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:	• 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: • 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 suing ERDAS Imagine
	Part II: • Calculate radiance from ASTER Level 1B pixel data • Calculate reflectance from the radiance data
	Part III: • Calculate the Normalized Burn Ratio (NBR)

	• Calculate the difference Normalized Burn Ratio (dNBR) • Evaluate fire damage and fire recovery and compare to MTBS data

*Tutorials may work with earlier versions of software but have not been tested on them

Fire Mapping using ASTER
Part II: Calculate radiance and reflectance

Objectives:

- Calculate radiance from ASTER Level 1B pixel data
- Calculate reflectance from the radiance data

ASTER level 1b data originally comes in digital number (DN) or pixel values. DNs are in scaled units (of radiance) from 0 to 255. To calculate the NBR and dNBR reflectance values are preferable because the images were taken at different times of the year.

Why does this matter?

Radiance is the amount of light energy coming off the earth per unit time, and is measured in $Wm^{-2}sr^{-1}$. Reflectance compares the amount of light coming off the earth to the amount of light coming in to the earth from the sun. To calculate reflectance we need to know the amount of incoming light which we can find from the angle of the sun, and sun to earth distance. Reflectance is measured as a fraction, decimal or percentage.

In order to calculate reflectance, first we have to calculate radiance from the DNs. Then we have to calculate reflectance from the radiance data.

1. Calculate Radiance

We will calculate radiance for bands 3 and 6 only because these are the only bands used in the subsequent exercises which utilize the normalized burn ratio (NBR).

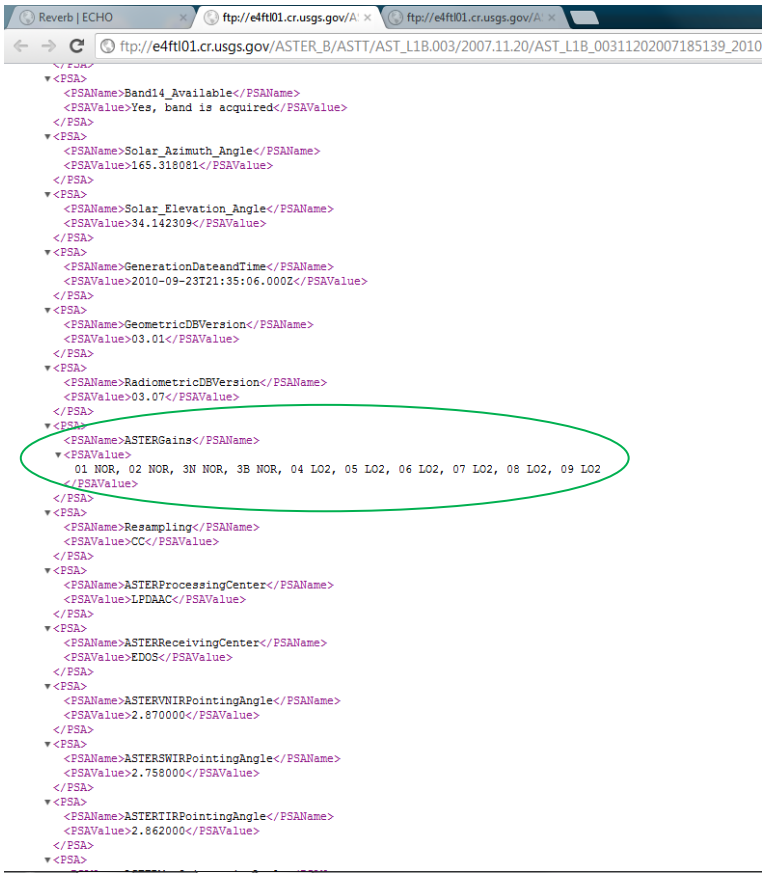
The equation to calculate radiance is:

$$\mathbf{L_{rad} = (DN-1)*Unit\ Conversion\ Coefficient}$$

http://www.gis.slu.edu/RS/ASTER_Reflectance_Temperature_Calculation.php

L_{rad}= radiance value, DN= digital number (from L1B image), Unit Conversion Coefficient (UCC)= from table below.

