testdata\TmpMosaic.hdf
Mosaic Array:
   file[ 0]  file[ 1]  file[-9]  file[-9]
   file[-9]  file[-9]  file[ 2]  file[ 3]
Mosaic : processing band Land_Cover_Type_1
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Output mosaic image info
-----------------------
output image corners (lat/lon):
   UL:  70.000000000000 120.006250000000
   UR:  70.000000000000 180.000000000000
   LL:  50.000000000000 120.006250000000
   LR:  50.000000000000 180.000000000000

output image corners (X-Y projection units):
   UL:  6671703.118599000387 7783653.638365999795
   UR:  11119505.197665000334 7783653.638365999795
   LL:  6671703.118599000387 5559752.598833000287
   LR:  11119505.197665000334 5559752.598833000287

    band             type lines smpls pixsiz      min    max    fill
  1) Land_Cover_Type_1  UINT8  2400  4800 926.6254      0    254     255

End Time:  Mon Dec 16 11:19:09 2002

Finished mosaicking!
```

MODIS Reprojection Tool GUI

Resampling

This section of the User's Manual describes how to run the resampler from the MRT GUI. In the following discussion, it may help to think of the GUI as a parameter file editor. By filling in fields in the GUI, you are basically creating/editing a resampler parameter file.

To start the GUI, type *ModisTool* at the command prompt. A ModisTool window will pop up on the screen in a few seconds. If it doesn't, there may be an error in your setup. Make sure you logged out and logged back in after the install process.
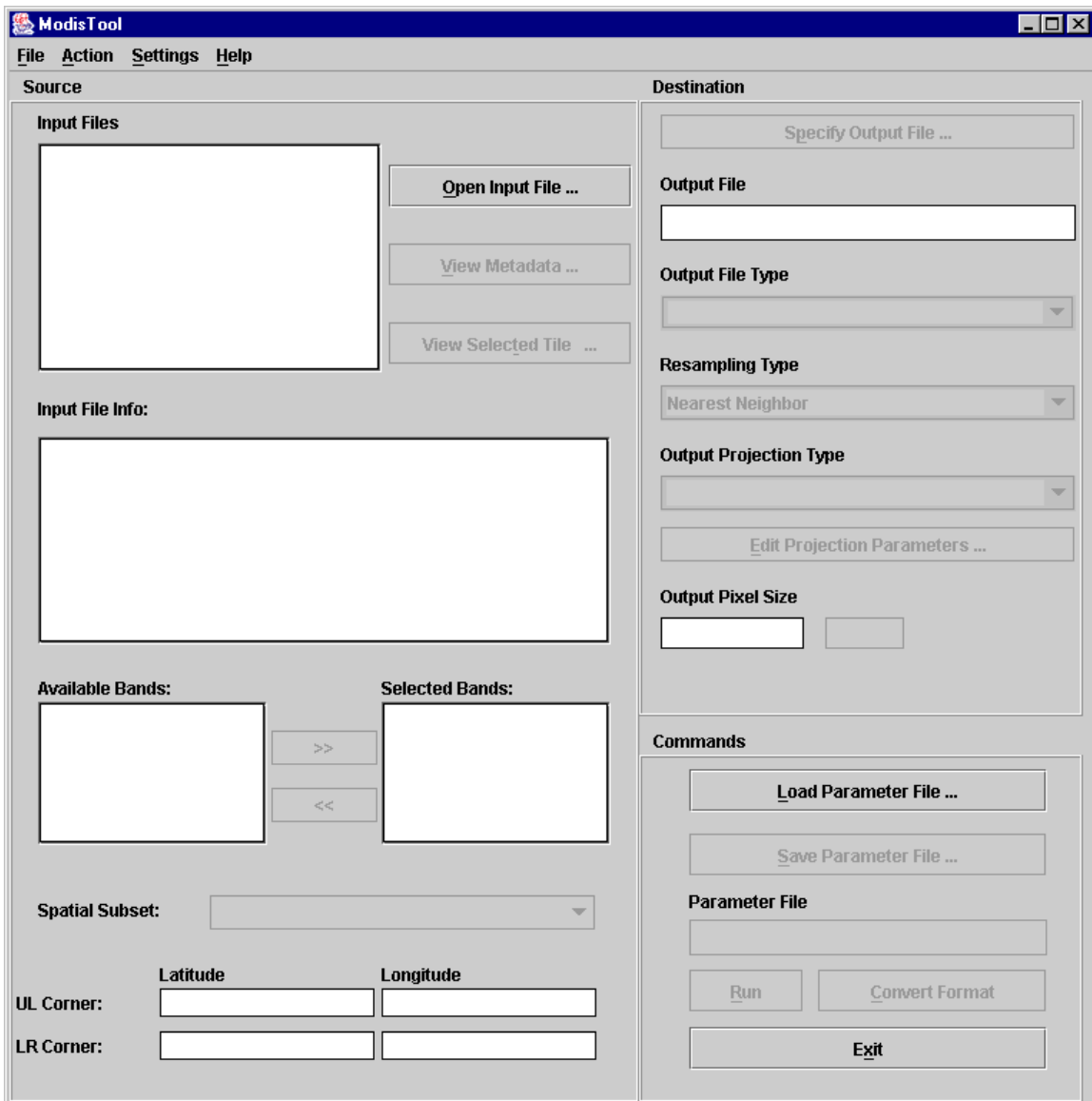
To run the resampler from the GUI, the various fields must be filled in and then the "Run" button clicked. In general, fields should be completed in roughly the order listed,

working down the left (input) side and progressing down the right (output) side. For example, you may not specify spectral and spatial subsetting until an input file(s) is opened, you may not edit output projection parameters until an output projection type is specified, etc. You may go back and change the contents of fields at any time prior to running the resampler. Simply click on the field and make the desired changes.

Let's go through a simple example of filling out the GUI fields. Suppose you need to process a MODIS file named MOD09GHK.A2000072.h08v05.001.2000084105003.hdf, which has 10 SDSs and an array dimension of 2400x2400. You wish to reproject bands 1 and 3 to the Lambert Azimuthal map projection.

Start by clicking on the "Open Input File" button to the right of the input file field. This will pop up an input file selection dialog box, allowing you to select the desired input file by pointing and left-clicking with the mouse.
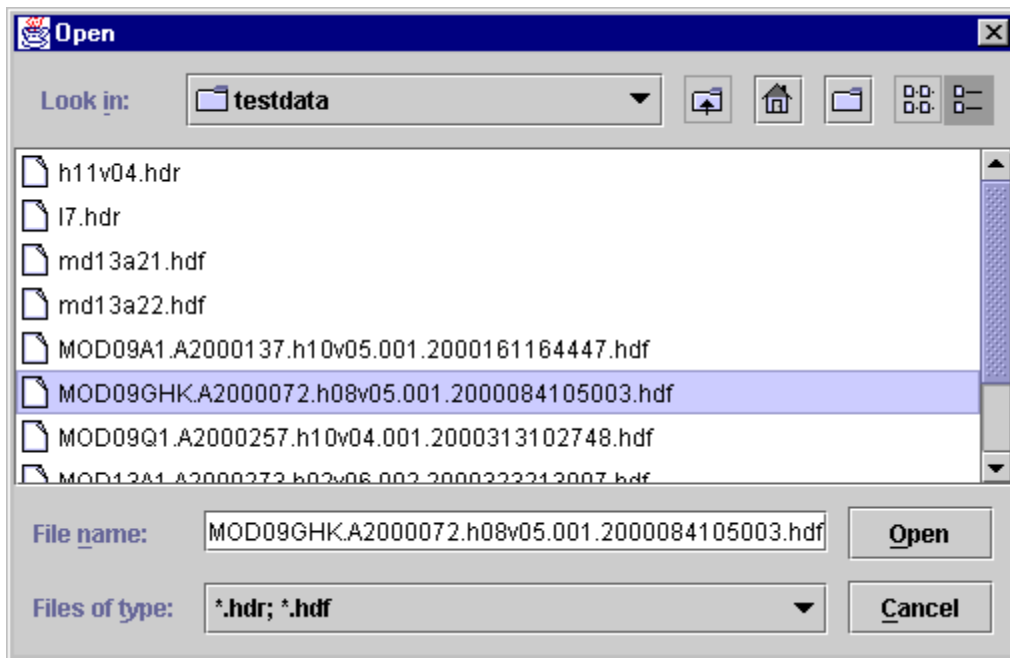
You may change the directory by clicking on the "Look in" button. You may also specify an input file by directly typing the file name into the "File name" field. When you have selected the input file, click the "Open" button to return to the main ModisTool window.

Notice the buttons to the right of the "Look in" directory field in the Open Input File dialog box. These allow you to move up a directory, move to your home directory, create a new directory folder, and switch between simple and detailed file display lists, respectively.

If you want to process several adjacent tiles at once then the MRT will allow you to select several input filenames at one time for input. This is discussed later in the mosaicking section of the User's Guide.

After selecting an input file and returning to the main ModisTool window, you may examine the internal metadata in the .hdf file by clicking on the "View Metadata" button. In addition to scrolling up and down through the metadata, you may also search for a string (note: case sensitive search). Type the desired search string into the "Find" box and click the "Find" button to perform the search. Here is an example of searching for "Latitude" in the metadata.
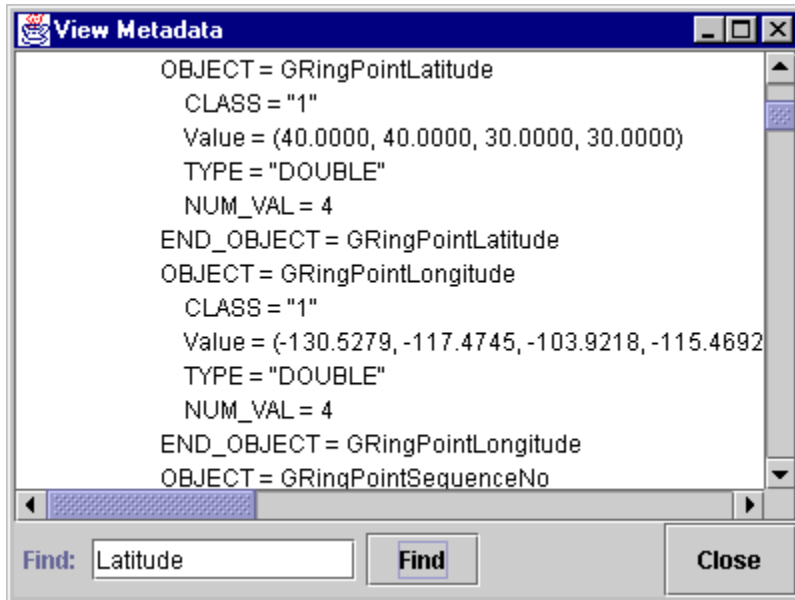
In addition to the View Metadata facility, you may examine basic input file information by scrolling the File Info box just below the Metadata buttons in the main ModisTool window. This scroll box displays the input projection type, projection parameters, corner points (in latitude/longitude), number of bands, image dimensions, pixel size, input data type, etc.

