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| Title: | Fire Mapping using ASTER |
| | Part I: The ASTER instrument and fire damage assessment |
| | Part II: Calculate radiance and reflectance |
| | Part III: Calculate the Normalized Burn Ratio (NBR) and difference Normalized Burn Ratio (dNBR) |
| Product Type: | Curriculum |
| Developer: | Helen Cox (Professor, Geography, California State University, Northridge): helen.m.cox@csun.edu Laura Yetter (Research Asst., Institute for Sustainability, California State University, Northridge) |
| Target audience: | Undergraduate or Graduate |
| Format: | Tutorial (pdf document) |
| Software requirements* : | ArcMap 9 or higher (ArcGIS Desktop) (Part III), ERDAS Imagine 2010 or higher (Parts I, II, III) |
| Data: | All data required are obtained within the exercise. Data is provided for those wishing to carry out Part III alone. |
| Estimated time to complete: | All parts: 10 hrs |
| | Part I: 3.5 hrs. - 4 hrs. |
| | Part II: 3 hrs. - 3.5 hrs. |
| | Part III: 3 hrs. |
| Alternative Implementations: | <ul style="list-style-type: none"> • Parts I and III together provide a standalone exercise of an approximate assessment of burn severity and fire damage for the Old Fire which burned in southern California in October 2003. • Parts I and II together provide a standalone exercise on how to download ASTER data and convert to reflectance • Parts I, II and III together provide a standalone exercise giving a more accurate assessment of burn severity and fire damage for the Old Fire as radiometric corrections are made (raw data is converted to reflectance) • Part III can be carried out as a standalone exercise if the optional data set is used |
| Learning objectives: | Part I: <ul style="list-style-type: none"> • Learn about the ASTER instrument and data • Learn how to assess burn severity and fire damage using initial and extended assessments • Download fire maps from the Monitoring Trends in Burn Severity (MTBS) project • Download ASTER data for initial and extended fire damage assessments • Prepare data for analysis by stacking layers, projecting and subsetting imagery using ERDAS Imagine |
| | Part II: <ul style="list-style-type: none"> • Calculate radiance from ASTER Level 1B pixel data • Calculate reflectance from the radiance data |
| | Part III: <ul style="list-style-type: none"> • Calculate the Normalized Burn Ratio (NBR) |

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| | <ul style="list-style-type: none">• Calculate the difference Normalized Burn Ratio (dNBR)• Evaluate fire damage and fire recovery and compare to MTBS data |
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*Tutorials may work with earlier versions of software but have not been tested on them

Fire Mapping using ASTER

Part I: The ASTER instrument and fire damage assessment

Objectives:

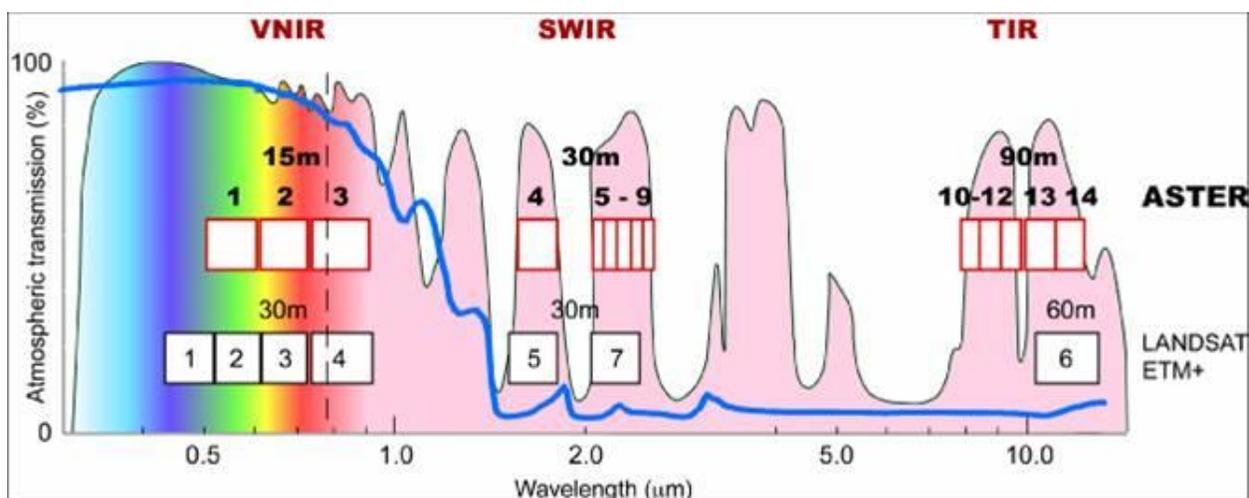
- Learn about the ASTER instrument and data
- Learn how to assess burn severity and fire damage using initial and extended assessments
- Download fire maps from the Monitoring Trends in Burn Severity (MTBS) project
- Download ASTER data for initial and extended fire damage assessments
- Prepare data for analysis by stacking layers, projecting and subsetting imagery using ERDAS Imagine



In this exercise you will learn about the ASTER instrument and its application to the study of fire mapping and fire recovery through a study of the Old fire, which was a part of the "2003 firestorm" or "fire siege of 2003" in October 2003 when 8 wildfires simultaneously burned southern California (Piru, Verdale, Simi, Grand Prix, Roblar, Paradise, Cedar, Otay fires). You will be using ASTER data to map the normalized burn ratio (an index used to evaluate burned areas), and to look at post fire recovery.

ASTER

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is considered the zoom lens of the Terra satellite. A subsystem of three sensors comprise ASTER. The first sensor captures 3 bands of visible and near infrared (VNIR) wavelengths at 15 m resolution. Band 3 is collected at nadir (directly below) and aft of (behind) the satellite making it possible to create stereo imagery which is used to generate digital elevation models (topography). The second sensor collects 6 bands of shortwave infrared (SWIR) at 30 m resolution. The third sensor captures thermal infrared (TIR) wavelengths in 4 bands at 90 m resolution.



