How to Retrieve Aerosol Plume Heights with MISR INteractive eXplorer (MINX) 4.0

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Introduction

The MISR Interactive eXplorer (MINX) is an interactive, GUI-based program designed to display images from MISR's nine cameras and to allow you to determine the height and speed of motion of aerosol plumes (smoke, dust and volcanic plumes) and clouds on those images. As used here, the term *plume* refers to the region of dense aerosol above and downwind of an aerosol source that often has well-defined edges and an apparent connection to the source so that the direction of transport can be determined. A *cloud* is a region of aerosol that has no obvious connection to a source or for which one cannot determine the direction of motion.

This document describes the methodology for determining aerosol heights. The mechanical skills involved in operating the software are rather easy to learn; acquiring the necessary interpretive skills can take longer. It is assumed that the reader already has some knowledge of the MISR instrument and its data and that he/she has a working version of MINX installed on his or her computer. MINX V4.0 is distributed as an IDL virtual machine (VM) application and includes the IDL VM as part of the distribution. You no longer need to download IDL or the IDL VM from the Exelis website!

An introduction to MISR can be found in the online documents "MISR - the Instrument, its Orbit and Data Products" and "MISR - Tools for Ordering and Viewing Data" on the Open Channel Foundation website. Detailed information about MINX can be found in the other five documents on that website and in the paper referenced at the end of this document.

When you want to start MINX, do the following:

- For PC: You should have a MINX icon on your desktop and in your start menu; double-click either to start MINX.
- For OS X: MINX installs to your Applications folder by default. Open the MINX4 folder in Applications and launch the MINX4 application.
- For Linux (option 1): Using your preferred file manager, open the folder where you extracted the MINX4 installation package. Launch the MINX4 script within the MINX4 folder. (option 2): Open a terminal and "cd" (change directory) to the folder where you extracted the MINX4 installation package. "cd" into the MINX4 folder and run the MINX4 script via "./MINX4".

On all Operating Systems you should then see the IDL Virtual Machine splash screen. Click anywhere in this window to proceed to MINX.

Refer to the first few slides of the document on the Open Channel website titled "Basic Features" for more information on getting started with and using MINX.

Finding and Ordering MISR Data

Finding orbits for one or a few aerosol plume or cloud events

If you wish to determine the height of a small number of plumes or clouds, then you may already know the orbit numbers for which you need to order MISR data. If not, then you need to first determine the date(s) and geographic coordinate(s) of the events.

MINX can use time and location information to find any MISR orbits that satisfy your date and geographic constraints. Proceed by loading MINX and selecting the option **Find Overpasses** from the **Program Options** menu. On the **MISR Overpass Finder** dialog box, enter your date or date range in the **Enter Date:** text box and your latitude and longitude location or range in the **Lat/Lon … Search** boxes (click **PDF Help** for additional details). Next click the **Add to list** button, and then click **OK**. Enter the name of the directory where you wish output data to be written in the **Selection** text box at the bottom of the **Select/Create Dir for Overpass Lists** dialog box that appears.

When you click **OK** in the dialog box, a message is displayed that summarizes the results of your query. It tells you how many orbits were found that satisfy your requirements and reiterates the location where your output information is stored. If you want to view AND save map images showing the location of your search area on each MISR orbit, click **Yes**. To save only text information, click **No**. If you clicked **Yes**, then a map for each orbit is displayed with two options at the bottom: **Continue** and **Cancel**. Clicking **Continue** will show the next map, whereas clicking **Cancel** will stop displaying and saving maps. If your search returned dozens or hundreds of orbits, you may want to select **Cancel**.

When your search is finished, go to the directory where your results are stored and open the file named MISR_OverpassLog_<current-date-time>.txt. Detailed information about the orbits that satisfied the search are presented. Near the top, below the phrase "List of Orbits satisfying search criteria :", is a line(s) containing a comma-separated list of orbit numbers. This list can be cut-and-pasted into the MISR Order Tool described below to download the orbit data you'll need to process in MINX.

Finding orbits for many-orbit smoke plume projects

If you're beginning a large project whose purpose is to determine the height of smoke plumes on many MISR orbits, finding those orbits that match your project's geographic region and date range and that have imaged smoke plumes can be daunting. As of May 2014, more than 76,000 orbits of MISR data had been acquired. Fortunately the MODIS instrument on the TERRA satellite sees everything seen by MISR, and it acquires far-infrared imagery that can be used to detect thermal anomalies (here termed "fire pixels"), which are processed and archived in an online MOD14 data set. These MOD14 files or granules can be used by MINX to determine which MISR orbits and blocks need to be ordered.