Immediately below the input file information box is the spectral subsetting area. Spectral subsetting is accomplished by clicking on the desired band and then clicking "<<" to deselect the band or ">>" to select the band. By default, all SDSs in the input image are selected. In this case we wish to deselect all but SDS 1 and 3.
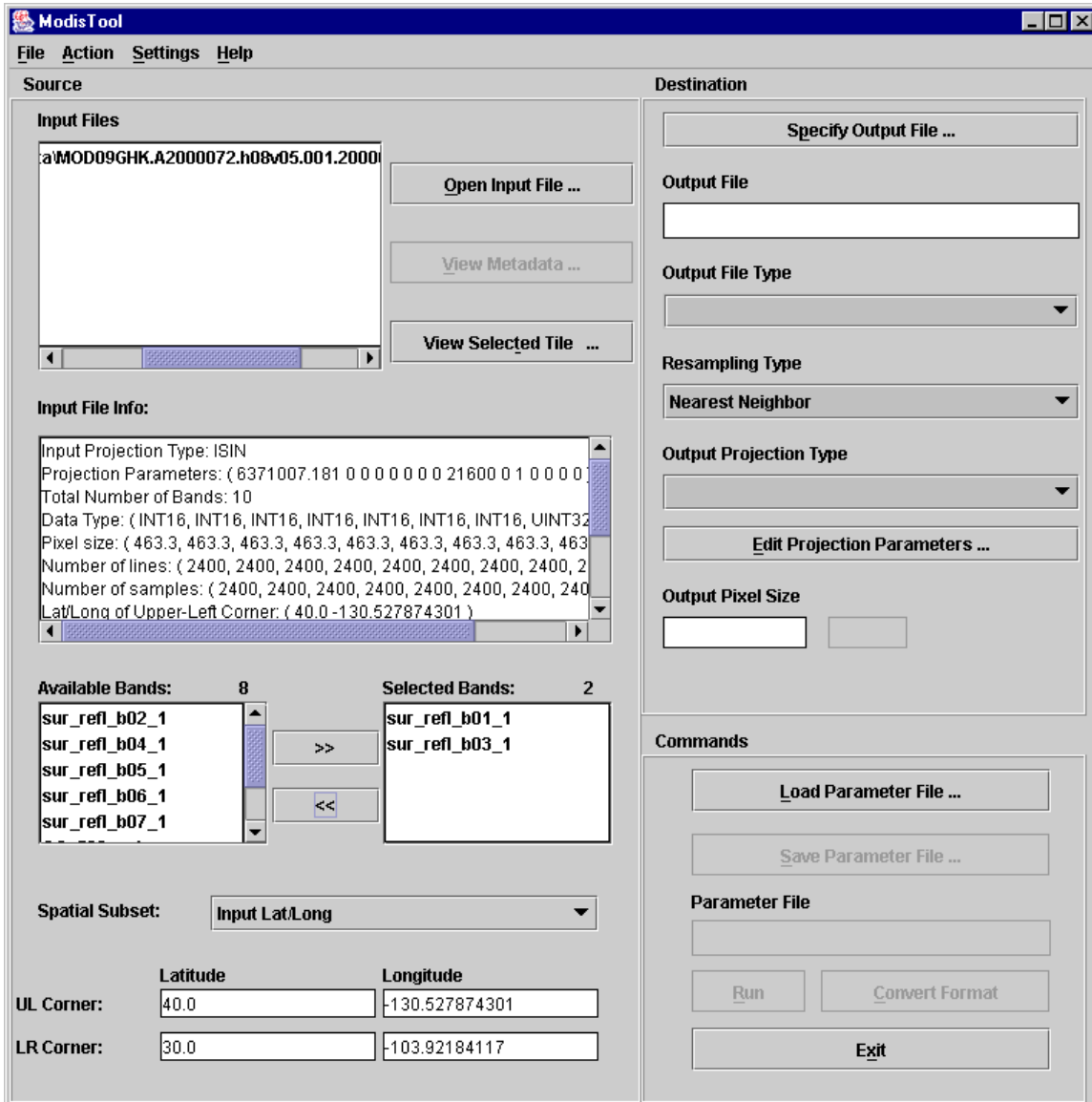
Below the spectral subsetting area is the spatial subsetting area of the ModisTool GUI. Spatial subsetting is accomplished by filling in the upper left (UL) and lower right (LR) corner coordinates of the region you wish to reproject. These two corner points specify a rectangle in the input image. Simply click on the appropriate box and enter the desired coordinate. Corners may be specified in latitude-longitude pairs or line-sample pairs or output projection x/y pairs (click on the Spatial Subset box to switch between these options). The default is to reproject the entire image using the input latitude/longitude corner points, which we will do in this example.

Returning to the main ModisTool window, specify the name of an output file by clicking on Select Output File to open the output file dialog box. You may select an existing file, or type in a new output file name, as shown below.
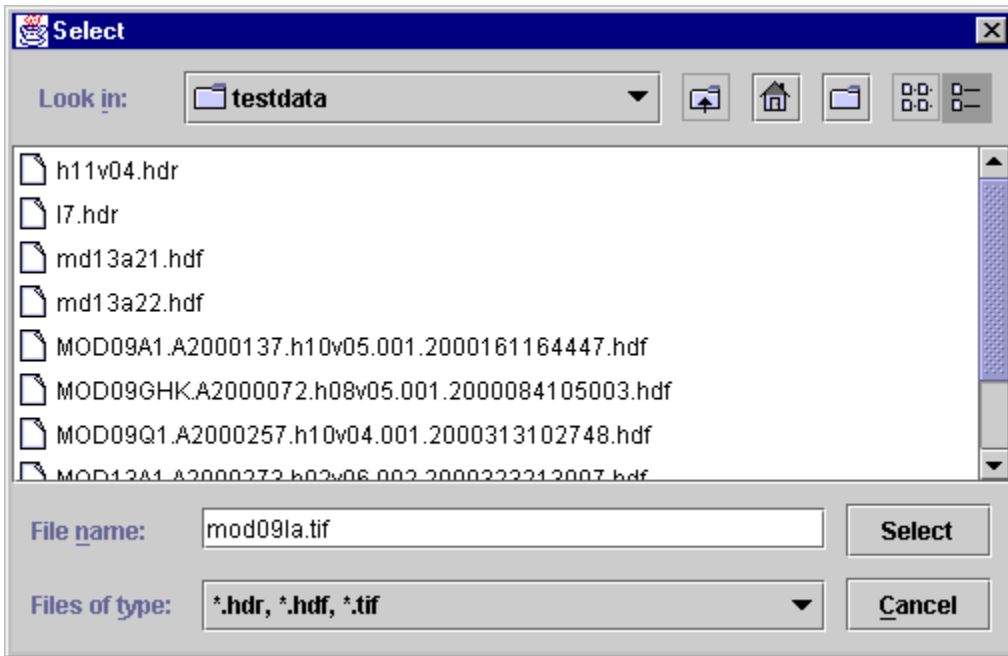
If you select an existing file (and do not modify the filename), you will be asked if you want to overwrite the existing file.

In the raw binary and GeoTIFF formats, unlike the HDF-EOS format, only one image band is stored per output file. However, the user does not need to specify a new output file name for each selected band. The band name is automatically appended to the base output file name. In this example, SDS 1 and 3 are stored in the output GeoTIFF files named mod09la.sur_refl_b01_1.tif and mod09la.sur_refl_b03_1.tif, respectively.

Now we need to specify more information about the output image by filling out fields on the right side of the main ModisTool window. If necessary, change the output file type (GeoTIFF, HDF-EOS, or Raw Binary) using the Output File Type dropdown list. The output filename extension will change automatically when you do this. Then select the resampling type (nearest neighbor, bilinear, or cubic convolution) using the Resampling Type dropdown list. Finally, select the output projection type (Geographic, UTM etc.) using the Output Projection Type dropdown list. In our example we will select the GeoTIFF output file type, bilinear resampling, and the Lambert Azimuthal output projection type.
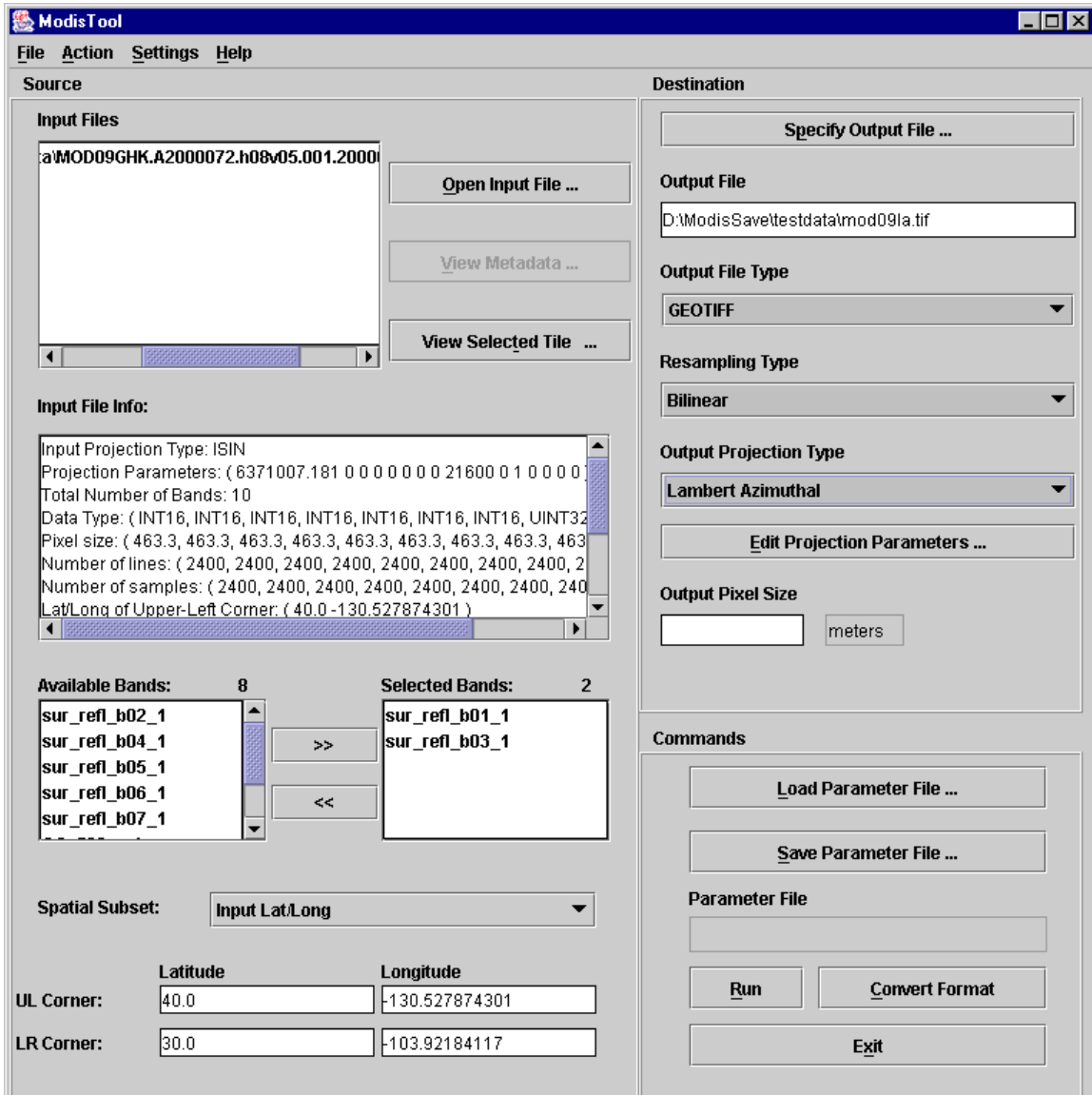
To specify the output projection parameters, click on the Edit Projection Parameters button. This will pop up the following dialog box, in which you can edit the 15 projection parameters by clicking on a field and entering the desired value. Integer values will automatically be converted to floating point. Note that some parameter fields will be grayed out (uneditable) when they are not used for a particular output projection. These fields are based on the table of projection parameters in Appendix C.

When editing the projection parameters, you may also specify the output datum. For all projections, the default will be No Datum. (See the Datum Conversions section for more information on this field.) As discussed in the Datum Conversions section, either the Datum or the first two projection parameters may be specified, but not both. If both are specified, then the MRT will exit with an error.

Returning to the main ModisTool window, an output pixel size may be specified (in degrees for the Geographic projection, meters for all other projections). If left blank, the output pixel size will be the same as the corresponding input pixel size for each selected band. If specified, the specified output pixel size will be used for all selected bands.

Now we're finally ready to run the resampler. Click the Run button on the main ModisTool window (or Run under the Action menu) and the resampler will start executing. The Status window allows you to monitor resampler progress.