Go to the metadata hyperlink that you obtained when you downloaded the data from the Reverb website. Open the link in your web browser. Scroll down until you see 'ASTERGains'. Here you will find the band number followed by an abbreviation; HIGH, NOR, LOW, LO2.



Use the band and the gain code to find the Unit Conversion Coefficient values in the table below that will be used in the radiance equation. Do this for initial pre-fire and post-fire images.

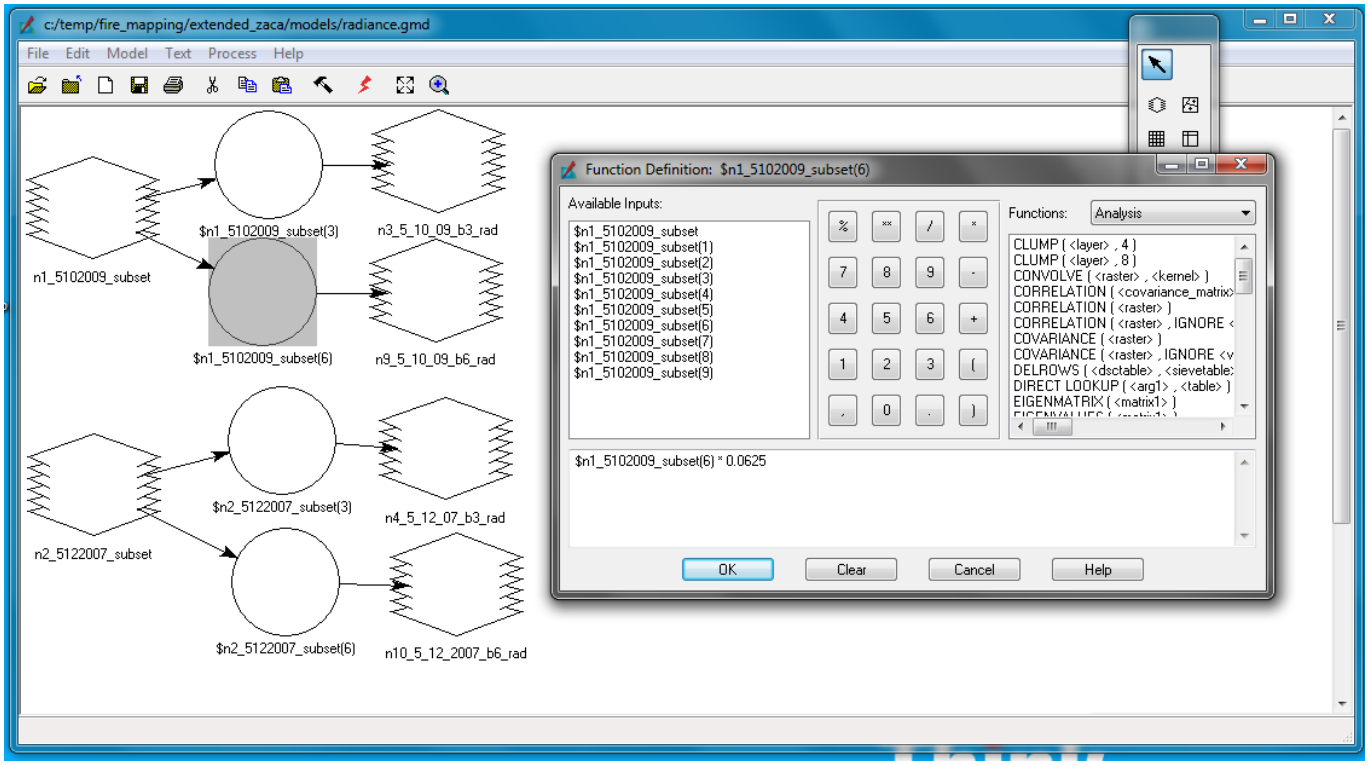
Table 1: Calculated Unit Conversion Coefficients