(Figure taken from: <http://asterweb.jpl.nasa.gov/images/spectrum.jpg>)

The figure above shows a comparison of ASTER and Landsat ETM + bands and resolution.

ASTER band characteristics:

| Subsystem | Band No. | Spectral Range (μm) | Spatial Resolution (m) | Quantization Levels |
|-----------|--------------|----------------------------------|------------------------|---------------------|
| VNIR | 1 | 0.52- 0.60 | 15 | 8 bits |
| | 2 | 0.63- 0.69 | | |
| | 3N nadir | 0.78- 0.86 | | |
| | 3B backwards | 0.78- 0.86 | | |
| SWIR | 4 | 1.60- 1.70 | 30 | 8 bits |
| | 5 | 2.145- 2.185 | | |
| | 6 | 2.185- 2.225 | | |
| | 7 | 2.235- 2.285 | | |
| | 8 | 2.295- 2.365 | | |
| | 9 | 2.360- 2.430 | | |
| | TIR | 10 | 8.125- 8.475 | 90 |
| 11 | | 8.475- 8.825 | | |
| 12 | | 8.925- 9.275 | | |
| 13 | | 10.25- 10.95 | | |
| 14 | | 10.95- 11.65 | | |

(Table taken from: http://asterweb.jpl.nasa.gov/content/03_data/04_Documents/aster_user_guide_v2.pdf)

ASTER data is available on a demand basis, meaning ASTER data is only collected when there is a request for it. This creates gaps in ASTER's data record, making it limited for temporal studies compared to Landsat. However if Landsat was to fail ASTER was designed so it could replace it. ASTER's purpose is to monitor land surface climatology, vegetation and ecosystem dynamics, volcano monitoring, hazard monitoring, hydrology, geology and soils, and land surface and land cover change (For details see: <http://asterweb.jpl.nasa.gov/science.asp>).

Be aware of the following announcement from NASA in seeking to use ASTER data for a project:

"ASTER SWIR detectors are no longer functioning due to anomalously high SWIR detector temperatures. ASTER SWIR data acquired since April 2008 are not useable, and show saturation of values and severe striping. All attempts to bring the SWIR bands back to life have failed, and no further action is envisioned. VNIR and TIR data continue to show excellent quality, meeting all mission requirements and specifications." (<http://asterweb.jpl.nasa.gov/swir-alert.asp>).

The fire examined in this exercise took place before 2008. To study fires since 2008 you should use Landsat imagery.

Initial and Extended Assessment

In this exercise an initial and extended assessment of wildfire will be conducted. The initial assessment identifies the fire perimeter and severity of the burn. Images for the **initial assessment** are taken

directly after the fire (post- fire image) **and a year before the fire** (pre-fire image) during the same month as the post-fire image. The difference between those two images will show how much vegetation there was before the fire and how much was left after the burn thereby identifying all the vegetation that was burned.

The **extended assessment** identifies the re-growth rate of the vegetation after the fire. An image is taken **just before the fire started** (pre-fire image) and is compared to an image taken **a year or more after the fire** (post-fire image) during the same month as the pre-fire image. This analyzes how long it takes for the vegetation to be restored to what it was before the fire.

MTBS

Monitoring Trends in Burn Severity (MTBS) is a project sponsored by the Wildland Fire Leadership Council (WFLC) and other agencies to implement the National Fire Plan and Federal Wildland Fire Management Policies (<http://www.mtbs.gov/>). The MTBS maps fire perimeters, and calculates burn severity for all fires from 1984 to 2010. In this exercise you will download MTBS data. Fire perimeter shapefiles from MTBS will be used to locate the relevant ASTER imagery and MTBS fire severity maps will be compared to your results to check your work.

The Old Fire



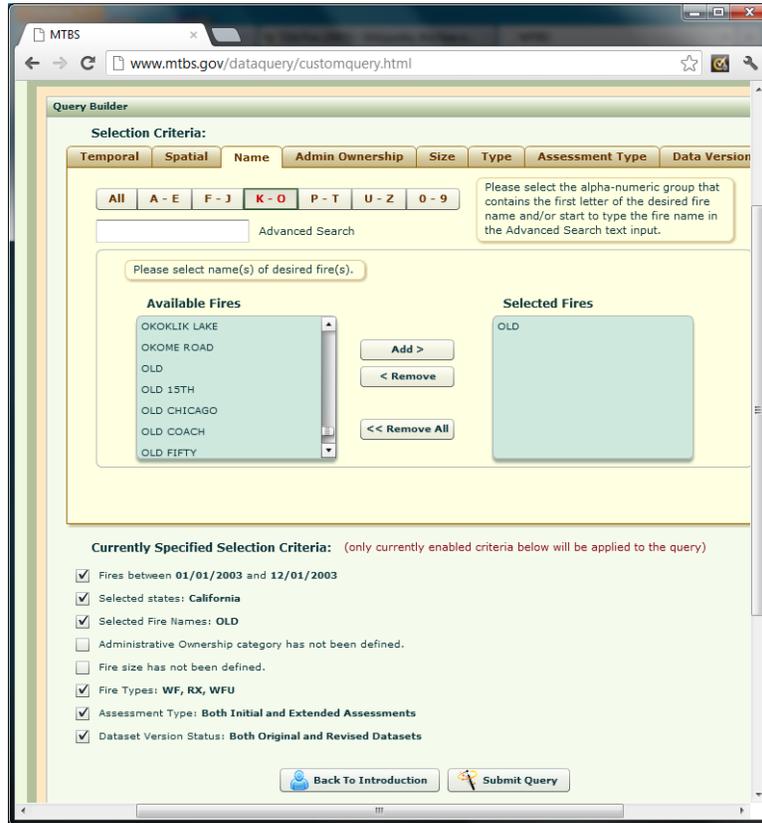
The Old fire was a part of the "2003 firestorm" or "fire siege of 2003" in October when 8 wildfires simultaneously burned southern California (Piru, Verdale, Simi, Grand Prix, Roblar, Paradise, Cedar, Otay fires). The Old fire ignited on October 25, 2003 by an arsonist in San Bernardino County. The fire burned 91,281 acres including the San Bernardino Mountains, Highland, and Lake Arrowhead. The fire was contained on November 2, 2003. Nine hundred and ninety three homes were burned and 6 lives were lost. The fire burned mixed residential and wild lands and cost \$42 million in damages. Burn severity and rate of vegetation re-growth will be calculated for this fire.

