

# Using ArcGIS for Geospatial Analysis with Multi/Hyperspectral Data

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## ABSTRACT

Geospatial data fusion can be conducted with ArcGIS using vector and raster data sets, specifically raster data containing spectral information. Geospatial analysis can be enhanced using both multispectral and hyperspectral data sets. Conversely, spectral analysis can be enhanced through geospatial information. The combination of geospatial information and spectral data can result in a product that can be analyzed by both geospatial analysts and spectral scientists. Such analysis can solve a host of problems (environmental, socioeconomic, military) that could not have been realized using traditional, stand-alone approaches to geospatial and spectral analysis. The purpose of this paper is to show how the functionality of ArcGIS, with a focus on the Spatial Analyst and 3D Analyst extensions, along with ArcMap and ArcScene, can enhance geospatial analysis through the use of multispectral and hyperspectral data sets.

*Future battlefields are more likely to resemble Kosovo than the Iraqi desert. There will be clouds, vegetation, villages and cities, and civilians whom we don't want to harm.*

General Wesley K. Clark, Waging Modern Warfare

## INTRODUCTION

ArcGIS is a powerful software package that has been used extensively for geospatial analysis using vector and raster data sets. Raster data sets containing spectral information from both multispectral and hyperspectral data sets can be analyzed using ArcMap in concert with the functionality of ArcGIS extensions (Spatial Analyst, 3D Analyst, Military Analyst). Traditional geospatial information from vector data sets and raster data sets derived from scanned paper maps can be used with spectral data sets for more robust geospatial analysis. The integration and fusion of geospatial data sets can be used by geospatial analysts and spectral scientists to analyze and solve a host of environmental, socioeconomic, urban planning, or military challenges. Solutions to these complex challenges could never have been realized using traditional, stand-alone approaches such as applying one process with one type of data set. The purpose of this paper is to demonstrate how the functionality of ArcGIS can enhance geospatial analysis through the integration of multispectral and hyperspectral data sets with other geospatial (vector, raster) data sets. The aim of this paper is to demonstrate the spectral analysis capabilities of ArcGIS's Spatial Analyst and 3D Analyst extensions, and the use of ArcMap and ArcScene applications for geospatial analysis.

It is important to understand the spectral sensor's characteristics in terms of spectral, spatial, temporal, and radiometric resolution before any in-depth geospatial analysis of the raster data can be conducted. These four "resolutions" will invariably impact the user's ability to analyze data in ArcGIS. Moreover, it is also important for the user to understand sensor data

formats and whether or not the raster imagery is orthorectified and/or georeferenced. For example, LANDSAT 7 is a multispectral sensor that collects 7 bands of spectral information and maintains a 16-day repeat cycle. It collects at a 30-meter spatial resolution from the visible portion through the midwave infrared portion of the electromagnetic spectrum, and at a 60-meter spatial resolution in the thermal infrared portion of the electromagnetic spectrum (Band 6). The spectral resolution of LANDSAT 7, Band 1 (Blue portion of the electromagnetic spectrum), is 0.450-0.515 $\mu$ m. It has 8-bit radiometric resolution and can be processed to various levels based upon the user's requirements. Other sensors will have similar characteristics in terms of ground sample distance, collection ranges for sensor bands, bit depth storage, and levels of processing. It is important for the user to gain an understanding of multispectral and hyperspectral sensor characteristics prior to conducting geospatial in ArcGIS.

Literal analysis of spectral data can be conducted using ArcCatalog and ArcMap. Below is an example of LANDSAT 7 data of downtown Washington, D.C., analyzed in ArcMap. If the user "drags-and-drops" the LANDSAT 7 image from ArcCatalog into ArcMap, the first three bands of the multispectral image will be portrayed through the computer screen's three RGB color guns. In this example, Band 1, or Layer 1, of LANDSAT 7 is displayed through the red color gun of the computer screen. Band 1 is collected in the blue portion of the electromagnetic spectrum. Band 2 (Layer 2), which is collected in the green portion of the electromagnetic spectrum, is displayed through the green color gun. Band 3 (Layer 3) which is collected in the red portion of the portion of the electromagnetic spectrum, is displayed through the blue color gun. Note that the trees and other healthy vegetation appear normal, given that the objects that reflect energy highly in the green portion of the electromagnetic spectrum are being portrayed through the green color gun.