```
 Status                                                      _ □ ×
  7) sur_refl_b07_1    0  INT16  2400  2400  463.3127     0  16000 -28672     ▲
  8) QC_500m_1         0 UINT32  2400  2400  463.3127     0 4294966019 787410671
  9) orb_cov_1         0  UINT8  2400  2400  463.3127     0    255      15
 10) num_observations  0   INT8  2400  2400  463.3127    62   -112       0

INTEGERIZED SINUSOIDAL PROJECTION PARAMETERS:
 Radius of Sphere             = 6371007.181000 meters
 Longitude of C. Meridian     = 0 0 0.000000
 False Easting                = 0.000000 meters
 False Northing               = 0.000000 meters
 Number of Latitudinal Zones  = 21600.000000
 Right Justify Columns Flag   = 1.000000


LAMBERT AZIMUTHAL EQUAL-AREA PROJECTION PARAMETERS:
 Radius of Sphere             = 6370997.000000 meters
 Longitude of Center          = -116 18 0.000000
 Latitude  of Center          = 35 0 0.000000
 False Easting                = 0.000000 meters
 False Northing               = 0.000000 meters

BIResample : Calculating ISIN shifts for input image
% complete (2400 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

BIResample : ISIN Shift Statistics:
  min delta shift = 0.000000
  max delta shift = 3.149742
  avg delta shift = 1.159607

BIResample : processing band sur_refl_b01_1
% complete (2592 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