1. Download MTBS data

Go to the MTBS website <http://www.mtbs.gov/>. (May not work well with Firefox.)

On the left menu bar select 'Data Access' > 'Get MTBS Data' > 'MTBS Data Search and Distribution Tools'. Under the 'Temporal tab' search around the dates of the fire in 2003, under the 'Spatial tab' select

California and then press “Add”, under the 'Name' tab locate OLD and press “Add”. Then click 'Submit Query'.



The next page shows the query results with an icon to download the GIS data compressed file.

Monitoring Trends in Burn Severity (MTBS)

MTBS Data Search and Distribution Tools

Query Results

To download a PDF, KMZ or GIS dataset for a specific fire, please click the appropriate icon from the fire listing below. To download a data product for **all of the fires listed below**, please check the box above the desired product and click **Download All** button.

Revision Codes

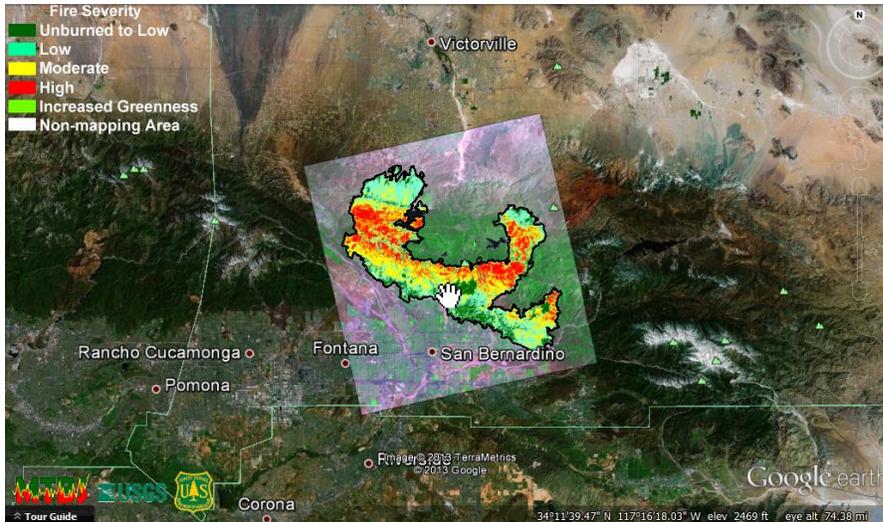
- A - Change of assessment strategy
- B - Change of burn severity class thresholds
- C - Change of imagery used in assessment
- D - Change of fire perimeter
- E - Change of fire ID only
- F - Change of fire ID and mapping change (A-D)

Number of Records: 1

| Fire ID | Fire Name | Fire Type | Version | Revision Code | Release Date | Fire Map (PDF) | Fire Map (KMZ) | GIS Data |
|--------------------|-----------|-----------|----------|---------------|--------------|----------------|----------------|----------|
| FS-0512-147-031025 | OLD | WF | Original | | 4/28/2008 | | | |

Download All

Save the downloaded data which contain the Old fire perimeter and the MTBS images showing fire severity. You may also like to download the Fire Map pdf to view MTBS results and/or the .kmz Google Earth data shown below.

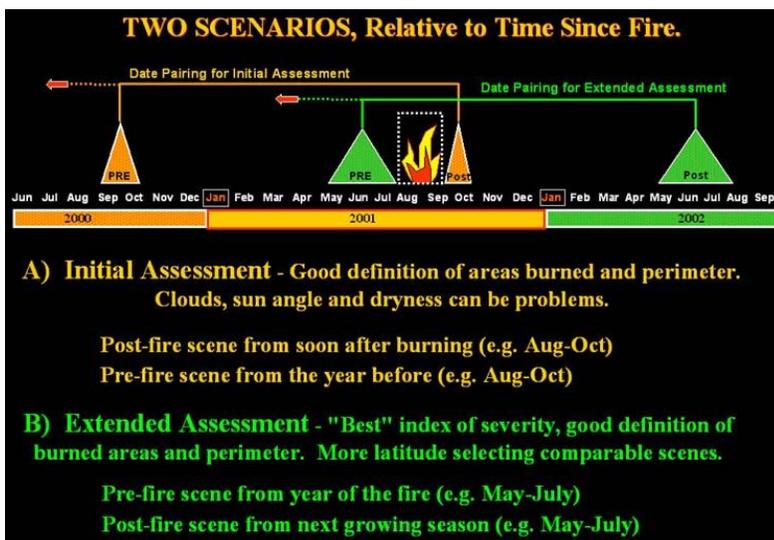


2. Initial and Extended Assessment images

To conduct the initial and extended assessment of the Old fire four images have to be downloaded. Two images are downloaded for the initial assessment and two images for the extended assessment.

The initial assessment post-fire image should be taken as soon after the fire as possible. The initial assessment pre-fire image should be taken the year before the fire started (ideally) and as close to the post-fire image date as possible.

The extended assessment pre-fire image should be taken during the growing season before the fire started. The extended assessment post-fire image should be taken 1 to 5 years after the fire during the same time as the pre-fire image. Use the diagram below to guide you.



Since ASTER only collects data if it is requested, it may be difficult to get your desired image, a cloud free image, or an image that covers the entire burn area. Make sure your images cover at least a portion of the fire area. The 2 initial assessment images should overlap each other (spatially). The 2 extended assessment images should overlap each other (spatially). However the initial and extended assessment images do not have to overlap.