**Figure 1: Using ArcGIS for Spectral Analysis**



In order to conduct proper literal analysis, it is good practice to portray the image in a "true color" composite, which is portraying the blue portion of the electromagnetic spectrum (Band 1) through the blue color gun, Band 2 through the green color gun, and Band 3 through the red color gun. This can be accomplished in ArcMap by double-clicking the image name in the data frame, or by right-clicking the image name and selecting Properties, and opening the Layer Properties dialog box. The Symbology tab will be the active tab and "RGB Composite" will be highlighted. At this point, the user can select the down arrows next to Red, Green, and Blue, and select any sensor band available to portray through the desired color gun. To obtain a "true

color” composite, the user can select the down arrow next to the red color gun, select Band 3 of LANDSAT 7, and repeat the process for the green and blue color guns for Band 2 and Band 1, respectively. The user can now select the Apply button at the bottom of the Layer Properties dialog box, and the LANDSAT 7 image will appear as a “true color” composite in ArcMap.

The user can continue to experiment with the LANDSAT 7 band combinations in ArcMap using the Layer Properties dialog box and the Symbology tab. Below is an example of literal analysis of multispectral data using LANDSAT 7’s Band 4 (Layer 4), which is collected in the near infrared portion of the electromagnetic spectrum, portrayed through the red color gun, Band 3 portrayed through the green color gun, and Band 2 portrayed through the blue color gun.

**Figure 2: Changing Band Combinations for Multispectral Imagery**



The resulting LANDSAT band combinations will display an image in ArcMap similar to the image shown below:

**Figure 3: Multispectral Analysis of a "Near Infrared" Composite**



The user has the option to change the names in the Data Layer area of ArcMap. In the image shown, the data frame was renamed from “Layers” to “Multispectral Analysis” and the image was renamed to “LANDSAT 7, Washington D.C.” to create more recognizable naming

convention. For literal analysis, the features that are easily recognizable are the rivers, the built-up areas, and the vegetation. Healthy vegetation reflects energy highly in the near infrared portion of the electromagnetic spectrum. LANDSAT Band 4 (near infrared) is portrayed through the red color gun, and as expected, objects reflecting energy highly in the near infrared will appear as red on the computer screen. Built-up areas such as concrete buildings appear cyan in this image because concrete reflects energy in somewhat similar proportions in the red portion of the electromagnetic spectrum (Band 3 through the green color gun) and in the green portion of the electromagnetic spectrum (Band 2 through the blue color gun). The river appears to be darker than other features because water tends to absorb energy in the red and near infrared portion of the electromagnetic spectrum.

Similar literal analysis can be conducted over a sample area using various multispectral sensors and ArcGIS. The multispectral sensors chosen for this paper were LANDSAT 7, IKONOS, and the Multispectral Thermal Imager (MTI). The sensors have different sensor characteristics (spatial, spectral, temporal, and radiometric) that can provide significantly more robust geospatial analysis of the sample area. For example, if the user were determining the general health of vegetation for the downtown area, then LANDSAT 7 would be a logical sensor to use. However, if the user was determining the health of vegetation along an airport runway, then LANDSAT 7 might be reconsidered. LANDSAT 7 (7 bands, 30-60 meter spatial resolution) will have the spectral resolution to determine areas of healthy vegetation, but lack the necessary spatial resolution. In this case, it would be more appropriate to use IKONOS (4 bands, 4 meter spatial resolution) or MTI (14 bands, 5 meter spatial resolution in the RGB and NIR bands). ArcMap can be used with all of the spectral data sets for literal analysis. Below are examples of MTI, IKONOS, and LANDSAT 7 imagery over Washington, D.C. in ArcMap using various bands combinations for geospatial analysis.

**Figure 4: Geospatial Analysis of Various Sets of Multispectral Data**



Change detection of an area can be conducted in ArcMap using two images taken from the same sensor covering the same exact area at different times of the year. Both images can be put into the same data frame as separate and distinct layers. If the images are correctly georeferenced, then the images will “overlay” one another in the ArcMap display. The user can either turn on/ turn off each image and analyze the spectral properties, or the user can go to

Properties – Display tab and change the “Transparency” percentage for either of the images. Below is an example of MTI imagery taken in the summer and in the winter and displayed in ArcMap. Note that the tidal basin is frozen in the winter image.