The steps involved in finding the MISR orbits to order are described in detail in a document entitled "MISR – Tools for Ordering and Viewing Data" on the Open Channel Foundation website. Here is a summary:

1) Order all MODIS MOD14 files that satisfy the geographic bounds and time range of your project. To begin, go to the Reverb website. Use the Search Term "MOD14" in Step 1 on the website, and select the item "MODIS/Terra Thermal Anomalies/Fire 5-Min L2 Swath 1km V005" in Step 2. Select the date range and geographic bounding box you desire. Download a list of file URLs by following website instructions and store the file in a project directory on your disk, e.g. ./Kenya-2008. Depending on the size of your project you could have dozens to thousands of files. Fortunately the files are small.

2) Download the MOD14 files using a MINX utility program. On the MINX **Program Options** menu, select **Plume Utilities**, then **Download MODIS MOD14 Fire**. After you enter the requested information in two dialog boxes, MINX downloads the granules into the output directory you specified in one of the dialog boxes.
3) Process the MOD14 files using another MINX utility program. On the MINX **Program Options** menu, select **Plume Utilities**, then **Process MODIS MOD14 Fire Granules**. After you enter the requested information in three dialog boxes, MINX reads the MOD14 files and writes the following files to the output directory you specified in one of the dialog boxes:
    - A file named "MisrProcessList_MOD14_<your Project Name>.txt" to be read by MINX during digitizing that lists the MISR orbits and their block ranges that contain fire pixels. This significantly speeds the loading of MISR images when digitizing smoke plumes on many orbits of data.
    - A file named "MisrOrderList_MOD14_<your Project Name>.txt" listing MISR orbits to order. This comma-separated list can be cut-and-pasted into the MISR Order Tool described below to download the MISR orbit data.
    - A directory named "FirePixels_MOD14_<your Project Name>" and populated with one file per orbit containing fire pixel coordinates and fire radiative power (FRP) for that orbit. During digitizing, MINX reads these files, displays the fire pixel locations on MISR images and captures the total FRP in each digitized plume's output file.
4) Rename and edit the file "MisrProcessList_MOD14_<your Project Name>.txt" created by the MINX utility. This file must be renamed to "PlumeProjOrbitList.txt". Check to make sure this file is in the project directory you specified for the digitizing. Then edit the first line of the file so it contains the name of the directory where your project's GRP_TERRAIN (and/or GRP_ELLIPSOID) files are stored, and edit the third line so it contains the name of the directory where you want all the images and data files created during MINX processing to be written.
5) Use the file "MisrOrderList_MOD14_<your Project Name>.txt" to download all the required MISR product files for the orbits of interest with the MISR Order Tool described below.

Finding orbits for many-orbit non-smoke plume projects

If you are preparing data for a large dust or volcanic plume or other aerosol project, then the task of finding candidate MISR orbits can be much harder. You can use a combination of methods:

- Use the literature to search for specific qualifying events (e.g. volcanic eruptions).
- Use the MISR Browse Tool to inspect individual MISR orbits. Only low-resolution images are available, so it may be difficult to resolve whether an orbit contains a feature of interest, but you can eliminate cases that won't serve the project, such as ones that appear too cloudy. You can significantly reduce the number of orbits to inspect by filtering the orbits by date and path number (paths correspond to specific longitude ranges).
- Browse MODIS Terra images using the LANCE Rapid Response tool. MODIS granules are about five times wider than the MISR swath, so only features near the granule centers will be visible on MISR data.

For events not identified using the MISR Browse Tool, you can use the date(s) and geographic coordinate(s) of those events to find the relevant MISR orbits. Refer to the description of the MINX **Find Overpasses** option above for instructions on doing this.