BIResample : processing band sur_refl_b03_1
% complete (2592 rows): 0% 10% 20%                                          ▼
◄                                                                        ►
                                                     Clear      Close
```

As discussed earlier, the resampler writes status information to a log file, as well as to the screen. The log file is called resample.log, and is written into the current directory (or the default parameter file directory if it is set in the GUI). Status information is appended to resample.log at the completion of every run. resample.log is an ASCII text file, and may be edited or printed with standard text file tools.

How does the GUI run the resampler? When you click the Run button, the GUI creates a temporary parameter file (*TmpParam.prm*) in the current directory and runs the resampler

using that file (*resample -p TmpParam.prm*). This file is overwritten on subsequent runs, but not deleted, so you may examine it with any ASCII text file viewer/editor when processing is complete.

Prior to exiting the GUI, you may wish to save this work so that you do not have to fill in the GUI fields again in order to perform a related processing task. For example, perhaps tomorrow you realize that you forgot to reproject SDS 2 of the MOD09GHK.A2000072.h08v05.001.2000084105003.hdf image. Saving your work in a parameter file allows you to reload all the GUI fields from this file, and then make any desired changes prior to running the resampler.

To save your work in a parameter file, click on Save Parameter File and type in a file name. You may also click on an existing parameter file, but be aware that this file will be overwritten if you do not modify the file name.

As mentioned at the start of this section, the MODIS Reprojection Tool GUI is basically a parameter file editor. It allows the user to easily create parameter files by filling in fields, rather than using a text editor to create the parameter file. If desired, the GUI may be invoked expressly for this purpose. Rather than running the resampler, the user may fill in parameter values and save the results to a parameter file for later processing. Parameter files may also be loaded into the GUI for inspection and/or editing.

If you wish to run the resampler on an existing parameter file, click "Load Parameter File," select the file (or type in its name) in the resulting dialog box, and then click "Open." The parameter file dialog box is shown below.
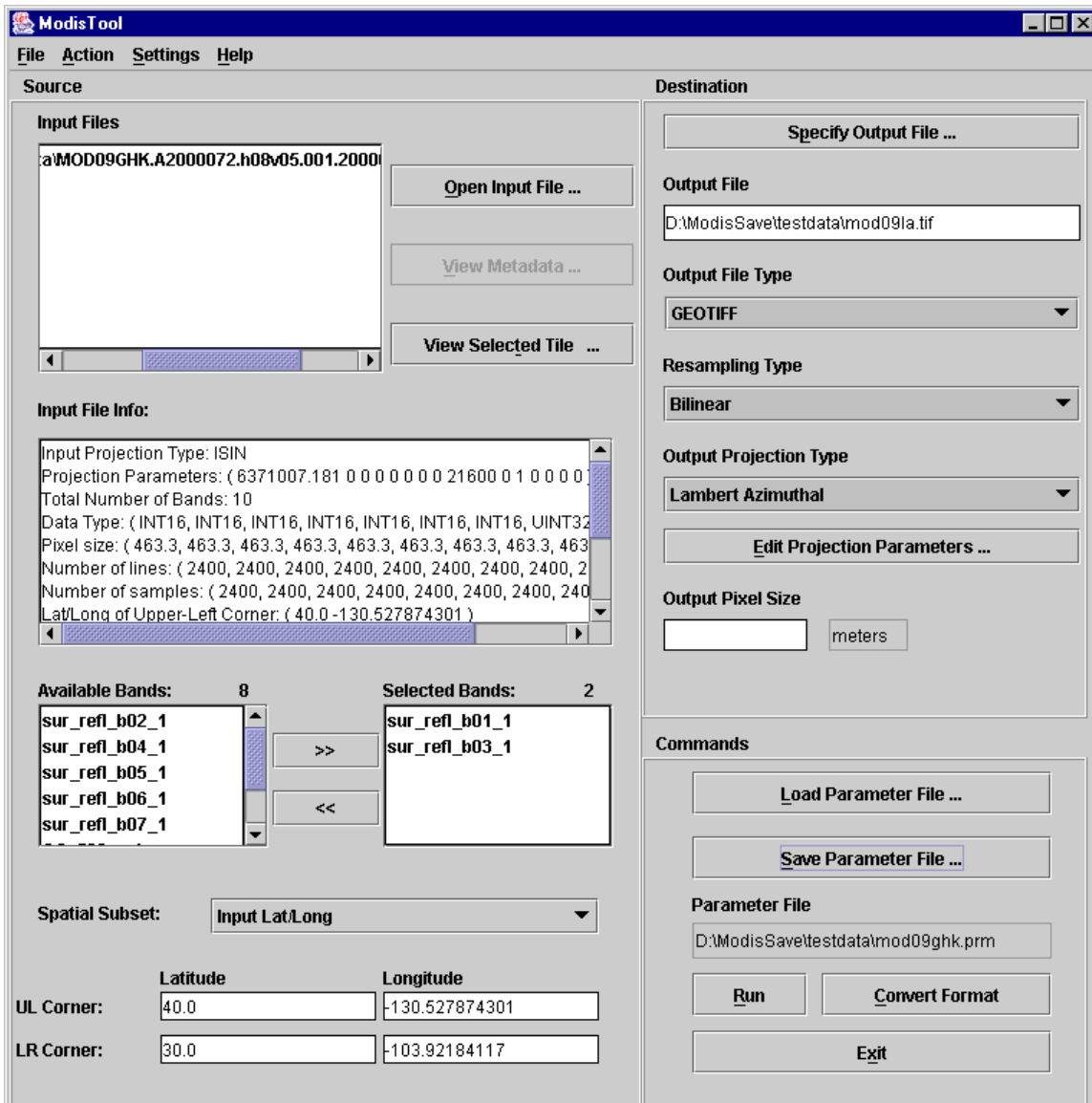
Loading an existing parameter file will automatically fill in the GUI fields. At this point, fields may be edited, or Run may be selected. You may go back and change the contents of GUI fields at any time prior to running the resampler. Simply click on the field and make the desired changes. In our example, we would deselect bands 1 and 3, select band 2, and click Run. (Because we have requested GeoTIFF output, it is unnecessary to specify a new output file name, since the new band name will automatically be appended to the output file name.)

To exit the ModisTool GUI, click the Exit button or click File, Exit on the menu bar. You may also close the window using the standard operating system commands (e.g., double click on the Close button, the "X" in the upper right hand corner of the window, in Microsoft Windows).
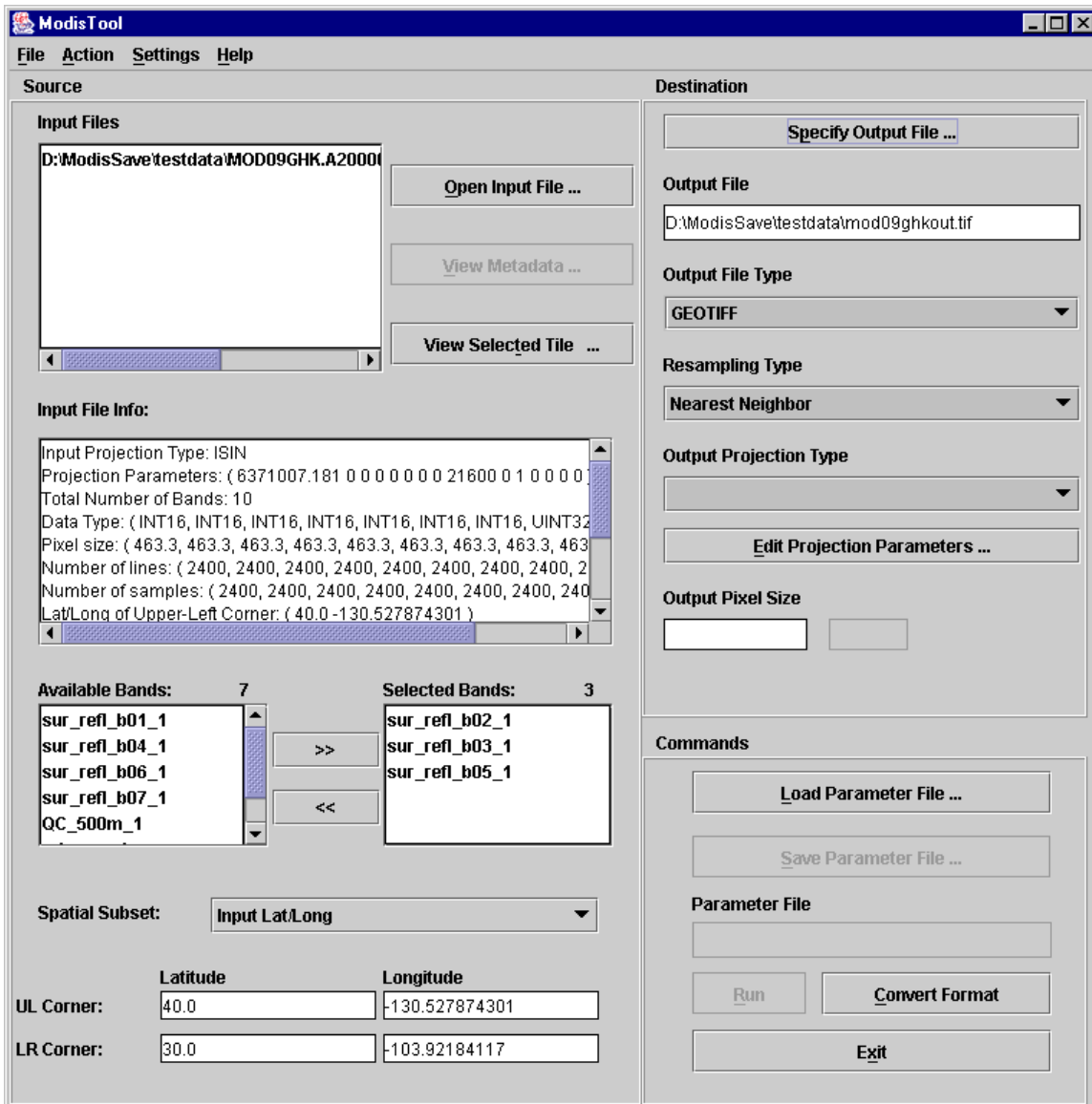
Format Conversion

The previous section, Resampling, discussed the resampler portion of the GUI. The MRT also provides a Format Converter, which allows you to convert the format of your input file to a specified output format. The Format Converter is similar to the Resampling option. The input file information must be specified first, then the output filename and file type. Spatial and spectral subsetting are supported by the Format Converter. As with the Resampling, the Format Converter by default will convert the entire image for all the SDSs.

Once the input information has been provided in the GUI, you must specify the output filename and file type. Unlike the Resampling process, the output projection type, output projection parameters, and pixel size are not used for the Format Converter. The output projection type and output projection parameters are the same as the input projection type and input projection parameters. The output pixel size is the same as the input pixel size. The Format Converter simply converts from one format to another. No reprojections are done in this process. If the output projection type, output projection parameters, or pixel size have been specified, the Format Converter will ignore them. Similarly, the resampling type is also not needed and will be ignored.

The Convert Format button, next to the Run button, is greyed out at startup of the MRT. Once the input file information and the output file information are provided, the Convert Format button will be available for use. Note: The Run button is not available until all the output information is provided (i.e. output filename, output resampling type, output projection type, and output projection parameters), however the Convert Format button is available once the output filename has been provided. The Convert Format command under the Action menu works the same as the Convert Format button.

The following shows the status of the GUI before running the Format Converter on the MOD09GHK.A2000072.h08v05.001.2000084105003.hdf image. SDSs 2, 3, and 5 will be converted from HDF-EOS to GeoTiff. Since the input projection is ISIN, the output GeoTiff file will be ISIN as well. The output projection parameters will be the same as the input projection parameters, and the output pixel size will be 463.3 meters for each band (since that is the input pixel size). In addition, the output data type for each SDS will be the same as the input data type, just as in the resampling process.