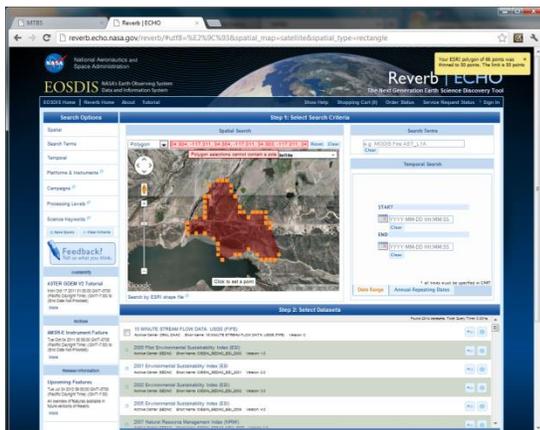
ASTER level 1b imagery is available from NASA's Reverb Echo website (<http://reverb.echo.nasa.gov/>) (works best in Internet Explorer or Chrome) or USGS's GloVis website (<http://glovis.usgs.gov/>) (This site requires Java. You may be prompted to install this. An alternative is to open the site in Chrome. Chrome allows the user to run Java applications without installing it through the "Run this time" selection.)

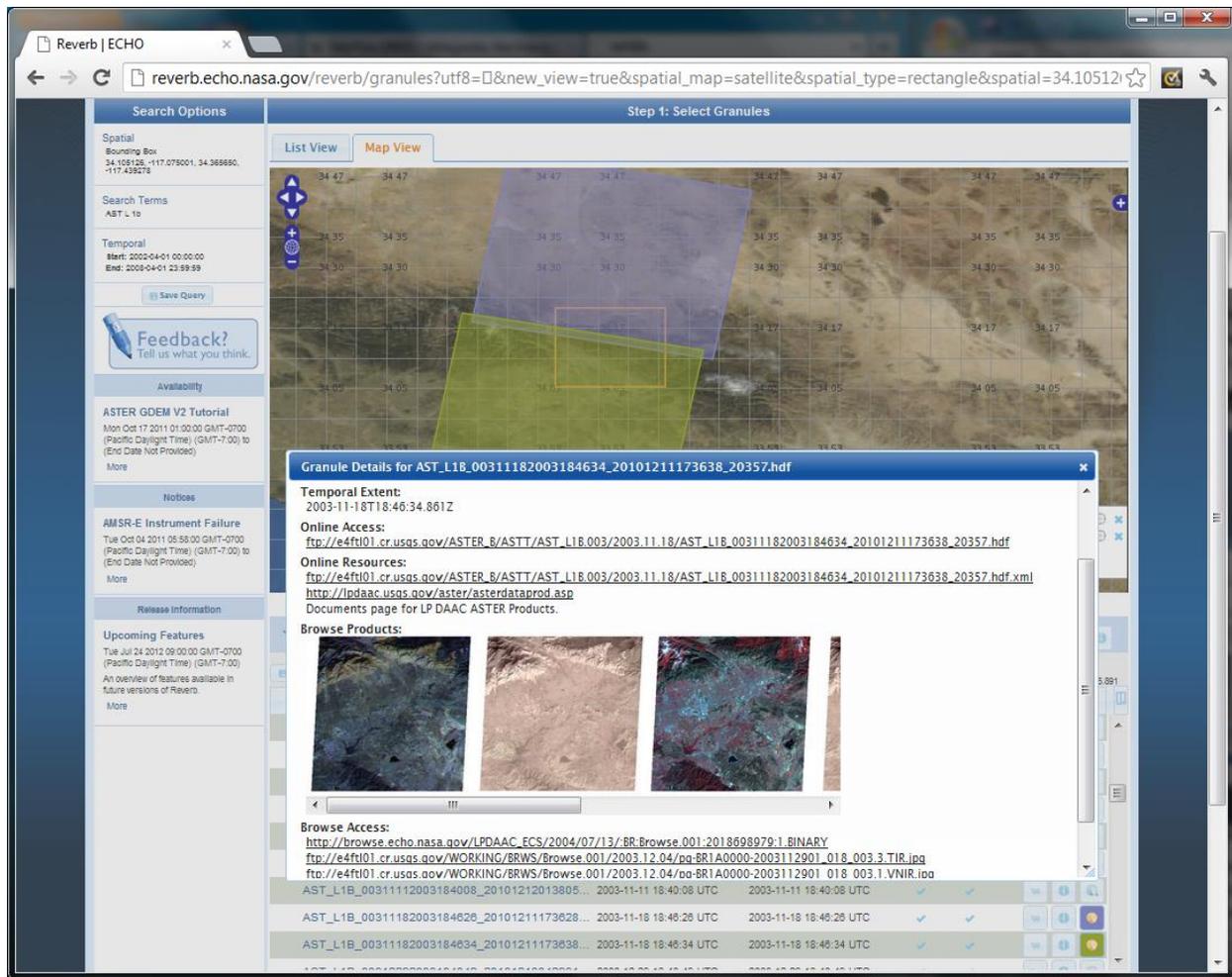
The directions here are for the Reverb website, but you may use which ever website you prefer.

Reverb Echo allows you to upload the fire perimeter shapefile from the MTBS website to the Reverb 'Spatial Search' box by using the link at the bottom of the map that says 'Search by ESRI shape file'. But this is not straightforward and requires image re-projection first.

Alternatively in ArcMap you can go to the fire perimeter Properties > Source > 'Extent' values and use those values as input coordinates for a 'Bounding Box' on the Reverb website. The shapefile from the MTBS website needs to be unzipped twice before it can be added to ArcMap. The first extract gives a .tar file which then needs to be unzipped again to get the shapefile.

Another option is to use the 'Place Name' option or get coordinates from the Google Earth .kmz file that you can download from the MTBS site.