Once you have compiled a list of the MISR orbits and block ranges of interest, then you can manually construct two files identical in format to the first two output files described for smoke plumes above. One should contain a comma-separated list of orbits to be cut-and-pasted into the MISR Order Tool, and the other should contain a three-line header followed by a list of orbits and block ranges to be read by MINX during height-retrieval processing. Here are the first few lines of a sample "PlumeProjOrbitList.txt" file:

```
/Users/dlnels/MISRdata/GRP_TERRAIN/
F03_0024
/Users/dlnels/TestOutput/
  7695   37   41   path 40  -  only the first 3 columns are read by MINX
 24298   37   37   path 68  -  the columns are: orbit number, first MISR block, last MISR block
 72716   53   57   path 31  -  everything after is merely annotation
```

Obtain MISR data using the MISR Order Tool

When you are ready to order MISR data, go to the MISR Order Tool website. Due to changes to the ASDC, you will need to register your username and password, and then log in. Here you can download entire orbits or subsets of orbits. Because of the large size of MISR files (~ 2 Gbytes/ orbit), it is strongly recommended that you subset your data to the smallest number of MISR blocks that your project requires. If you are ordering a large number of orbits and some require different block ranges than others, you will need to place a separate order for each group of orbits that share a block range. Study the "MISR - Tools for Ordering and Viewing Data" document cited above for details on using this tool.

Once downloaded, the MISR files can be collected into separate directories organized by product type. For example, these directories could be created and populated:

- ./TERRAIN (required) - level 1 GRP_TERRAIN (terrain-referenced) radiance files; nine files per orbit, each containing imagery for one of MISR's cameras; designated as MI1B2T in the order tool.
- ./GEOM (required) - level 1 GP_GMP files; one file per orbit containing camera and sun geometry; designated as MIB2GEOP in the order tool.
- ./AGP (required) – ancillary geographic files; one file for each of MISR's 233 paths containing digital elevation data and surface type masks; designated as MIANCAGP in the order tool.
- ./AEROSOL (optional) – level 2 AS_AEROSOL; one file per orbit containing retrieved aerosol data such as aerosol optical depth, single-scatter albedo etc.; designated as MIL2ASAE in the order tool. This is required for plume results intended for the Plume Height Project database and website.
- ./SVM (optional) – level 2 TC_CLASSIFIERS; one file per orbit containing smoke/cloud mask files; designated as MIL2TCCL in the order tool.

Load a MISR Orbit into MINX

If you do not have a list of orbits to process

To load a few blocks of a single MISR orbit into MINX, start MINX, proceed to the **Program Options** menu and select **Animate Cameras.** Then click the long bar at the top of the **Animate Cameras Options** dialog box requesting you to **Select Orbit 1 Nadir HDF File**. In the **Select Nadir Camera File** dialog box enter or select the name of the AN camera file for the desired MISR orbit and click **OK**. Fill in the desired **First Block** and **Last Block** on the **Animate Cameras Options** dialog box and click **OK** again. MINX will load the requested data for all nine cameras if they are located in the same directory or in subdirectories named after the cameras: DF, CF, BF, AF, AN, AA, BA, CA and DA.

MINX will load and preprocess the GRP_TERRAIN data for the selected orbit and block range. This can take a minute or more if many blocks are being loaded. The resulting MINX window will contain color images, one for each of MISR's nine cameras, displayed one after the other as a looping animation. You can stop this animation by clicking the video stop button in the upper left corner (the button with two vertical bars).

If you have a list of orbits to process

Start MINX, proceed to the **Program Options** menu and select **Process Plume Project**. When you press **OK,** MINX will read and display the list of orbit numbers and block ranges from your "PlumeProjOrbitList.txt" file. Highlight one of the orbits in the list with the mouse. When you press **OK,** MINX will load and preprocess the block range for the selected orbit and display the images as described above. The "PlumeProjOrbitList.txt" file must be in the Project directory you declared for this to work. Refer to the first few slides of the document on the Open Channel website titled "Basic Features" for more information on project directories.

Preparing to Digitize

Load fire pixels

If you are processing smoke plumes and have MODIS fire pixel data for this orbit, you may prefer to load and display them first, because this operation is very fast, and fire pixels are good indicators of the source of a smoke plume. If there are no smoke plumes worth digitizing on the orbit, less time will have been lost than if the steps below are done first.

Click the **Task Menu** button on the MINX animation window, click **Select Digitizing Tool**, then select **Load MODIS Fire Pixels…**. This will display the **Select Fire Pixel File** dialog box. In the **Directory** text box, enter the name of the directory where your fire pixel files are located and press **Filter**. The **Files** list box should become populated with the name(s) of fire pixel files for this orbit. When you double click on the filename or highlight it and select **OK**, the file will be read and red dots will be posted over the MISR image corresponding to locations where MODIS detected thermal anomalies.