Now you may press the Convert Format button to run the Format Converter. Or, you may fill in the rest of the output parameters and press Run to run the MRT resampler.

How does the GUI run the Format Converter? When you click the Convert Format button, the GUI creates a temporary parameter file (*TmpParam.prm*) in the current directory and runs the Format Converter using that file (*resample -p TmpParam.prm -f*). This file is overwritten on subsequent runs, but not deleted, so you may examine it with any ASCII text file viewer/editor when processing is complete.

Mosaic Tool

The MRT will allow the user to specify several input files to be processed. The MRT will mosaic the input tiles into one large image, then process that image as specified by the

user in the output information. Processing several tiles is very similar to processing a single tile. The only difference is that the user must select multiple tiles in the Open Input File process.

The following example shows the user selecting four tiles for processing. The user may select multiple files by using the Shift and Ctrl keys along with pressing the left mouse button. The Shift key will select all files between the previous mouse click and the current mouse click. The Ctrl key will simply add the current mouse click to the list of files.
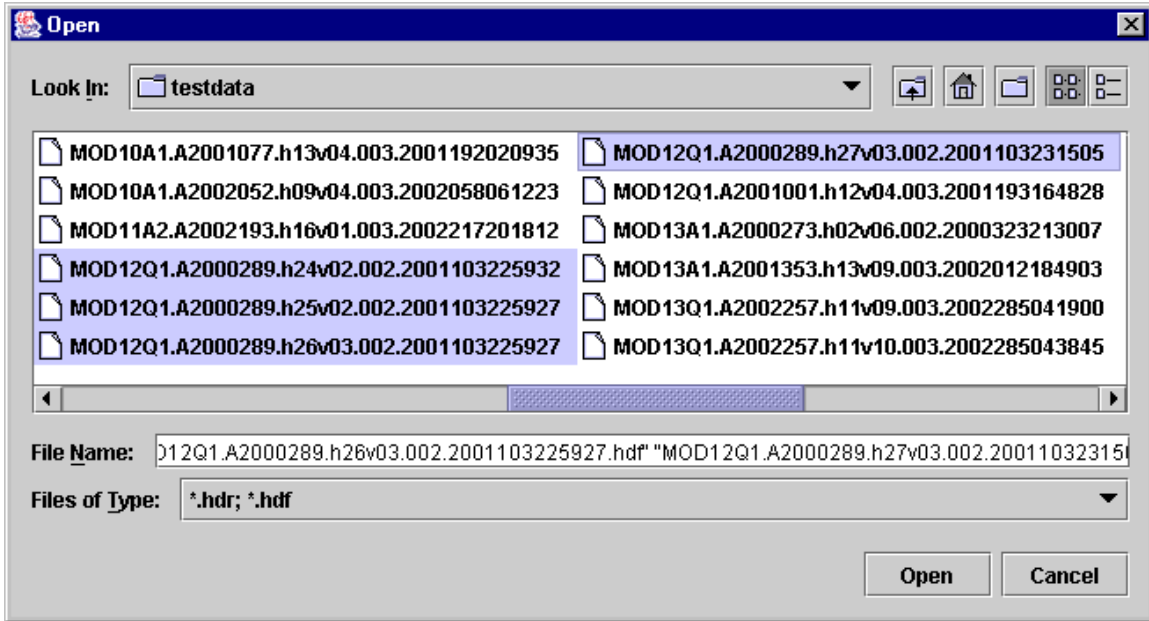
The mosaic tool requires that all input tiles are of the same product type and thus contain the same SDSs which remain the same size, data type, projection, pixel size, etc. for all input tiles. If the input tiles are not of the same product type, the MRT will exit with an error.

Setting Default Directories

The MRT will allow the user to specify default directories for the Input File, Output File, and Parameter File. These default directories are set using the Settings option in the MRT Toolbar. If the user chooses not to set these default directories, then the default directory will be the current directory (as was the case with previous versions of the MRT).

To set the default directory, select "Settings" then the specific default directory you wish to specify (Input Files Directory, Output File Directory, and/or Parameter File Directory). A box will pop up which contains a Browse button. Select the Browse button to specify your default directory. To specify your default directory, simply click on the desired directory until your full directory path has been specified. For Windows users, when the last directory in the path has been specified, you may have to type that directory in the

"File Name:" box as well. Windows won't allow you to select the Open button without doing so.
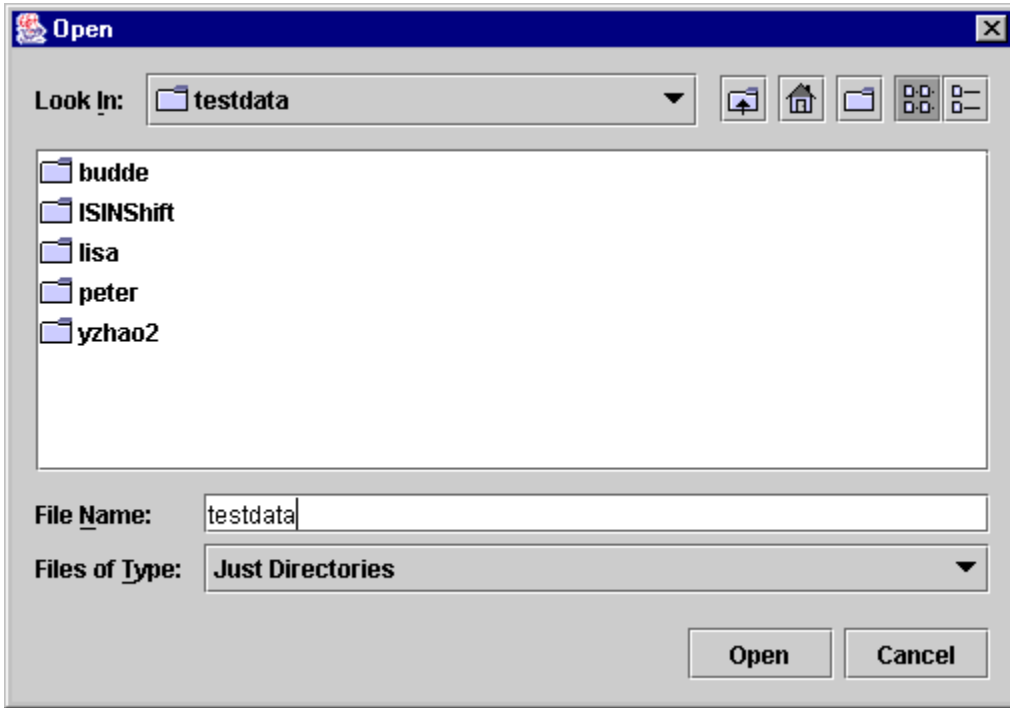
Once you have selected the desired path, you can click the Open button. Your desired directory path will be displayed for you in the default directory box.
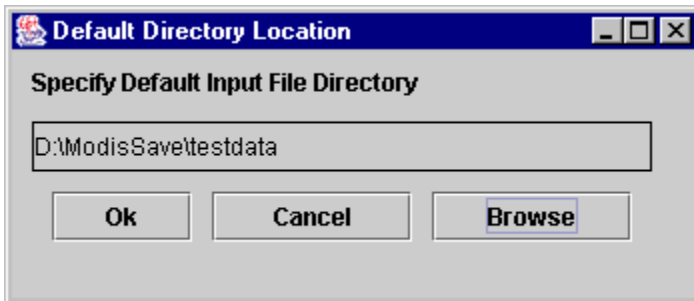
Once you have specified your default directory, that value will be used by the MRT for the current instance of the GUI and for all future instances of the GUI. In order to save these directory values for later reading and to support multiple users of the MRT on one system, the MRT creates a text file (DefaultInputFileLocation, DefaultOutputFileLocation, and DefaultParameterFileLocation) in your $HOME directory for each of the default directory options. Do not delete these files unless you no longer want to use the default directory option.

The MRT will allow any grouping of tiles to be selected. If the tiles are not adjacent, thus output selection of tiles is not rectangular, then the MRT will use the background fill value to fill in any missing tiles in the output rectangle. The user may view their tile arrangement by selecting View Selected Tile on the MRT GUI. A graphic will pop up showing the selected tiles in light blue.
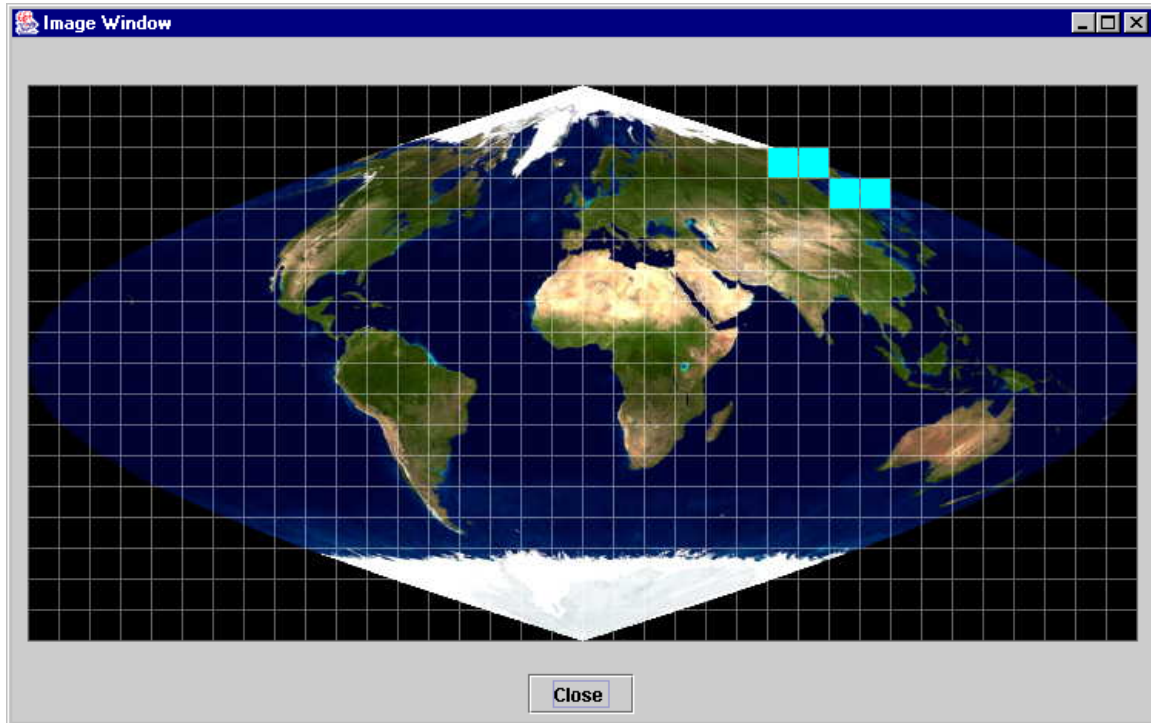
In this example, the first row will have two fill tiles (last two tiles) and the second row will also have two fill tiles (first two tiles). The output image will be based on a rectangular input image containing two rows of tiles and four columns of tiles.

When processing several tiles the Input File Info, Available Bands, and Spatial Subsetting information will all be populated with data from the entire mosaic of input files. Spectral and spatial subsetting may be specified, just like when processing one single input file. Output file information is also specified as when processing on input file.

When processing several tiles, the user may resample the data (via the Run button) or use the Format Convert option. In both cases, the input tiles are first mosaicked (using *mrtmosaic*) into one file called TmpMosaic.hdf (TmpMosaic.hdr if input data is raw binary). TmpMosaic.hdf/hdr is created in the same directory as the output file. This mosaic file may require significant disk space, so make sure your output directory disk has enough space. Once the mosaic file has been created, then the *resample* executable is called using the TmpMosaic.hdf/hdr file as input. Once the resampling (or format conversion) process has completed, the MRT automatically deletes the TmpMosaic.hdf/hdr file.

It is important to note that the TmpParam.prm file used in the resampling process specifies TmpMosaic.hdf/hdr as the input file. Since the TmpMosaic.hdf/hdr file is deleted it will no longer be available to reload when opening the TmpParam.prm parameter file.

The mosaic status is output to both the resample.log file and to the status box, similar to the resampling status information.