**Figure 5: Summer (left) and Winter (right) Images of downtown Washington, D.C.**



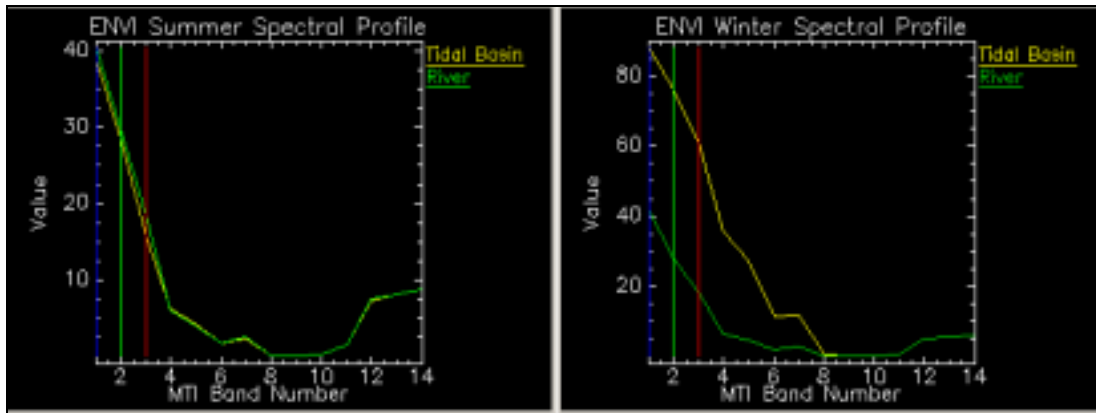
The ArcGIS user could also use the “Reclassify” tool in Spatial Analyst or 3D Analyst to classify each image based upon the digital number values, and then compare the classifications of each image. For example, the Reclassify tool can be used with the MTI data from the summer and winter images for geospatial analysis. Note that the reclassification for the summer image does not distinguish a difference between the water in the tidal basin and the river, whereas in the winter image the reclassification outlines the differences in the tidal basin and the river. The spectral response of frozen water in the tidal basin can be contrasted from the river water, which is not frozen. Further analysis could be conducted to determine the thermal properties of the water features by using the thermal bands of the MTI or LANDSAT 7 sensors. Below are the results of the reclassification for both images.

**Figure 6: Classifying and Analyzing Multispectral Imagery**



ArcGIS, although widely considered a tool for strictly geographical analysis, is a valid and powerful tool for conducting literal analysis of multispectral data. The Reclassify tool was used to determine the differences in spectral values for the features within each image, and then used to compare the summer image to the winter image. The Reclassify tool was useful in classifying the water in the summer image, and in classifying the differences between the water and the ice in the winter image. Below are the MTI spectral profiles of the phenomena in the tidal basin and in the river derived using ENVI 4.0, a powerful multispectral/hyperspectral software package used for advanced spectral analysis.

**Figure 7: ENVI Spectral Profiles: Tidal Basin and River Phenomena in Summer and Winter**



In the summer image, the water in the tidal basin and the water in the river have the same spectral response. In the winter image, the water in the tidal basin has a different spectral response than the water in the river. This is due to the water being frozen in the tidal basin. The water in the river has a very similar spectral response to the water from both the tidal basin and the river in the summer image. When compared to the information derived from ENVI 4.0, the Reclassify tool in ArcGIS's Spatial Analyst and 3D Analyst extension provides a similar answer in terms of spectral response of the phenomena analyzed. The Reclassify tool was useful in determining that a difference existed between the water in the tidal basin and in the river for the winter image.