Band#	Unit Conversion Coefficient (W m^{-2} sr^{-1} μm^{-1})			
	High gain	Normal Gain	Low Gain 1	Low gain 2
1	0.676	1.688	2.25	N/A
2	0.708	1.415	1.89	
3N	0.423	0.862	1.15	
3B	0.423	0.862	1.15	
4	0.1087	0.2174	0.290	0.290
5	0.0348	0.0696	0.0925	0.409
6	0.0313	0.0625	0.0830	0.390

http://www.gis.slu.edu/RS/ASTER_Reflectance_Temperature_Calculation.php

(eg. if band 3= NOR then the equation = (band 3 - 1) * 0.862)

After you have found the UCC values, create the radiance equation in Model Maker for your initial assessment pre-fire bands 3 and 6 and your post-fire bands 3 and 6. The output data type should be Float Single.



Repeat the above steps for the extended assessment pre- and post- fire images.

(Radiance should be calculated for initial assessment pre-fire bands 3 and 6, initial assessment post-fire bands 3 and 6, extended assessment pre-fire bands 3 and 6, extended assessment post-fire bands 3 and 6.)

After this is complete for all the above, calculate reflectance.

2. Calculate Reflectance

After radiance values are calculated, reflectance at the top of the atmosphere (TOA) can be calculated. Start with the initial assessment pre- and post- fire radiance images.

R_{TOA} is calculated using the following equation:

$$R_{TOA} = (pi * L_{rad,i} * d^2) / ESUN_i * COS(z))$$

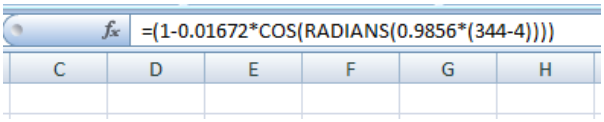
R_{TOA}= Reflectance at top of atmosphere, L_{radi}= radiance, d= earth - sun distance, $ESUN_i$= the mean solar exoatmospheric irradiance, z = solar zenith angle.

d is calculated using the follow equation:

d= (1- 0.01672 * COS(0.9856 * (Julian Day - perihelion day)))

where Julian Day is the day number from the start of the year and can be calculated in Excel using: A2 - DATE (YEAR (A2), 1, 0) where A2= the date the data was collected in mm/dd/yyyy format. (The value inside the cosine must be in radians. You can use the RADIANS function to convert degrees to radians, or calculate it form the fact that π radians equals 180°). Perihelion Day = when the earth is closest to the sun. This is January 1,2,3, or 4 depending on the year. You may just use 4 but if you would like use the website http://aa.usno.navy.mil/data/docs/EarthSeasons.php/ to look up table for each year.

d calculation in Excel:



Use the following table to find the $ESUN_i$ value:

Table 4: ASTER Solar Spectral Irradiances (W m^{-2} μm^{-1})

Band#	Smith: E_{SUN}	Thome et al (A): E_{SUN}	Thome et al (B):E_{SUN}
1	1845.99	1847	1848
2	1555.74	1553	1549
3N	1119.47	1118	1114
3B			
4	231.25	232.5	225.4
5	79.81	80.32	86.63
6	74.99	74.92	81.85
7	68.66	69.20	74.85
8		59.82	66.49
9	59.74	57.32	59.85
	56.92		
10	N/A	N/A	N/A
11			
12			
13			
14			

http://www.gis.slu.edu/RS/ASTER_Reflectance_Temperature_Calculation.php

*** For this assignment use Smith 2007 $ESUN_i$ values.

The solar zenith angle = 90 - solar elevation angle, and should be expressed in radians. (Solar elevation angle can be found in the metadata.)