When you have found a good initial post-fire image copy, save the link (from the (i) button> 'Granules Details' box > under 'Online Resources'> the link that ends in .xml) for the metadata, and add the item to your cart.

Next, start looking for a pre-fire image. Leave the post-fire image footprint on the map. Add the pre-fire image footprint to the map and make sure the layers overlap as much as possible. Check that the pre-fire image was taken at least a year before the post-fire image and during the same month/ time period as the post-fire image. The pre-fire image should also have minimal cloud coverage and include both VNIR and SWIR bands.

This may take some going back and forth to find good pre- and post- fire images. Suggested dates are Dec 10, 2002 for initial pre-fire and January 14, 2004 for initial post-fire.

Copy and save the link for the pre-fire metadata, and add the image to your cart for download.

The screenshot shows the Reverb | ECHO web interface. The browser address bar displays the URL: reverb.echo.nasa.gov/reverb/granules?utf8=&new_view=true&spatial_map=satellite&spatial_type=rectangle&spatial=34.10512. The page title is "Return to dataset results" and the current step is "Step 1: Select Granules".

On the left side, there are search options including Spatial (Bounding Box: 34.105125, -117.075001, 34.365550, -117.432573), Search Terms (AST L 1a), and Temporal (Start: 2002-04-01 00:00:00, End: 2002-04-01 23:59:59). There are also sections for Feedback, Availability (ASTER GDEM V2 Tutorial), Notices (AMSR-E Instrument Failure), and Release Information (Upcoming Features).

The main area features a map with two red rectangular overlays representing granules. A legend in the bottom right of the map identifies the granules:

- AST_L1B_00301142004184039_20101209123953_21610.hdf
- AST_L1B_00312102002184112_20101229233643_15540.hdf

Buttons for "Add to cart" and "Remove all" are visible below the legend.

Below the map, the dataset is identified as "ASTER L1B Registered Radiance at the Sensor V003" with Archive Center: LPDAAC, Short Name: AST_L1B, and Version: 3. A table shows the first 8 granules out of 127 results:

| Granule ID | Start Time | End Time | Online Access | Browse |
|---|-------------------------|-------------------------|---------------|--------|
| AST_L1B_00309052002184104_20110103133509... | 2002-09-05 18:41:04 UTC | 2002-09-05 18:41:04 UTC | ✓ | ✓ |
| AST_L1B_00309212002184110_20110102103853... | 2002-09-21 18:41:10 UTC | 2002-09-21 18:41:10 UTC | ✓ | ✓ |
| AST_L1B_00309272002060117_20110102052235... | 2002-09-27 06:01:17 UTC | 2002-09-27 06:01:17 UTC | ✓ | ✓ |
| AST_L1B_00309282002184703_20110102044217... | 2002-09-28 18:47:03 UTC | 2002-09-28 18:47:03 UTC | ✓ | ✓ |
| AST_L1B_00309282002184711_20110102044237... | 2002-09-28 18:47:11 UTC | 2002-09-28 18:47:11 UTC | ✓ | ✓ |
| AST_L1B_00310072002184041_20101228024144... | 2002-10-07 18:40:41 UTC | 2002-10-07 18:40:41 UTC | ✓ | ✓ |
| AST_L1B_0031209200205551b_20101228072001... | 2002-12-09 05:55:15 UTC | 2002-12-09 05:55:15 UTC | ✓ | ✓ |
| AST_L1B_0031209200205552b_20101228143752... | 2002-12-09 05:55:23 UTC | 2002-12-09 05:55:23 UTC | ✓ | ✓ |
| AST_L1B_00312102002184112_20101229233643... | 2002-12-10 18:41:12 UTC | 2002-12-10 18:41:12 UTC | ✓ | ✓ |

December 10, 2002 metadata:

ftp://e4ftl01.cr.usgs.gov/ASTER_B/ASTT/AST_L1B.003/2002.12.10/AST_L1B_00312102002184112_20101229233643_15540.hdf.xml

January 14, 2004 metadata:

ftp://e4ftl01.cr.usgs.gov/ASTER_B/ASTT/AST_L1B.003/2004.01.14/AST_L1B_00301142004184039_20101209123953_21610.hdf.xml

Once you have found good pre- and post- fire imagery and added them to your cart, go to the View Cart section. Choose "Download" and then Choose "Data" and "text file" as your download options. The system should download a text file to you that contains links for downloading all your files. A window appears that asks if you want to open in Notepad or save. Select save. If it asks for login information you should be able to ignore the requests (Close the request box) and try again. When you have the text file downloaded, open it in Wordpad or Notepad. Wordpad is better because it will put the line breaks in for you. With Notepad you have to manually press the "Enter" key on your keyboard to put line breaks in the right places. After opening the text file and making sure the line breaks are in the right places, there should be a series of lines that start with "ftp://....." or "http://....". These lines can be individually copied and pasted into a browser to locate and download the data. You only need the one

that ends in .hdf, as this is the actual data. The one ending in .hdf.xml contains the metadata. The others are jpg images of the data that you don't need. Use the hdf links to obtain your data (.hdf files) and save them.

Repeat the downloading process for the extended assessment images. The extended pre-fire image should be taken from the growing season before the fire of the same year as the fire and the extended post-fire image taken in the growing season 1 to 5 years after the fire. Recommended extended pre-fire date is July 6, 2003, and extended post-fire: July 8, 2004.