```
Status                                                    _ □ ✕

MODIS Mosaic Tool (v3.0 December 2002)
Start Time:  Mon Dec 16 10:54:49 2002


-------------------------------------------------------------


Input filenames (4):
   D:\ModisSave\testdata\MOD12Q1.A2000289.h24v02.002.2001103225932.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h25v02.002.2001103225927.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h26v03.002.2001103225927.hdf
   D:\ModisSave\testdata\MOD12Q1.A2000289.h27v03.002.2001103231505.hdf
Output filename: D:\ModisSave\testdata\TmpMosaic.hdf
Mosaic Array:
   file[ 0]  file[ 1]  file[-9]  file[-9]
   file[-9]  file[-9]  file[ 2]  file[ 3]

Mosaic : processing band Land_Cover_Type_1
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Mosaic : processing band Land_Cover_Type_2
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
% complete (1200 rows): 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Mosaic : processing band Land Cover Type 3

                                            Clear      Close
```

Contacts

The MODIS Reprojection Tool is available from the USGS EROS Data Center. Software requests, bug reports, and other comments should be sent to:

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Credits

This wonderful piece of software was written by the SDSM&T Modis Team:

Faculty
Dr. John M. Weiss – software task lead, C code, install script, documentation
Dr. Toni Logar – administrative support, GUI design
Dr. Gregg Stubbendieck – Java GUI code
Dr. Judy Sneller – technical writing

Graduates
Rob Burrell – C code
Gail Schmidt – software project lead, C code, testing, documentation

Students
Chris Ahlers – Tcl/Tk GUI code
Klaus Heuser - testing
Shujing Jia – Java GUI code
Brad Misterek – install script
Karthik Parameswar – Java GUI code, testing
John Rishea – metadata, testing

Appendix A: MRT Parameter File Format

Parameter files are user-editable ASCII text files that contain information required by the MODIS Reprojection Tool for processing MODIS data. Information entered by the user in the MRT Graphical User Interface is stored in a parameter file, either for future use, or to run the Resampler. In fact, the MRT GUI is basically a parameter file editing tool. This document specifies the parameter file format for the MRT.

The MODIS Reprojection Tool requires information about the input and output data products in order to perform the desired data transformations. The parameter file contains this information in user-editable ASCII text format. For the most part, this information is stored as field-value pairs, corresponding to GUI fields and values.

File naming conventions

By convention, all related files in a data set should be given the same base filename. Different extensions indicate the file type: parameter files (.prm), header files (.hdr), metadata files (.met), HDF-EOS files (.hdf), and GeoTIFF files (.tif).

Parameter file format

The parameter file consists of field-value pairs and comments. Comments begin with the '#' character, and extend to the end of the line. Each field must begin on a new line, and may span more than one line for convenience and readability. Fields may occur in any order. All field-value tokens must be separated by white space (including the equals and parentheses symbols).[7]

INPUT_FILENAME = input file name
- The input file name must include an appropriate extension, and may optionally contain a directory path. The input file type is determined automatically from the extension (.hdr = Raw Binary, .hdf = HDF-EOS). This field is required, since much of the information required by the MRT does not come directly from the parameter file, but must be read from the input data file. An invalid file name or extension will generate an error.

SPECTRAL_SUBSET = (band1 band2 … bandn)
- This is an *n*-element array of binary values corresponding to the *n* bands (Scientific Data Set or SDS elements) in the input data set. In this array, a 1 indicates that a band was selected, and a 0 indicates that it was not. This field is optional; by default, all input image bands will be selected. If there are fewer binary values than input image bands, the remaining bands will not be selected. If there are more binary values than input image bands, the extra values will be ignored.

---

[7] In the command-line MRT, space around tokens is not required. List values may be separated by either white space or commas.

SPATIAL_SUBSET_TYPE = type
- The spatial subset type may be INPUT_LAT_LONG, INPUT_LINE_SAMPLE, or OUTPUT_PROJ_COORDS. If neither the SPATIAL_SUBSET_UL_CORNER nor SPATIAL_SUBSET_LR_CORNER are specified, then this field defaults to INPUT_LAT_LONG and the entire image will be processed. This field is required if the SPATIAL_SUBSET_UL_CORNER and SPATIAL_SUBSET_LR_CORNER are specified.

SPATIAL_SUBSET_UL_CORNER = (UL_line UL_sample) or (UL_lat UL_lon) or
(UL_proj_x UL_proj_y)
SPATIAL_SUBSET_LR_CORNER = (LR_line LR_sample) or (LR_lat LR_lon) or
(LR_proj_x LR_proj_y)
- These are the coordinates of the upper-left and lower-right corners for spatial subsetting. Float values (containing a decimal point) indicate lat/lon in decimal degrees; integer values indicate line/sample pairs. If *any* value is float, then lat/lon will be assumed. In the case of multi-resolution data sets, the highest resolution of any spectral band will be assumed for line/sample values. These fields are optional; by default, the entire input image will be selected. Note that spatial subsetting takes place in the input image space, not the output image space.

OUTPUT_FILENAME = output file name
- The output file name must include an appropriate extension, and may optionally contain a directory path. The output file type will be determined automatically from the extension (.hdr = Raw Binary, .hdf = HDF-EOS, .tif = GeoTIFF). Note that an existing file with the same name as specified in OUTPUT_FILENAME will be overwritten by the resampler. This field is required. An invalid or missing extension will generate an error.

RESAMPLING_TYPE = type
- The resampling type may be nearest_neighbor (NN), bilinear (BI), or cubic_convolution (CC). This field is optional; by default, nearest neighbor resampling will be selected.

OUTPUT_PROJECTION_TYPE = type
- The output projection type may be ALBERS (AEA), EQUIRECTANGULAR (ER), GEOGRAPHIC (GEO), HAMMER (HAM), INTEGERIZED SINUSOIDAL (ISIN), INTERRUPTED_GOODE_HOMOLOSINE (IGH), LAMBERT_AZIMUTHAL (LA), LAMBERT_CONFORMAL_CONIC (LCC), MERCATOR (MERCAT), POLAR_STEREOGRAPHIC (PS), SINUSOIDAL (SIN), TRANSVERSE_MERCATOR (TM), or UNIVERSAL_TRANSVERSE_MERCATOR (UTM).

OUTPUT_PROJECTION_PARAMETERS = (p1 p2 … p15)

- This array contains the 15 output projection parameter values[8]. This field is optional; by default, all projection parameter values will be set to zero. (An exception is UTM: when the first two UTM projection parameters are zero, the projection will default to the scene center.) Projection parameter values are floating point; integer values will automatically be converted to floating point. If there are fewer than 15 projection parameter values specified, the remaining values will be set to zero. If there are more than 15 values specified, the extra values will be ignored.

UTM_ZONE = zone
- When the output projection type is UTM, a UTM zone value may optionally be specified. If present, the UTM zone overrides values specified in the output projection parameters field.

DATUM = datum value
- Datums may be specified for output projections. Valid datums are NAD27, NAD83, WGS66, WGS72, and WGS84. A NODATUM option is also available. If the NODATUM option is used, then the user must specify the spheroid semi-major and semi-minor axes in the projection parameters. If the DATUM is not specified, WGS84 is the default value. (See the Datum Conversions section for more information.)

OUTPUT_PIXEL_SIZE = size
- A single output pixel size may be specified in output projection units (typically meters). This field is optional; by default, the output pixel size will be the same as the input pixel size for each band.

Editing parameter files

Parameter files may be created and modified in two ways: by directly editing the parameter file with an ASCII text editor, or by using the MODIS Reprojection Tool GUI. In the MRT GUI, selecting Load Parameter File allows the user to load parameter values from an existing parameter file. Selecting Save Parameter File allows the user to save the current parameter values to a specified parameter file.

---

[8] See Appendix C for more information on projection parameters.

Appendix B: MRT Raw Binary File Format

This document specifies the format of the header file for the MODIS raw binary file format. In this file format, raw binary data and metadata are stored in separate files. The header file contains information required by the MODIS Reprojection Tool for processing MODIS data in the raw binary file format. Header files consist of user-editable ASCII text in the format described below.

Raw binary MODIS data are stored in individual data files, with one file per band. (In this document, the term "band" is used interchangeably with the HDF term "Scientific Data Set", or SDS.) Within files/bands, data are stored in row-major order, starting at the upper-left corner of the image. The data type may be 8-bit integer, 16-bit integer, 32-bit integer, or 32-bit float. Integer values may be signed or unsigned. Two-byte and four-byte data types are stored in big-endian order (high byte followed by low byte).

A metadata file contains information about a corresponding data file. Metadata are stored in the metadata file as user-editable ASCII text in ODL format. The metadata file format specification shall be described in another document.

File naming conventions

By convention, all related files in raw binary file format are given the same base filename. Header files are given the .hdr extension. Data filenames are generated from the basename and the Scientific Data Set (SDS) name, and given the .dat extension, as follows: basename.SDS_name.dat.

For example:
MOD09GHK.A2000072.hdr   - header file
MOD09GHK.A2000072.sur_refl_b01_1.dat   - data file (band 1)
MOD09GHK.A2000072.sur_refl_b02_1.dat   - data file (band 2)
                              etc.

Because of these naming conventions, there is no need to specify raw binary data filenames inside the header file. Data filenames are automatically generated by appending the appropriate extension onto the basename of the header file.

Header file format

The header file contains information required by the MODIS Reprojection Tool for processing data in the raw binary file format. An ODL-like format is used, as illustrated by the following:

