

Geog 577 Advanced Remote Sensing
Spring 2007
Due: 5pm Feb 7, 2007

Lab 2 Atmospheric Correction

1. Objectives

- (1) This lab will convert the digital numbers of a satellite image to surface reflectance.
- (2) Understand the theory of atmospheric effects.
- (3) Understand the effects of sensor gain and bias in the process.

2. Theory

The physical basis of atmospheric correction can be expressed by the following equation to calculate surface reflectance.

$$\rho = \frac{\pi(L_{sat} - L_{haze})}{T_v(E_0 \cos(\theta_z)T_z + E_{down})}$$

E_0 is exo-atmospheric irradiance. $E_0 = E_{sun}/d^2$, where E_{sun} is the mean exo-atmospheric irradiance, and d is the distance between the sun and the earth in astronomical unit. The parameter d can be obtained based on a table provided in the Landsat Handbook. (http://landsathandbook.gsfc.nasa.gov/handbook/handbook_htmls/chapter11/chapter11.html)

E_{down} is the down welling diffuse radiation on the surface. Usually we do not have a measurement for this term. Thus many people assume it to be zero for convenient purpose. But it is significantly different from zero. One way to obtain it is to run an atmospheric radiative transfer model. We will run sixs (6s) in this lab.

T_v and T_z are the atmospheric transmittance in the viewing and illumination directions. For Landsat satellite, the sensor viewing zenith is 0. $T_v = \exp(-\tau)$, where τ is the atmospheric optical depth. $T_z = \exp(-\tau/\cos(\theta_z))$, where θ_z is the solar elevation angle. Image header usually provides the sun elevation angle (h) at the time of image acquisition. The sun zenith angle is $(90 - h)$ degrees. The optical depth (τ) is a wavelength dependent parameter, and it varies from time to time and place to place depending on the amount of aerosols in the atmosphere. Unfortunately, reliable atmospheric aerosol data only comes from the measurement at the time of image acquisition, the so called *in situ* measurement. Sometimes people try to derive aerosol optical depth based on the images at hand. My experience is this practice sometimes may introduce more noise than not doing it at all despite its complexity. Song et al. (2001) found that the best approaches in classification and change detection is using the equation given above and assuming Rayleigh atmosphere, i.e. just the molecular scattering, not aerosol scattering. Under such circumstance, the atmospheric optical depth is completely determined by the molecules in the atmosphere and its optical depth is

$$\tau = 0.008569\lambda^{-4} (1 + 0.0113\lambda^{-2} + 0.00013\lambda^{-4})$$

Where λ is wavelength in μm . Therefore, we can derive T_v and T_z based on τ .

L_{sat} and L_{haze} are at-satellite radiance and radiance contributed from haze respectively.

$$L_{\text{sat}} = G \times DN + B$$

Where G is the sensor gain and B is the sensor bias, both of which are from the image header file.

$$L_{\text{haze}} = G \times DN_{\text{min}} + B - 0.01T_v (E_0 * \cos(\theta_z)T_z + E_{\text{down}})$$

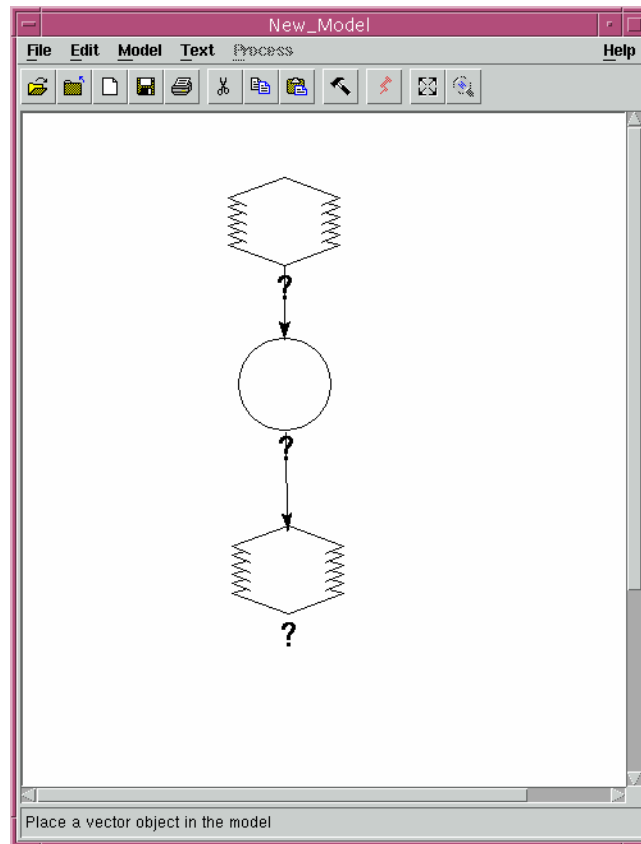
Where DN_{min} is the minimum DN value for a band which has at least 1000 pixels immediately to the lower side of the peak of the entire histogram for a whole Landsat scene at 30×30 meter spatial resolution. We assume these pixels have 1 percent of surface reflectance. The remaining radiance from these pixels is caused by haze. Note you may see some very low DNs with over a 1000 pixels, but the histogram soon become lower than 1000 again. These pixels are not good pixels, perhaps at the edges.