After the file is read, the **Fire Pixels** check box becomes sensitive and enabled. You can toggle this off and on anytime while digitizing to aid in locating plumes, in distinguishing smoke plumes from water clouds and in determining the direction the wind is blowing smoke from fires. Fire pixel data are not perfect; occasionally an active fire is not marked by fire pixels or, more

frequently, thermal detections are not reported because the heat is masked by smoke or cloud. Before proceeding it is usually advisable to scan the entire orbit to become familiar with where fire pixels are located. If they are difficult to see because of a bright background, drag the **Camera:** slider to the far left (to the **OP**eration window) where the fire pixels can be seen against a black background. If there are no plumes you want to digitize, you can click **Exit** on the bottom of the animation window and proceed to another orbit.

Adjust the color scaling

When MINX first loads MISR images, it scales the displayed RGB values for each camera's spectral bands according to the maximum value of radiance found in that camera's bands (relative color state – this is the default). After all nine cameras are loaded, you have the option to change the color scaling so all cameras and spectral bands are scaled according to the maximum radiance value found in all 36 channels (true color state). The relative color and true color states can be selected using the **True Color** button on the bottom left of the MINX animation window. Two sliders labeled **Contrast** and **Brightness** lie to the right of the **True Color** button. These function more or less as one would expect to change the contrast and brightness of the images.

You should spend a moment adjusting the colors so both foreground aerosols and background terrain can be seen clearly. This is important because MINX takes snapshots of the plumes during height retrieval operations and saves them to disk. They are of little use if they are too dark or too washed out. Scaling colors is especially important if these are smoke or volcanic plumes intended for the Plume Height Project website.

Register the Cameras

Before you begin digitizing, you should evaluate how well the nine camera images are co-registered, that is, how precisely terrain features such as rivers, lakes, mountains etc. overlay on successive camera images. Test this by clicking the **Fixed Grid** check box on and then animating the cameras by clicking the animate back-and-forth button in the upper left corner of the MINX window or by dragging the **Camera:** slider back-and-forth. The yellow "+" symbols of the grid remain geographically and visually stationary, allowing you to see any "wobble" in the images as they change. Stare at a river or other distinct feature near a grid mark during animation to assess the quality of the registration, and look in several different locations, since mis-registration can vary across an image. Mis-registration of even half a pixel on several cameras can affect the height calculations. It is generally preferable to perform a registration correction (described below) on every orbit rather than taking time to evaluate any mis-registration.

Make one pass of registration correction by clicking on the **Task Menu** button, select the **Correct Registration** option, and finally select **Warp Orbit 1 Cameras for Plumes**. The **Select AGP File** dialog box will appear. In the **Directory** textbox, you should enter the directory where you have put the ancillary geographic files. Press **Filter**, and the **Files** listbox will show the available versions of the AGP file for the MISR path that corresponds to the orbit you selected. You can double-click the AGP file you want or highlight it and press **OK**. If there is more than one file, choose the most recent one as indicated by the version number (the latest version as of May 2014 is F01_0024). It may take several seconds for the file to load.

After specifying the AGP directory the first time, the directory name will be stored in a file named "MINX_dflt_path.sav" in your home directory and will be used next time as the default to populate this dialog box. Other files you select for input have the same time-saving feature. Also note that this dialog box and the other file-selection dialog boxes mentioned below are displayed in the upper left corner of your screen. If these dialog boxes become covered by other windows, it may appear that the program is locked up. So it is advisable to leave a bit of window-free space in the upper left of your screen.

Whenever you load an AGP file, you are also asked to load a **Biome File**. This is a global dataset derived from the MODIS Land Cover Product, MCD12C1. The IGBP biome classifications have been stripped out for MINX at 0.05 degrees resolution. Whenever a plume is digitized, MINX finds the biome class at the location of the fire pixel in the digitized plume polygon with the largest fire radiative power. This biome class is recorded in the output raw data file. The default biome file, included in MINX, is for 2008. Versions for other years can be downloaded from the Open Channel website.

When you have specified the AGP and Biome file, MINX will attempt to automatically assess and correct the registration for each camera in this order: Df, Cf, Bf, Af, Aa, Ba, Ca, Da. Each camera is compared with the An camera at each point on a regular grid. The across- and along-swath mismatches in pixels are posted on the current camera image at each point to within 0.2 pixels, starting at the bottom and working up, and the images are then warped non-linearly to provide a correction that makes each camera best match the An camera.