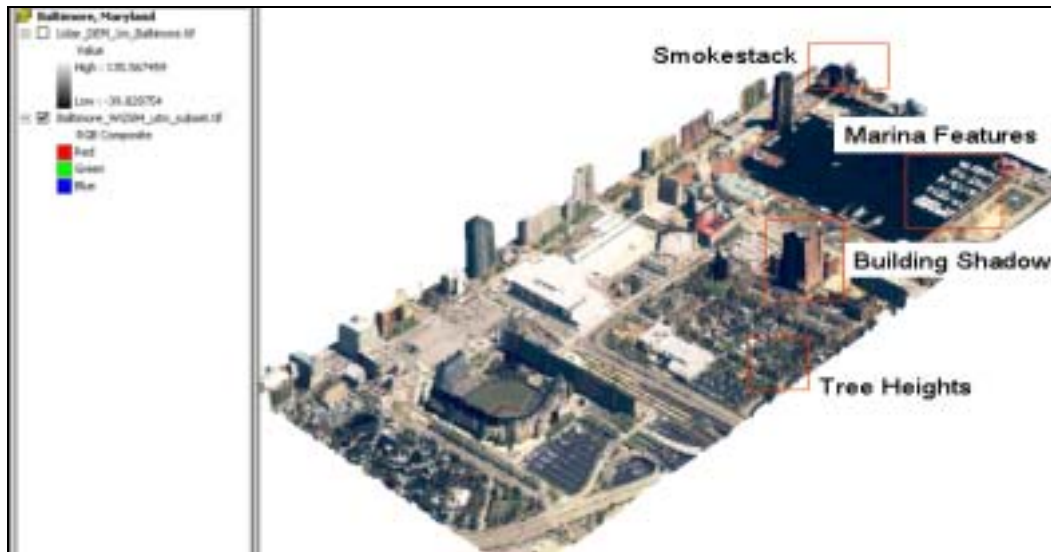
Geospatial analysis can also be conducted in ArcGIS, specifically ArcScene, using the fusion of data sets to include hyperspectral and Lidar. It is important to have data sets of similar spatial resolution, and that each are correctly referenced to the same datum and projection system to ensure a quality image drape. This is especially important for urban environment geospatial analysis. Multispectral imagery can be draped over a Lidar digital elevation model (DEM) for more in-depth geospatial analysis. Both can be used to confirm the existence of natural and manmade features, or to determine the changes in such features. For example, the spectral responses from the multispectral imagery can be used to determine whether a tree grove has been harvested. This can be compared to the Lidar DEM to determine the actual height of the trees, and the analyst can note any changes. Another example of using multispectral imagery and Lidar DEMs is to determine whether or not features are located in flood-prone areas.

In ArcScene, the user can double-click the Lidar Dem, select Properties, and the Layer Properties dialog box will appear. The user can select the Base Heights tab, and then click on "Obtain base heights for layer from surface" ensuring that the Lidar DEM is shown in the dialog box. Next, the user can set the Z unit conversion to an appropriate ratio, such as 3.00. The user can then select apply and then close the Layer Properties box. The Lidar DEM will now appear

in 3D in ArcScene. The user can now use 3D Analyst to reclassify the Lidar DEM based upon elevation, or create a Contour or Slope calculation, and drape the multispectral image over the results. The user can now compare the results to the spectral analysis and determine which features are located at high and low elevations. It would be difficult to identify the features based solely on the Lidar data, and it would be difficult to determine which features were in flood-prone areas based upon the spectral analysis alone. Using both types of data sets in ArcScene with 3D Analyst can provide a complete solution to the geospatial question.

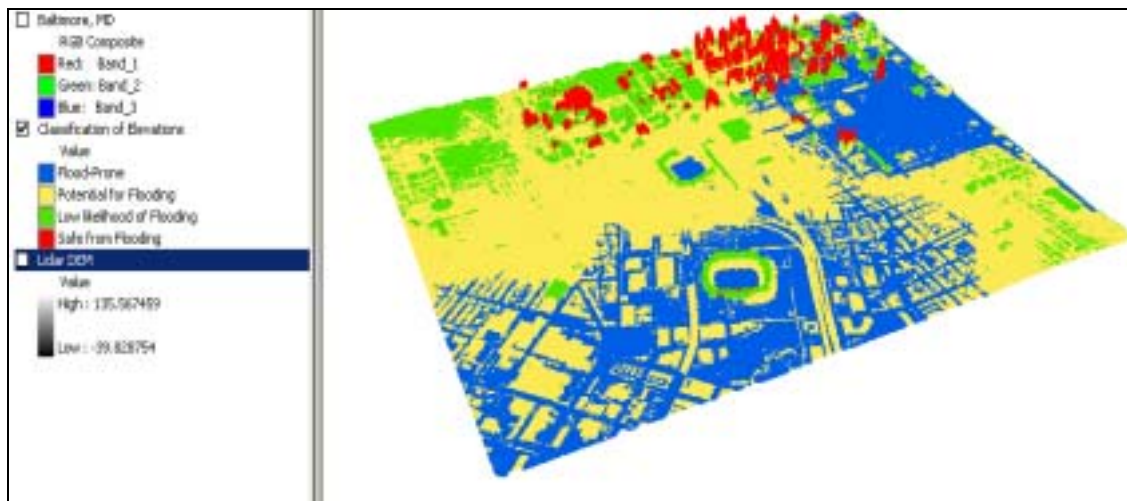
Below is an example of literal analysis of MTI draped over a 1-meter Lidar data set of Baltimore, Maryland. Various features were classified using the spectral information and the Lidar elevation data, and then appropriately labeled based upon the specific feature.