```
# Header file for MOD09GHK.A2000072.h08v05.001.2000084105003

PROJECTION_TYPE = ISIN

PROJECTION_PARAMETERS = ( p1 p2 p3 p4 p5 p6 p7 p8 p9 p10
    p11 p12 p13 p14 p15 )

# COORDINATE_ORIGIN = UL

UL_CORNER_LATLON = ( lat lon )      # lat/long in decimal degrees
UR_CORNER_LATLON = ( lat lon )      # for the outer extent of the pixel
LL_CORNER_LATLON = ( lat lon )
LR_CORNER_LATLON = ( lat lon )

# UL_CORNER_XY = ( x y )            # projection coordinates for the
# UR_CORNER_XY = ( x y )            # outer extent of the pixel
# LL_CORNER_XY = ( x y )
# LR_CORNER_XY = ( x y )

NBANDS = n
BANDNAMES = ( band1 band2 ... bandn )
DATA_TYPE = ( t1 t2 ... tn )
NLINES = ( r1 r2 ... rn )
NSAMPLES = ( c1 c2 ... cn )
PIXEL_SIZE = ( s1 s2 ... sn )
MIN_VALUE = ( v1 v2 ... vn )
MAX_VALUE = ( v1 v2 ... vn )
BACKGROUND_FILL = ( f1 f2 ... fn )
```

Notes

- Fields may occur in any order. Each field should begin on a new line, but may span more than one line for readability. Field values should be separated by white space. Otherwise, there are no significant restrictions on field formatting.

- All text following a "#" on a line is considered to be a comment. Some comment lines are automatically generated by the Modis Reprojection Tool for reprojection to a raw binary output image, for informational purposes only.

- Field names should be largely self-explanatory. Lower-case items represent numeric and string values for the various fields. Several fields require arrays of *n* values for imagery containing *n* bands (SDS elements). Different bands may have different data types, dimensions, resolutions, etc.

- The BANDNAMES field is optional; by default, bands are named according to their SDS name. The MIN_VALUE, MAX_VALUE, and BACKGROUND_FILL fields are also optional; by default, no background fill value is used in resampling.

- Only one input projection type is permitted in this file format. All 15 projection parameters must be specified.

- When inputting UTM data types, the UTM_ZONE or first two projection parameters may be used to specify the zone. Valid UTM_ZONE values between –60 and 60 may be entered. If the UTM_ZONE is not specified the first two projection parameters must be specified. If both the UTM_ZONE and first two projection parameters are specified, then the UTM_ZONE is used to determine the zone.

- A DATUM may be specified for input data. Valid values are NAD27, NAD83, WGS66, WGS72, WGS84, and NODATUM. If not specified then WGS84 will be used. If NODATUM is specified, then the first two values in the projection parameters must specify the semi-major and semi-minor axes of the spheroid.

- The COORDINATE_ORIGIN is an optional comment field that is not used by the MRT on input, but is written on output for information purposes only. It specifies the location of the coordinate origin as one of the four corners (UL,UR,LL,LR). The resampler assumes the coordinate origin is UL for raw binary data.

- There are two sets of corner coordinate fields. The CORNER_XY coordinates (in projection units) are optional comment fields. These fields are not used by the MRT on input, but are automatically generated on output for informational purposes only. The CORNER_LATLON coordinates are required (lat/lon in decimal degrees).

- Valid DATA_TYPE values are INT8, UINT8, INT16, UINT16, INT32, UINT32, and FLOAT32.

Editing header files

Header files may be created and modified by directly editing the header file with an ASCII text editor. Running the MODIS Reprojection Tool and selecting raw binary file output also creates header files. In this case, the MRT automatically generates an output header file, along with output data files.

Appendix C: Projection Parameters

<u>Projection Parameters 1-8</u>

```
--------------------------------------------------------------------------------
                        |                   Array Element                |
  Code & Projection Id  |------------------------------------------------------
                        |  1   |  2   |  3   |  4   |  5    |   6      |7 | 8|
--------------------------------------------------------------------------------
 0 Geographic           |      |      |      |      |       |          |  |  |
 1 U T M                |Lon/Z |Lat/Z |      |      |       |          |  |  |
 2 State Plane          |      |      |      |      |       |          |  |  |
 3 Albers Equal Area    |SMajor|SMinor|STDPR1|STDPR2|CentMer|OriginLat |FE|FN|
 4 Lambert Conformal C  |SMajor|SMinor|STDPR1|STDPR2|CentMer|OriginLat |FE|FN|
 5 Mercator             |SMajor|SMinor|      |      |CentMer|TrueScale |FE|FN|
 6 Polar Stereographic  |SMajor|SMinor|      |      |LongPol|TrueScale |FE|FN|
 7 Polyconic            |SMajor|SMinor|      |      |CentMer|OriginLat |FE|FN|
 8 Equid. Conic A       |SMajor|SMinor|STDPAR|      |CentMer|OriginLat |FE|FN|
   Equid. Conic B       |SMajor|SMinor|STDPR1|STDPR2|CentMer|OriginLat |FE|FN|
 9 Transverse Mercator  |SMajor|SMinor|Factor|      |CentMer|OriginLat |FE|FN|
10 Stereographic        |Sphere|      |      |      |CentLon|CenterLat |FE|FN|
11 Lambert Azimuthal    |Sphere|      |      |      |CentLon|CenterLat |FE|FN|
12 Azimuthal            |Sphere|      |      |      |CentLon|CenterLat |FE|FN|
13 Gnomonic             |Sphere|      |      |      |CentLon|CenterLat |FE|FN|
14 Orthographic         |Sphere|      |      |      |CentLon|CenterLat |FE|FN|
15 Gen. Vert. Near Per  |Sphere|      |Height|      |CentLon|CenterLat |FE|FN|
16 Sinusoidal           |Sphere|      |      |      |CentMer|          |FE|FN|
17 Equirectangular      |Sphere|      |      |      |CentMer|TrueScale |FE|FN|
18 Miller Cylindrical   |Sphere|      |      |      |CentMer|          |FE|FN|
19 Van der Grinten      |Sphere|      |      |      |CentMer|OriginLat |FE|FN|
20 Hotin Oblique Merc A |SMajor|SMinor|Factor|      |       |OriginLat |FE|FN|
   Hotin Oblique Merc B |SMajor|SMinor|Factor|AziAng|AzmthPt|OriginLat |FE|FN|
21 Robinson             |Sphere|      |      |      |CentMer|          |FE|FN|
22 Space Oblique Merc A |SMajor|SMinor|      |IncAng|AscLong|          |FE|FN|
   Space Oblique Merc B |SMajor|SMinor|Satnum|Path  |       |          |FE|FN|
23 Alaska Conformal     |SMajor|SMinor|      |      |       |          |FE|FN|
24 Interrupted Goode    |Sphere|      |      |      |       |          |  |  |
25 Mollweide            |Sphere|      |      |      |CentMer|          |FE|FN|
26 Interrupt Mollweide  |Sphere|      |      |      |       |          |  |  |
27 Hammer               |Sphere|      |      |      |CentMer|          |FE|FN|
28 Wagner IV            |Sphere|      |      |      |CentMer|          |FE|FN|
29 Wagner VII           |Sphere|      |      |      |CentMer|          |FE|FN|
30 Oblated Equal Area   |Sphere|      |Shapem|Shapen|CentLon|CenterLat |FE|FN|
31 Integerized Sinusoid |Sphere|      |      |      |CentMer|          |FE|FN|
--------------------------------------------------------------------------------
```

Projection Parameters 9-15