After all cameras have been corrected, the mean and RMS correction for each camera are presented in a dialog box. If there are RMS corrections greater than about 0.3 pixels, you should make a second pass of registration correction. More than two passes seldom improves results. However, there are some registration problems that cannot be corrected. If there appears to be a horizontal discontinuity in registration in the middle of a block or between blocks, it is a flaw in the level 1 processing, and it cannot be removed. If there are rapid changes in registration in mountainous terrain, it may be due to inaccuracies in the digital elevation map (DEM) used in level 1 processing. MINX can only partially remove these problems.

Turn off the yellow **Fixed Grid** when you are done.

Digitize Plumes

Study plume scene

Before you begin digitizing *each* plume, you should carefully study the plume to understand its structure and dynamics. Some plumes are simple to interpret, because they form neat, narrow triangular plumes as they spread from their source under strong winds, and the active source area near the tip of the triangle may support a single, cylindrical aerosol column that can be seen rising from the ground during camera animation.

However, many plumes are more difficult to interpret. The cylindrical column may be absent if winds are weak, or it may be hidden from view; if the wind is very weak, the plume may rise almost vertically or stagnate to form a difficult-to-interpret cloud overlying the source; in the case of wildfires, multiple, closely-spaced fires along a moving front may contribute smoke

along a broad source region to form complex, merging plumes; one plume may rise from the middle of another; water clouds (or even a higher layer of aerosol) may partially obscure a scene, confusing the image-matcher algorithm; pyro-cumulus water clouds formed above an active fire may develop high above smoke; the wind direction may have shifted since a plume was initiated causing the plume to bend, or the bend may reflect an ongoing circulation pattern.

By using the animation feature and toggling the fire pixels (if present), you can usually answer the following critical questions before beginning to digitize each plume.

- Where is the active aerosol source? – You want to digitize the first point near this. For simple plumes, it can often be identified as the point where the column of rising aerosol leaves the ground and where there may be a concentration of MODIS fire pixels. If there is an active fire front or dust source with many point sources whose plumes merge but can be visually separated, consider digitizing the plume as several smaller ones. If aerosols from the source cannot easily be separated into individual plumes, choose a first point near a particularly dominant source of aerosol, or choose a point near the middle of the sources.
- What region of aerosol comprises the plume? - This is the area to be circumscribed during digitizing. Isolated plumes may have distinct edges that make the task easy. If the aerosol from two or more plumes is merging into one plume but the edges can continue to be distinguished by height or by other visual characteristics, digitize the plumes separately. If there are water clouds above the plume on the An camera, carefully digitize around them, leaving a margin of several pixels on each side; this may result in plume polygons with narrow necks over the clouds which connect different parts of the plume. It is generally better to digitize with a margin of a few pixels outside the plume than several pixels inside, because the points used in height retrievals are situated on a grid that often begins a few pixels inside the polygon. This is especially true near the source point which is often narrow and can easily be under-sampled.
- In what direction is the aerosol load currently moving? - This is the plume direction line, and its determination is often the most challenging aspect of the digitizing process. Once the location of the active aerosol source has been identified, the direction in which the aerosol is moving must be inferred from the shape of the plume and sometimes from the shape of better-behaved neighboring plumes. A simple linear plume shape requires only a single additional point to define the direction. But if a plume is curved or bent and it appears from adjacent plumes that the wind direction is changing locally or that there is an obvious circulation pattern, you may want to use several points to define a curved wind vector (MINX applies a spline to smooth the line). Sometimes a bent plume indicates that the distal portion of the plume was generated when the wind was blowing in a different direction than currently and that the entire plume, bend and all, are now moving in the direction indicated by the proximal portion of the plume. In this case the plume direction line could be straight and in the direction of the portion of the plume nearest the source. Many plumes have spatial variations in the wind direction within the plume. MINX can only apply the wind direction from a single direction line, so this line should be, in some sense, an average direction for the plume. Alternatively, you can digitize the plume in segments.

Select digitizing options

To initiate digitizing of plumes, click the **Task Menu**, choose **Select Digitizing Tool**, then select **Enable Digitizing…** (or use the shortcut CNTL-D). This displays the **Digitizing Options** dialog box. The default options are generally appropriate for digitizing most smoke plumes. If you don't want to read aerosol data from MISR AS_AEROSOL products, uncheck that box (if your results will be archived on the MISR Plume Height Project website, leave the box checked). If you want to digitize volcanic plumes, select that option instead. If you think your plumes are higher than 6 km or the wind speed is greater than 25 m/s, enter the value(s) you think are appropriate. Desert dust plumes can present a special problem, because they often lie close to the ground. You may need to set the value in the **Min hght above terrain (km)** textbox to less than 0.25 km so very low heights are not rejected. The danger is that, if the cameras of the orbit are poorly co-registered, image matches on the terrain may appear as heights above the terrain, which will be mistaken for aerosol heights. Click **OK** when you're done.