The screenshot shows the ECHO Reverb web interface. The main content area displays a map with a yellow and blue rectangular selection box over a satellite image of a landscape. Below the map is a table of granules. The table has columns for Granule ID, Start Time, End Time, Online Access, and Browse. Two granules are highlighted in yellow and blue, corresponding to the selection box on the map.

| Granule ID | Start Time | End Time | Online Access | Browse |
|--|-------------------------|-------------------------|---------------|--------|
| AST_L1B_00307062003183925_20101218133555... | 2003-07-06 18:39:25 UTC | 2003-07-06 18:39:25 UTC | ✓ | ✓ |
| AST_L1B_00307222003183847_20101218013436... | 2003-07-22 18:38:47 UTC | 2003-07-22 18:38:47 UTC | ✓ | ✓ |
| AST_L1B_00308072003183851_20101217143640... | 2003-08-07 18:38:51 UTC | 2003-08-07 18:38:51 UTC | ✓ | ✓ |
| AST_L1B_00308232003183900_20101216113448... | 2003-08-23 18:39:00 UTC | 2003-08-23 18:39:00 UTC | ✓ | ✓ |
| AST_L1B_00309062003183859_20101215163942... | 2003-09-06 18:38:59 UTC | 2003-09-06 18:38:59 UTC | ✓ | ✓ |
| AST_L1B_00309242003183921_20101214082743... | 2003-09-24 18:39:21 UTC | 2003-09-24 18:39:21 UTC | ✓ | ✓ |
| AST_L1B_00310262003183941_201012212204048... | 2003-10-26 18:39:41 UTC | 2003-10-26 18:39:41 UTC | ✓ | ✓ |

July 6, 2003 metadata:

ftp://e4ftl01.cr.usgs.gov/ASTER_B/ASTT/AST_L1B.003/2003.07.06/AST_L1B_00307062003183925_20101218133555_6228.hdf.xml

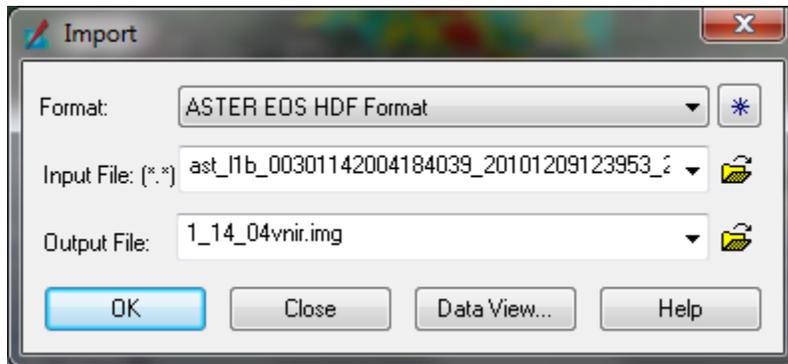
July 8, 2004 metadata:

ftp://e4ftl01.cr.usgs.gov/ASTER_B/ASTT/AST_L1B.003/2004.07.08/AST_L1B_00307082004183927_20101130193748_20438.hdf.xml

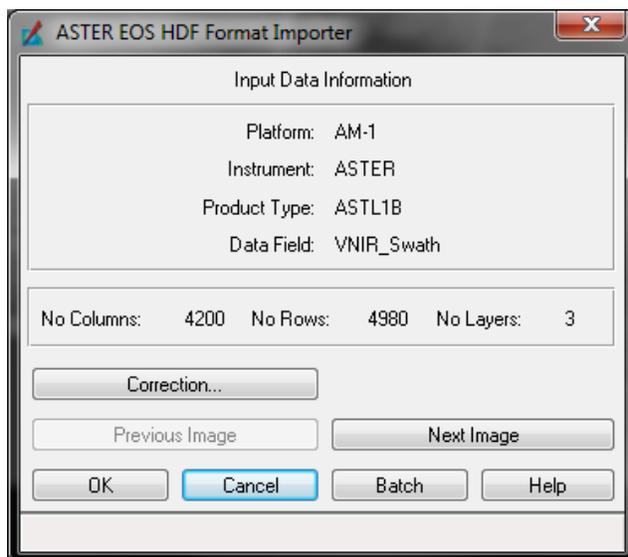
3. Import the ASTER hdf data into ERDAS

ASTER has three subsystem instruments that collect and store VNIR, SWIR, and TIR bands separately. Because of this these three sets of bands have to be imported into Imagine separately.

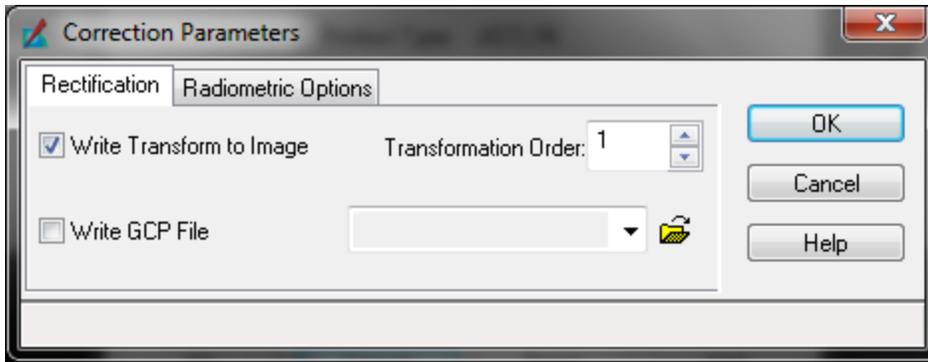
In Imagine 2010 under the 'Manage Data' tab choose 'Import Data'. In the Classic Interface just click on the Import button. In the Import dialog box that opens select 'ASTER EOS HDF Format' for the format. Input your initial assessment pre-fire image. First the VNIR bands will be imported, name your output file accordingly.