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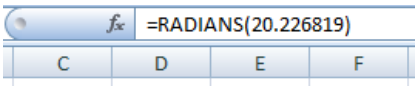
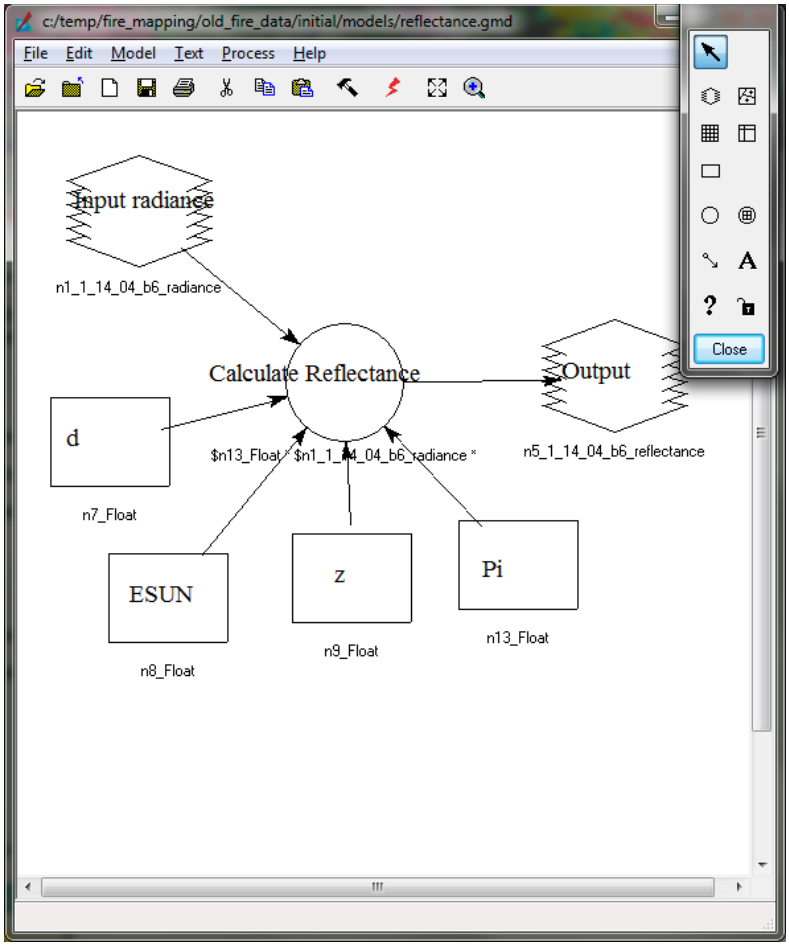
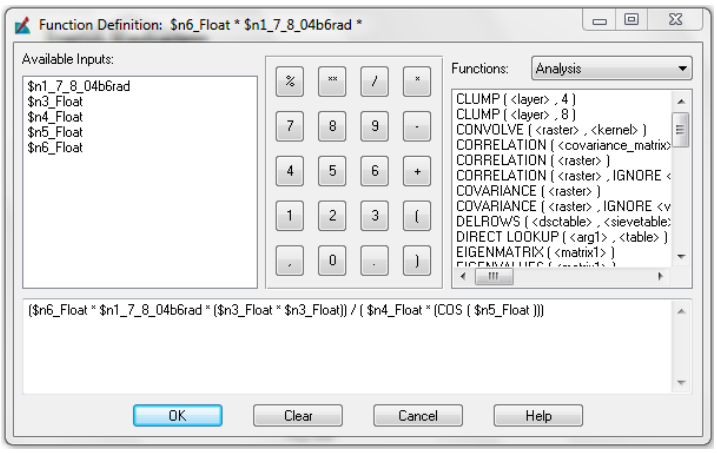


If necessary you can pre-calculate all of these variables in Excel first then use the results to create the R_{TOA} equation in model maker for initial assessment pre-fire bands 3 and 6 and initial assessment post-fire bands 3 and 6. Set the output to 'Float Single'.



** Use the rectangle shaped tool to place a scalar objects (constants) in model maker.



After saving and running your model to generate reflectance images for bands 3 and 6 for the initial assessment, repeat the above steps for the extended pre- and post- fire band 3 and 6 images.

Save your models and output. Continue to the next exercise.