After clicking **OK**, the standard arrow cursor (or the current cursor) should change to the digitizing cursor, which is a fine crosshairs. The digitizing state, including the current digitizing options, will be maintained until you change the state by selecting a different menu option. If you wish to change a digitizing option, you need to return to the **Digitizing Options** dialog box.

Digitize plumes

To keep oneself oriented, it is helpful to begin digitizing plumes starting from the top end of the MISR blocks you've loaded (smaller block numbers) and work down toward the bottom (larger block numbers). For each plume you identify, often with the help of MODIS fire pixels, study the scene as described in the section above. Determine where to begin digitizing, what plume outline you intend to follow and where the direction line should go.

When you are ready to begin, click the left mouse button *behind* (upwind of) what you have decided is the source of the plume. This point should be selected carefully, making sure to encircle all the MODIS fire pixels (if present) you believe are associated with this plume as well as the aerosol. This is important because MINX calculates the total fire power of the plume, and if all pixels are not within the plume outline, they will not be included in the calculation. An aqua colored dot will mark the first point. As you click the left mouse button on more points along the boundary of the plume, aqua crosses will appear with dashed lines connecting them to previous points. As you finish digitizing the plume and prepare to close the polygon, click as close as possible to the first point. If you are within a few pixels, the line will automatically close, and the polygon you have created will be assigned a name that will be posted near the first point. This name consists of the orbit number, the block number that the first point falls in and a sequential plume number within *that block*.

If you haven't yet closed the polygon for a plume and decide that you are not satisfied with your digitizing, you can cancel work in progress by clicking the right mouse button anywhere in the data window. This will erase the digitized points from the screen and the internal database, and you can start over with this plume.

After you have clicked to close the polygon, you are ready to specify the direction in which the smoke particles of the plume are currently moving. The first/last point digitized is automatically

assigned to become the first point in a direction line that you complete by continuing to digitize. If the plume is reasonably linear, you can define the direction with only one additional point, but you can digitize as many points as you wish. If you determine that portions of the plume are being affected by winds from different directions, you should bend the direction line in the direction you think the winds were blowing *at the time the image was acquired*. The direction line does not have to be confined to the plume polygon and could extend past the end of the plume for aesthetic reasons only; the current direction of motion is the only important criterion.

The plume direction is computed and stored by MINX at many points on the direction line. When plume heights and winds are later computed at grid points in the interior of the polygon, the direction used in the height calculation for the grid point being evaluated is taken from the point on the direction line nearest to it. So rapid changes in wind direction should never occur – make the transition gradual over a few points.

The last step in digitizing a plume is to click the right mouse button anywhere in the data window. This signals the program to go ahead with the analysis. The interior of the polygonal region you have defined is filled with uniformly spaced points at which heights, wind velocities and several other parameters will be computed. The spacing of these points is determined by the **Sample Spacing** button on the **Digitizing Options** dialog box. However, if this is the first plume to be digitized in an orbit, additional data needs to be loaded first. If you did not perform a registration correction (see *Register the Cameras*), the **Select AGP File (Terrain Hts)** and **Select Biome IGBP Grid File** dialog boxes will appear and you must choose the file to use. Next, whether or not you performed a registration correction, the **Select Geometry (GP_GMP) File** dialog box will appear, and you must choose a GP_GMP file to use. If there is more than one file, choose the most recent one as indicated by the version number (the latest version as of May 2014 is F03_0013). It may take several seconds for the file to load. You will not have to specify these files or wait for the data to be loaded again for subsequent plumes on the portion of the orbit you've loaded.

When the GP_GMP file has finished loading, a yellow line and arrowhead will be drawn over the plume representing the direction line you digitized. Then an image-matching step compares the An camera with each of the six near-nadir cameras (Cf, Bf, Af, Aa, Ba, Ca) for each point inside the digitized polygon. The result of this matching process for each point and camera pair is an across-swath and an along-swath offset or disparity representing the number of pixels in each direction that the matched camera must be displaced to best fit the An camera image at that point. This process is the slowest operation in the plume digitizing process.