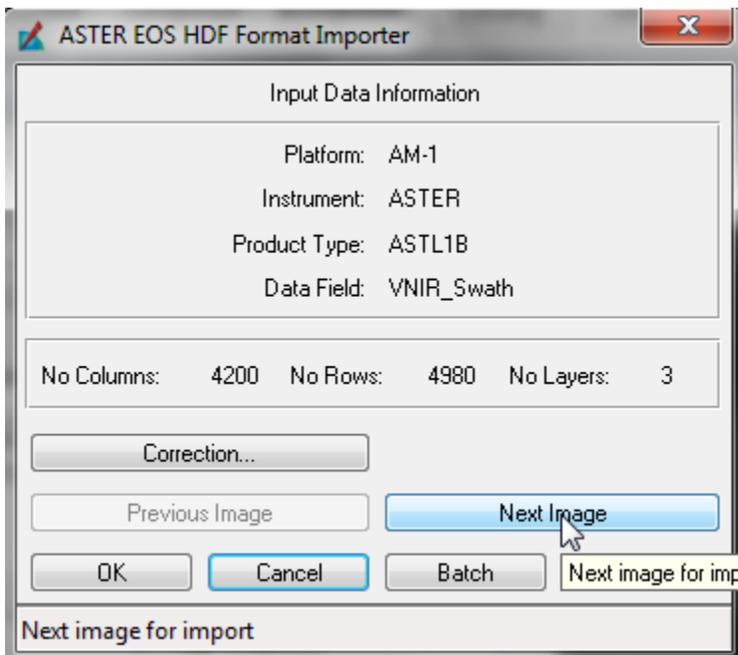
The 'ASTER EOS HDF Format Importer' opens. Make sure that the Data Field says VNIR_Swath.



Click on the 'Correction' button. On the 'Rectification' tab check 'Write Transform to Image' and choose 'Transformation Order' as 1. This will project the data when it is imported. Click OK and Click OK on the 'ASTER EOS HDF Format Importer' to import the VNIR bands.



Repeat the Import steps for the SWIR band using the same input file, but on the 'ASTER HDF Format Importer' box click the 'Next Image' button until the 'Data Field' name changes to 'SWIR_Swath'. Now you are importing the SWIR bands. Set the same 'Correction Parameters' and be sure to name the output file accordingly.



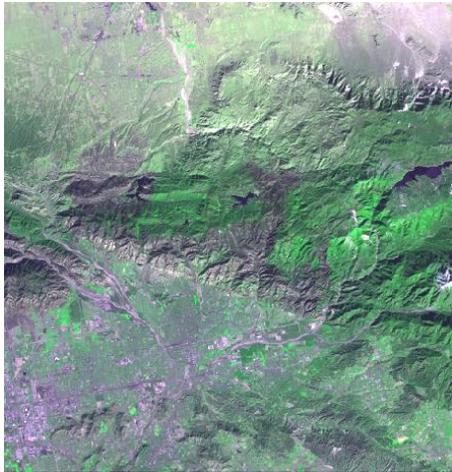
We do not need the thermal images (TIR) for this exercise.

Repeat this process for all four of your images, so that you have 8 new files containing pre and post fire images in VNIR and SWIR for your initial and extended assessment.

Examine your images by opening them in Imagine.

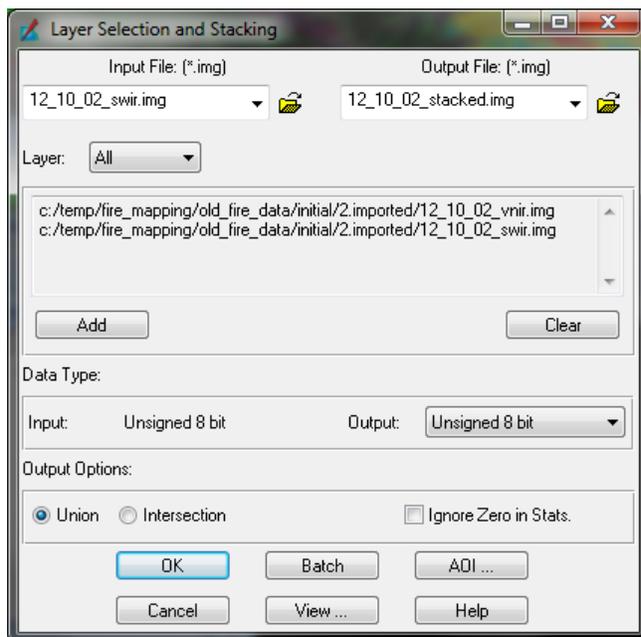
1. How would you display the bands to see a false color IR image? (Turn in a screen shot.)
2. Notice that one of the visible color bands is missing. Which color?

3. How would you display the bands to see something resembling a true color image? (Use the red gun to display the red band but try displaying the NIR band as green, and the green band as blue. See if you can make a pseudo-true color image this way and turn in a screen shot.)



4. Stack the VNIR and SWIR layers together.

In Imagine 2010 on the Raster tab> select Spectral> Layer stack. Using the Classic Interface, under Image Interpreter choose Utilities then Layer Stack. Navigate to your initial assessment pre-fire VNIR, under layers Select All then click the Add button. Next navigate to the initial assessment pre- fire SWIR file, under layers Select All and click the Add button. Leave the output data type as Unsigned 8-bit and Click OK.