3. Steps.

- (1) Find out the gains and offset for the 6 bands and put it in a convenient place for use later.
- (2) Find the solar zenith angle from the header, and compute $\cos(\theta_z)$ for use later on.
- (3) Calculate τ for each band using the wavelength at the center of each band as λ .
- (4) Start imagine, and open the whole scene in data/images/1635-etm24may2002.img. find the DN_{min} for each band and put it in a convenient place. The best way to find the DN_{min} is not the ImageInfo histogram as graph does not provide an exact number. Click Raster in the Viewer window, select Attributes.... You can have the exact pixel number in the image for each layer.
- (5) The E_{down} value can be obtained by running sixs (will demonstrate in class). For your convenience, I have found them for you. $E_{\text{down}} = 124.28, 61.81, 29.78, 7.40, 0.09$ and 0.0 $\text{w/m}^2/\mu\text{m}$ for TM bands 1 to 7, respectively. You might learn how to use it in the future. A copy of the program codes are given in the data/ directory, you might want to make a copy for future use. You also might want to copy the 6s.input-no-aerosols and 6s.input-with-aerosols as template for future use.
- (6) Now with all the data available, we will do the atmospheric correction using the Modeler module. Click Modeler on the main menu, and click Model Maker.... A model maker window and a tool bar will appear. You can click the tools and drop it on the model window. Create one as in the following graph. Double click the raster icon on the top, and select chapelhill-etm24may2002.img. then double click the circle in the middle. You will see the whole image with six layers and each layer are made available to you. We will have to do the atmospheric correction one band at a time. Click on "\$n1_chapehill(1)" and you will see it appears in the empty space at the bottom. Modify it so that it appears like:

$$3.1415926 * ((\$n1_chapehill(1)-1) * G + B - L_{\text{haze}}) / (T_v * (E_0 * \cos(\theta_z) T_z + E_{\text{down}}))$$

Please replace G , B , L_{haze} , T_v , T_z , $\cos(\theta_z)$, E_{down} with the appropriate values you calculated in the previous steps.



- (7) Double click the last raster icon, and give the name as “chapelhill-etm24may2002-b1-ref.img”. Then click the run model icon on the top, the one next to the hammer.
- (8) Repeat the above process for all other bands.
- (9) You layer stack to put the images together, call it “chapelhill-etm24may2002-ref.img”.
- (10) Open the stacked reflectance image file in a viewer. Compare with the original images and see any difference.
- (11) Open the ImageInfo window, look at the image histogram, compare with the original image histogram, describe the similarity and difference and explain why.
- (12) Identify the following objects in the atmospherically corrected image and find their surface reflectance: water, bare soil, concrete, conifers, deciduous forests, golf course grass. The find the exact pixel in the original image, and find their DN values. Put the reflectance and DN values in an Excel file as in the following table.

	Ref1	Ref2	Ref3	Ref4	Ref5	Ref7	DN1	DN2	DN3	DN4	...
water											
Soil											
Concrete											
Conifers											
deciduous											
grass											
Asphalt											

- i) Make a graph with the data above with x-axis being bands and y-axis being the DN, each feature as a series. Please describe how they vary.
- ii) Make a graph with the data above with x-axis being bands and y-axis being Ref, each feature as a series. Please describe how they vary.
- iii) Compare the two figures above, describe the difference for the same feature and explain the difference.
- iv) Make another graph with the data above, with x-axis being the DN, y-axis being the reflectance, make each band DN-Ref as a series. Describe the pattern you see and explain why.