When the image-matching pass of processing is finished, the second pass begins. This involves using the derived disparities, the plume wind directions, the known camera geometries and the assumption of a spherical earth to compute the height and the along- and across-track wind components at each point for each camera paired with An. If at least three cameras return height and wind estimates that are within a threshold value of each other for the point being evaluated, then we compute a weighted mean of these estimates and report them as the retrieval values. If the **Relax retrieval thresholds** button on the **Digitizing Options** dialog box is checked, then only two cameras must return similar height and wind estimates, and the thresholds are relaxed as well.

When the second pass has finished, several things happen in rapid succession. First, the digitized plume polygon is filled with colored squares at points where a height retrieval was successful. The colors represent the wind-corrected heights computed for each point. If you wish, a color key can be displayed to interpret the colors and the scale can be changed by going to the **Task Menu** and selecting **Select Data Overlay Options** and entering the desired information in the dialog box.

Next a profile window is created that contains height and wind information. The upper pane shows a profile of zero-wind heights, wind-corrected heights and terrain heights, and the bottom pane shows a profile of across-swath and along-swath wind speeds. The x-axis is the distance of each point in the plots from the first point digitized on the plume measured in kilometers.

If this is the first plume digitized in an orbit and you checked the **Show AS_AEROSOL data** checkbox in the **Digitizing Options** dialog box, a **Select AS Aerosol File** dialog box will appear next from which you should select the file to use. If there is more than one file, choose the most recent one as indicated by the version number (the latest version as of 3/2015 is F12_0022). It may take several seconds for the file to load. For subsequent plumes, you will not have to specify this file or wait for the data to be loaded.

If you accepted the default value of **Match Twice: w/ red and blue** in the **Digitizing Options** dialog box, a second identical pass of image-matching, height/wind calculation and display of results will be made next. The first pass will have been done using the MISR red-band images, and the second pass with blue-band images. See *Nelson et al*., 2013 (*Remote Sens*.) for an explanation of the utility of each.

All the plots presented on the screen and more are saved to disk in the output directory you specified on the third line of the "PlumeProjOrbitList.txt" file. If you chose both red and blue band retrievals, the saved files include:

- 1 animation of the 9 cameras over the plume, saved as an MP4 file,
- 1 image of the digitized outline on the An image, saved as a JPEG file,
- 2 images of the colored heights on the An image plus a color key, saved as JPEG files,
- 2 height/wind profile windows, saved as PNG files,
- 2 histograms of the heights and winds, saved as PNG files,
- 1 histogram of the aerosol parameters near the plume, saved as a PNG file, extracted from the MISR Standard aerosol product,
- 2 TXT files containing multiple values at each point where a valid retrieval was made; these values include geographic and MISR location coordinates, terrain heights, aerosol heights and wind speeds, aerosol physical and optical parameters, fire radiative power, etc.

If you chose to retrieve heights with only one spectral band, there will be 7 files.

If you wish to stop digitizing plumes and return to complete work on an orbit later, you can select the **Save Session…** option on the **Task Menu.** This will allow you to specify where to write the entire session - images, digitized plumes and active states – to a file on disk. Later you can restore the saved session in either of two ways:

1) Load any orbit at random, select **Restore Session…** on the **Task Menu,** and choose the name of the file where you saved the session previously.
2) Choose **Animate Cameras** on the MINX **Program Options** menu, then click the long **Select Orbit 1…** button near the top of the first dialog box, next click the **Filters:** drop-down list at the very top of the next dialog box, and choose ***.sav**. Finally choose the name of the file where you saved the session previously.

Saving and restoring sessions is a slow process and results in very large disk files. Also, the format of .sav files changes with each version of MINX, so you may not be able to load a .sav file created with a different version.

In order to delete a plume, first click the **Task Menu**, select **Select Digitizing Tool**, then select **Delete Objects** (or use the shortcut CNTL-R). The current cursor should change to the delete cursor, which is a large "X". Now you can click the cursor inside any digitized polygon. The clicked polygon will blink several times and a message box will appear asking whether you really want to delete the plume. After answering Yes or No, you can continue deleting plumes until you change the digitizing state by selecting a different menu option. When you delete a plume, the image is deleted from the screen, the data are deleted from memory and the files stored for the plume are deleted from disk.

If you have digitized a plume more than once so retrievals are overlain on the MISR image and you haven't deleted the unwanted copies, it is important to do so. MINX stores the retrieved results in memory in a first-in-first-out order. Therefore if you click to delete on a plume polygon with multiple stacked copies, the earliest one beneath the clicked point will be deleted first.