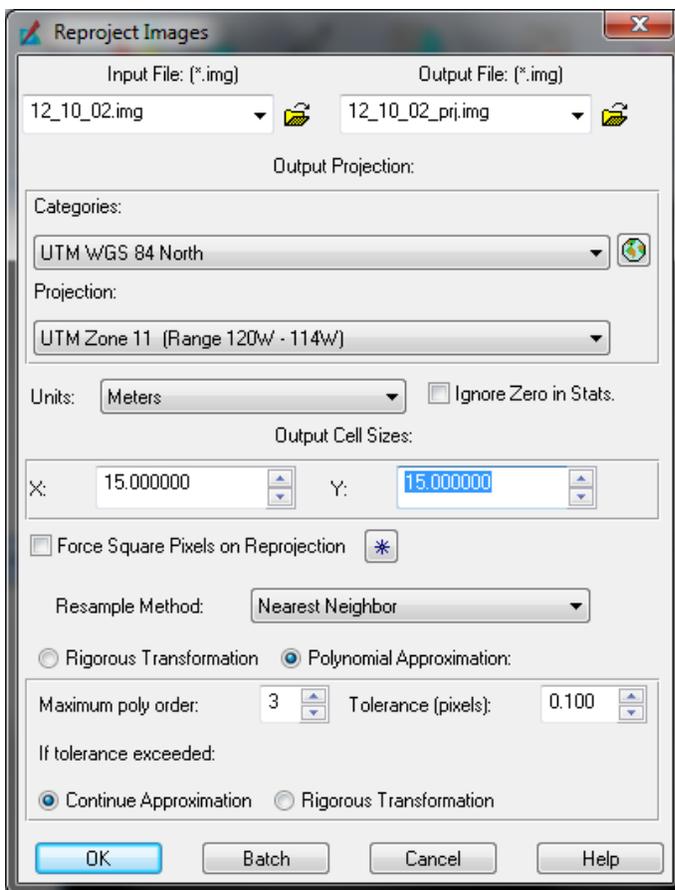


Repeat stacking for all of your images, saving each as its own output image (.img). (Stack: initial pre-fire image, initial post-fire image, extended pre-fire image, and extended post-fire image. Be sure to add VNIR layers first then SWIR layers.)

5. Project layers and Resample SWIR cell size

VNIR bands have a cell size of 15 meters and SWIR bands have a cell size of 30 meters. The SWIR bands need to be re-sampled down to a cell size of 15 m. In Imagine re-sampling takes place when an image is being projected. Therefore this is also a good time to project all images.

In ERDAS 2010> go to the 'Raster' tab> 'Reproject'> input your pre-fire (stacked) file> under 'Categories' select 'UTM WGS 84 North'> for 'Projection' select 'UTM Zone 11'> change the 'Output Cell Sizes' to 15 m. In the Classic Interface the Reproject Images menu can be found under Image Interpreter -> Utilities

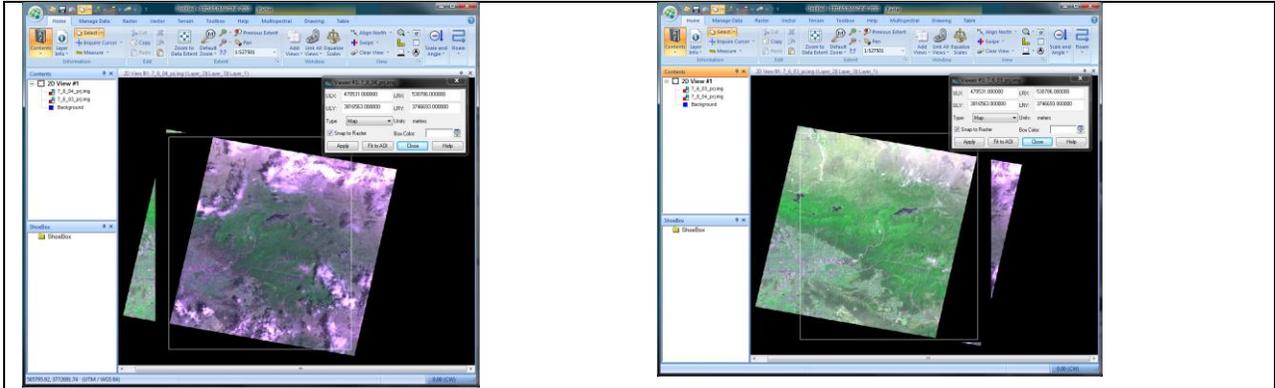


After setting up the options, press OK. Now the SWIR bands have the correct cell size. Repeat this step for all four images (initial pre-fire, initial post-fire, extended pre-fire, extended post-fire).

6. Subset Images

Add your initial assessment projected images to a Viewer in Imagine (pre-fire initial and post-fire initial). The pre- and post- fire images may not line up exactly but there should be overlap between them. Use

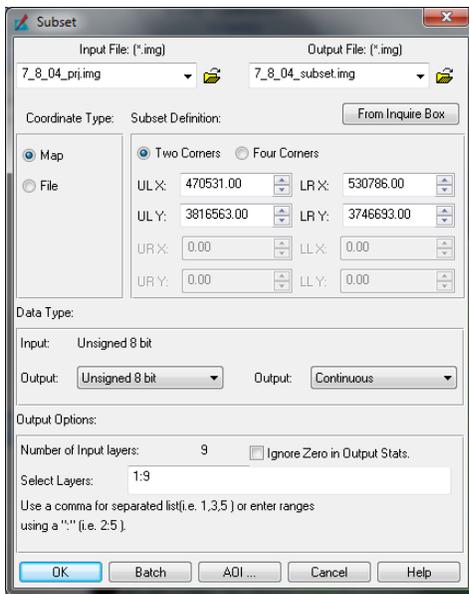
the Inquire Box (Home tab> Inquire Cursor down arrow> Inquire Box in Imagine 2010 or Utility -> Inquire Box from the Viewer window in Classic Interface) to draw a box around the overlap areas. Toggle your pre- and post- fire images back and forth to get all the overlapping area in the Inquire Box or link the Viewers to achieve the same effect. Try to leave out as much of the black area (no data) as possible.



First screen shot: pre-fire image on top, second screen shot: post-fire image on top

**** Tip:** Try to get the right edge of the pre-fire layer in the box, put the post-fire layer on top, try to get the left edge of the post-fire image in the box.

Subset the images based on the Inquire Box. (If the images line up exactly you will not need to perform a subset.) In Imagine 2010, go to the Raster tab> Subset & Chip in the Geometry Group> Create Subset Image. In Classic Interface choose Interpreter -> Utilities -> Subset. Input one of the layers, and choose the 'From Inquire Box' as the subset definition and the XY values will update. Leave the output as 'Unsigned 8 bit'. Name the output image accordingly. Press OK to complete. Make sure not to exit out of the Inquire Box before you subset the next post-fire image. Repeat for the post-fire image.



Repeat this for the set of extended assessment images.