```
-----------------------------------------------------------
                           |       Array Element       |
 Code & Projection Id      |---------------------------
                           | 9  | 10 |  11 | 12 | 13 |
-----------------------------------------------------------
 0 Geographic              |     |     |     |     |     |
 1 U T M                   |     |     |     |     |     |
 2 State Plane             |     |     |     |     |     |
 3 Albers Equal Area       |     |     |     |     |     |
 4 Lambert Conformal C     |     |     |     |     |     |
 5 Mercator                |     |     |     |     |     |
 6 Polar Stereographic     |     |     |     |     |     |
 7 Polyconic               |     |     |     |     |     |
 8 Equid. Conic A          |zero |     |     |     |     |
   Equid. Conic B          |one  |     |     |     |     |
 9 Transverse Mercator     |     |     |     |     |     |
10 Stereographic           |     |     |     |     |     |
11 Lambert Azimuthal       |     |     |     |     |     |
12 Azimuthal               |     |     |     |     |     |
13 Gnomonic                |     |     |     |     |     |
14 Orthographic            |     |     |     |     |     |
15 Gen. Vert. Near Per     |     |     |     |     |     |
16 Sinusoidal              |     |     |     |     |     |
17 Equirectangular         |     |     |     |     |     |
18 Miller Cylindrical      |     |     |     |     |     |
19 Van der Grinten         |     |     |     |     |     |
20 Hotin Oblique Merc A    |Long1|Lat1|Long2|Lat2|zero|
   Hotin Oblique Merc B    |     |     |     |     |one  |
21 Robinson                |     |     |     |     |     |
22 Space Oblique Merc A    |PSRev|LRat|PFlag|    |zero|
   Space Oblique Merc B    |     |     |     |     |one  |
23 Alaska Conformal        |     |     |     |     |     |
24 Interrupted Goode       |     |     |     |     |     |
25 Mollweide               |     |     |     |     |     |
26 Interrupt Mollweide     |     |     |     |     |     |
27 Hammer                  |     |     |     |     |     |
28 Wagner IV               |     |     |     |     |     |
29 Wagner VII              |     |     |     |     |     |
30 Oblated Equal Area      |Angle|     |     |     |     |
31 Integerized Sinusoidal  |NZone|    |RFlag|    |     |
-----------------------------------------------------------
```

<u>Notes</u>

- Lon/Z: Longitude of any point in the UTM zone or zero. If zero, a zone code must be specified.
- Lat/Z: Latitude of any point in the UTM zone or zero. If zero, a zone code must be specified.
- SMajor: Semi-major axis of ellipsoid. If zero, Clarke 1866 in meters is assumed.
- SMinor: If zero, a spherical form is assumed, eccentricity squared of the ellipsoid if less than one, or if greater than one, the semi-minor axis of ellipsoid.
- Sphere: Radius of reference sphere. If zero, 6370997 meters is used.
- STDPAR: Latitude of the standard parallel
- STDPR1: Latitude of the first standard parallel
- STDPR2: Latitude of the second standard parallel
- CentMer: Longitude of the central meridian
- OriginLat: Latitude of the projection origin
- FE: False easting in the same units as the semi-major axis
- FN: False northing in the same units as the semi-major axis
- TrueScale: Latitude of true scale
- LongPol: Longitude down below pole of map
- Factor: Scale factor at central meridian (Transverse Mercator) or center of projection (Hotine Oblique Mercator)
- CentLon: Longitude of center of projection
- CenterLat: Latitude of center of projection
- Height: Height of perspective point
- Long1: Longitude of first point on center line (Hotine Oblique , format A)
- Long2: Longitude of second point on center line (Hotine Oblique , format A)
- Lat1: Latitude of first point on center line (Hotine Oblique , format A)
- Lat2: Latitude of second point on center line (Hotine Oblique , format A)
- AziAng: Azimuth angle east of north of center line (Hotine Oblique , format B)
- AzmthPt: Longitude of point on central meridian where azimuth occurs Hotine Oblique Mercator, format B)
- IncAng: Inclination of orbit at ascending node, counter-clockwise equator (SOM, format A)
- AscLong: Longitude of ascending orbit at equator (SOM, format A)
- PSRev: Period of satellite revolution in minutes (SOM, format A)
- LRat: Landsat ratio to compensate for confusion at northern end orbit (SOM, format A -- use 0.5201613)
- PFlag: End of path flag for Landsat: 0 = start of path, = end of path (SOM, format A)
- Satnum: Landsat Satellite Number (SOM, format B)
- Path: Landsat Path Number (Use WRS-1 for Landsat 1, 2 and 3 and -2 for Landsat 4, 5 and 6.) (SOM, format B)
- Shapem: Oblated Equal Area oval shape parameter m
- Shapen: Oblated Equal Area oval shape parameter n

- Angle: Oblated Equal Area oval rotation angle
- NZone: Number of equally spaced latitudinal zones (rows); must be 2 or larger and even
- RFlag: Right justify columns flag is used to indicate what to do with zones with an odd number of columns. If it has a value of 0 or 1 it indicates the extra column is on the right (zero) or left (one) of the projection y-axis. If the flag is set to 2 the number of columns are calculated so there are always an even number of column in each zone.
- Array elements 14 and 15 are set to zero
- All array elements with blank fields are set to zero
- All angles (latitudes, longitudes, azimuths, etc.) are entered in decimal degrees and the MRT then converts them to packed degrees/minutes/seconds (DDDMMMSSS.SS) format for the call to GCTP.

Appendix D: Overview of the MODIS Reprojection Tool Resampling Process

The resampling process in the MODIS Reprojection Tool (MRT) is a two-step process. The first step is the spatial transformation, shown in Figure 1. This is the concept of mapping an (x, y) in output space back to an (x′, y′) in input space. This can result in (x′, y′) being a fractional coordinate.
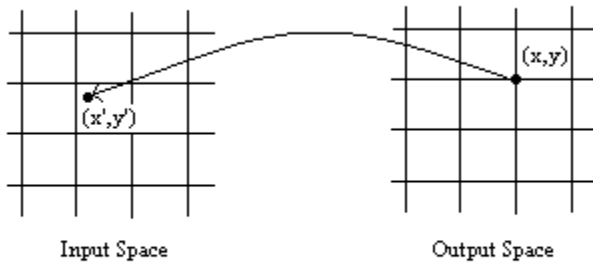

Figure 1 - Spatial Transformation

The second step is resampling the input space pixels in the neighborhood of the fractional coordinate to create the output pixel. The MRT provides three types of resampling: nearest neighbor, cubic convolution, and bilinear resampling.

Nearest neighbor (NN) resampling uses the pixel value of the closest integer coordinate neighbor (see Figure 2).
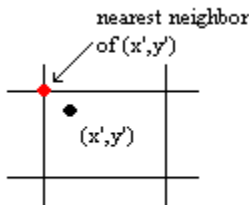
Figure 2 - Nearest Neighbor

Bilinear (BI) resampling uses the pixel values of the four nearest neighbors. A set of linear weights is used so that the closest neighbors are weighted more heavily in the final pixel value (see Figure 3). The following equations specify how (x′, y′) is calculated using bilinear interpolation.

```
x1 = int (x')    x2 = x1 + 1
y1 = int (y')    y2 = y1 + 1
pixel value of (x',y') = w1 * pixel value at (x1,y1) +
                         w2 * pixel value at (x2,y1) +
                         w3 * pixel value at (x1,y2) +
                         w4 * pixel value at (x2,y2)
```

The weights (w1, w2, w3, w4) are fractions that all add up to 1.0. The closer the point (xn, yn) is to (x′, y′), the higher the value for wn.
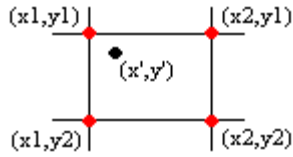
Figure 3 - Bilinear

Cubic convolution (CC) resampling uses the pixel values of the 16 nearest neighbors. A set of weights is also used so that the closest neighbors have more weight in the overall pixel value (see Figure 4).
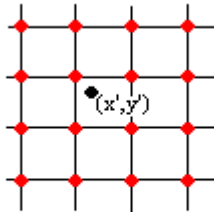

Figure 4 - Cubic Convolution

Given this understanding of the spatial transformation and interpolation steps that take place in the resampling process of the MRT, we will now look at comparing two separately resampled scenes. An issue has arisen where a subset has been taken from a scene. The full scene and subscene were both resampled, and then the two scenes were compared. Given that the subscene is a part of the original scene, the initial thought is that the resampled subscene should match a subset of the original scene. Although this thought is reasonable, it is also untrue for several reasons.

Unless the pixels in the subscene match exactly with the pixel locations in the original scene, resampling of the scene and subscene will not produce exactly the same results. To understand this reasoning look at Figure 5. Let's assume we are resampling the full scene and the subscene at point (x, y) in output space. Furthermore, let's assume that the subscene pixels are slightly shifted from those in the original scene (which would be the case if the upper-left corner of the subscene does not match up exactly with the upper-left corner of a pixel elsewhere in the original scene.) Since we are resampling both scenes to the same projection, a point (x, y) in output space would map back to the same (x′, y′) in input space for both scenes.

In Figure 5, the black cross hairs refer to the pixel locations in the full scene and the blue cross hairs refer to the pixel locations in the subsetted scene (slightly shifted from the pixel locations in the full scene). The black dot represents our (x′, y′) in output space. Using cubic convolution to interpolate (x′, y′), the red dots represent the pixel locations that would be used in the interpolation for the full scene. The green dots represent the pixel locations that would be used in the interpolation for the subscene. From this example it is clear that the 16 pixel values used for the interpolation in the full scene are

different from the 16 pixel values used for the interpolation in the subscene, which will then result in a different value for (x′, y′). It should be noted that even though this example uses cubic convolution, similar results will be seen using bilinear and nearest neighbor interpolation.
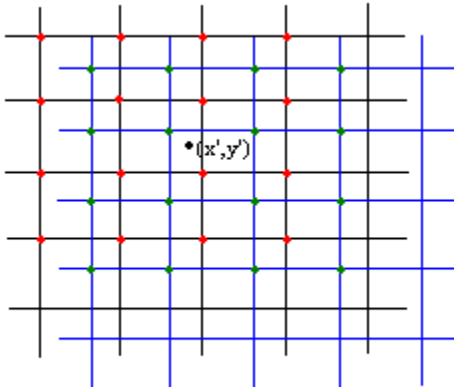

Figure 5 - Pixel Shifts and Resampling

What about the case where the pixel value locations in the subscene match up with the pixel value locations in the full scene? There will still be differences in the resampled products, this time around the edges. In the case of cubic convolution, the interpolated pixel value depends on the lines and samples surrounding the fractional pixel location. Around the extreme edges of the scene, it will be the case that there are not two rows or two columns on either side of (x′, y′) to be used in the interpolation. If more than 50% of the pixel values to be used in the interpolation are background fill values (or do not exist), then (x′, y′) is assigned the value of background fill. In the case that fewer than 50% of the pixel values to be used in the interpolation are background fill (or do not exist), then those values are ignored and only the valid pixel values are used. In this latter case, the weights for the valid pixels are also readjusted to account for the fact that fewer pixel values are being used in the interpolation.

This difference in the interpolation rules around the edges of the scenes must be taken into account when comparing resampled subscenes with the resampled original scene. The "edge" pixels in the subscene will not be "edge" pixels in the original scene, thus the interpolated values will be slightly different for the full scene versus the subscene. Also, the smaller the subscene, the greater percentage of pixels that will be "edge" pixels and thus the greater percentage of pixels that will have different interpolated values.