Review and edit plumes

When all digitizing processes are completed for a plume, a **Finished retrieval** dialog box is presented that requires you to specify whether a pyrocumulus cloud was observed above this plume, to give your estimate of the retrieval quality (Poor, Fair or Good), to enter any observations that warrant recording and to delete or not delete the profile windows. The estimate of retrieval quality is qualitative and can be based on the number of valid height points retrieved, the consistency of the heights and whether complicating factors such as clouds, uncertain wind direction, etc. make the results suspect. Either a Yes or No answer to the final question in the dialog box will remove the box and allow you to digitize the next plume. If you opt to leave the profile windows on the screen for further study, you can delete them manually at any time.

The importance of evaluting the quality of the plume just digitized cannot be stressed enough. In addition to the above criteria, you should carefully study the height/wind profile(s) and the color-coded heights on the MISR image. If you blundered during digitizing or believe a better result can be obtained by changing the plume outline or direction line, then redigitize the plume. You can either delete the plume first and redigitize, or you can digitize over the existing plume and then delete the earlier, underlying plume later. It is sometimes necessary to experiment by redigitizing several times in order to understand what the smoke is doing. For example, you can digitize the same plume outline several times, each time changing the wind direction line to see how height retrievals respond.

Digitize Clouds

If there are extensive regions of aerosol hanging over a scene that are not clearly associated with a particular plume or with fire pixels but appear important to understanding the transport of the aerosol, it is desirable to digitize representative portions of them. The procedure for accomplishing this is very similar to the process of digitizing plumes. However, there are a few differences:

- You should choose the **Use no wind direction (MINX cloud)** option on the **Digitizing Options** dialog box rather than **Provide wind direction (MINX plume)**.
- The third character in the last portion of plume names will be 'N' rather than 'W' (e.g., O44038-B81-SPNB1 is a smoke cloud and O44038-B81-SPWB1 is a smoke plume).
- The default spacing for points in digitized clouds is 2200 meters rather than 1100 meters for plumes, so there are 1/4 as many points per unit area. Nevertheless, you shouldn't choose really large areas to process unless you are patient.
- Because we don't know the wind direction, no direction line can be specified for clouds. Once you close a cloud polygon, the height analysis begins immediately.
- Also because no wind direction is available, no winds or wind-corrected heights are computed for clouds, so only zero-wind heights are presented in the height/wind plots and histograms and in the raw text files.

As with aerosol plumes, after you have finished digitizing each aerosol cloud region, screen shots and text files will be captured and saved in the directory defined in the third line of the "PlumeProjOrbitList.txt" file.

Done

When you have finished digitizing all the plumes and other features on an orbit, simply click the **Exit** button at the bottom of the MINX animation window. The program will clean up the memory it has been using and will redisplay either the **Animate Cameras** dialog box or the list of orbits from which to choose in the **Plume Processing** dialog box. To process another orbit, repeat the appropriate steps in **Load a MISR Orbit into MINX** above. To exit MINX instead, select **Cancel** and then **Exit** on the MINX **Program Options** menu.

Additional Features

MINX has many additional features that can be accessed while working with plumes or MISR data in general. For example you can:

- save all or a portion of a MISR image in any of several formats (Google Earth, .tif, .jpg, .png, .mp4, …) with overlying data toggled on or off;
- display colored maps of terrain, land-water mask, camera and sun angles, as well as data from aerosol, cloud height, albedo, and other MISR standard products, and modify the color scaling and show a color bar;
- change the type of data displayed inside digitized features including zero-wind heights, wind speeds and disparity values, and modify the color scaling and show a color bar;
- change the default color palette;
- overlay points on the MISR image from standard sets of volcano locations and AeroNet instrument locations or from a custom set of points;

- assign red, green and blue colors to different combinations of MISR cameras and bands to highlight angular- and spectrally-sensitive features;
- create, view and print 3D red/blue images that require the use of red/blue glasses for viewing;
- view 11 “context-sensitive” PDF files that can be accessed from within MINX that document specific features of the program.

References

Nelson, D.L., Garay, M.J., Kahn, R.A., Dunst, B.A. 2013. Stereoscopic Height and Wind Retrievals for Aerosol Plumes with the MISR INteractive eXplorer (MINX), Remote Sens. 5, no. 9: 4593-4628.