**Figure 8: Multispectral Imagery and Lidar DEM**



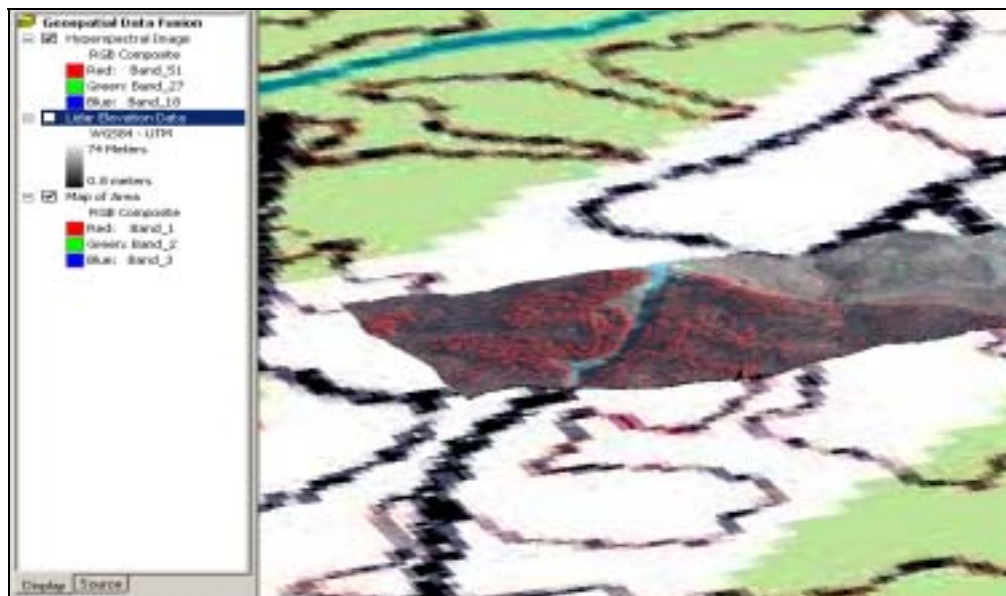
Below is an example of the Lidar DEM classified using 3D Analyst based upon elevation, and then labeled based upon likelihood of flooding. The results can be compared with the spectral responses to determine if any features will need to be protected from potential flooding.

**Figure 9: Using ArcGIS 3D Analyst and Geospatial Data Fusion**



Hyperspectral imagery can be used in ArcGIS is a similar process to that of multispectral imagery. Hyperspectral imagery contains many more bands of spectral information, which increases the spectral resolution and also the ability to analyze specific features. Again, it is important for the user to understand the hyperspectral sensor's characteristics before conducting spectral analysis. Below is an example of COMPASS hyperspectral data draped over a Lidar DEM in ArcScene and a raster map of the area. The hyperspectral image is being portrayed as a "near infrared" composite. The vegetation and the road features can be clearly identified, which demonstrates that hyperspectral data could potentially be used to update features on outdated maps. However, hyperspectral data sets are not often referenced and the increased number of spectral bands significantly increases the size of the data.

**Figure 10: Geospatial Data Fusion: Hyperspectral, Lidar, and Raster Map**



The purpose of this paper was to demonstrate that ArcGIS could be used to conduct geospatial analysis with multispectral and hyperspectral data sets. The aim of this paper was to demonstrate the spectral analysis capabilities of ArcGIS's Spatial Analyst and 3D Analyst extensions, as well as the functionality of both ArcMap and ArcScene for geospatial analysis. The combination of geospatial information and spectral data can result in a product that can be analyzed by both geospatial analysts and spectral scientists. The fusion and integration of multiple data sets, especially spectral data sets, can significantly increase an analyst's ability to solve a variety of issues that could not be realized using panchromatic imagery or traditional processes. ArcGIS has proven to be a powerful GIS software package that can perform literal analysis of multispectral and hyperspectral data for higher-order geospatial analysis.

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