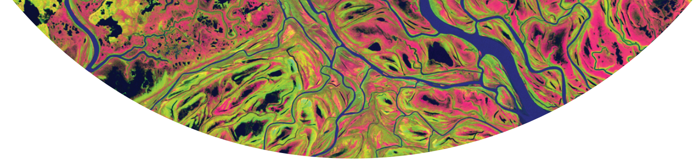


CHAPTER 5

Performing radiometric calibration

Objectives

- Use the Apparent Reflectance function to perform atmospheric calibration.
- Use a formula to convert the radiometric values of an image.

Introduction

Satellite-based sensors collect all reflected energy through the atmosphere, which is in a state of constant flux. The atmosphere scatters and absorbs all this solar radiation as well as emitted energy from the surface and therefore affects the energy that reaches the sensor and is recorded. Ideally, researchers want to correct for these atmospheric conditions. However, to perform atmospheric correction, you would need complex atmospheric models or information about atmospheric conditions at the time of collection. ArcGIS Pro provides a way to account for some of these conditions and allows you to radiometrically calibrate imagery for common, well-known atmospheric effects. Radiometric calibration—in the form of atmospheric calibration—rescales your imagery and provides scientists and analysts with a more accurate measurement of surface properties. Additionally, atmospheric calibration ensures a consistent measurement scale that can be understood and applied to different images collected at different times and through varying atmospheric conditions.

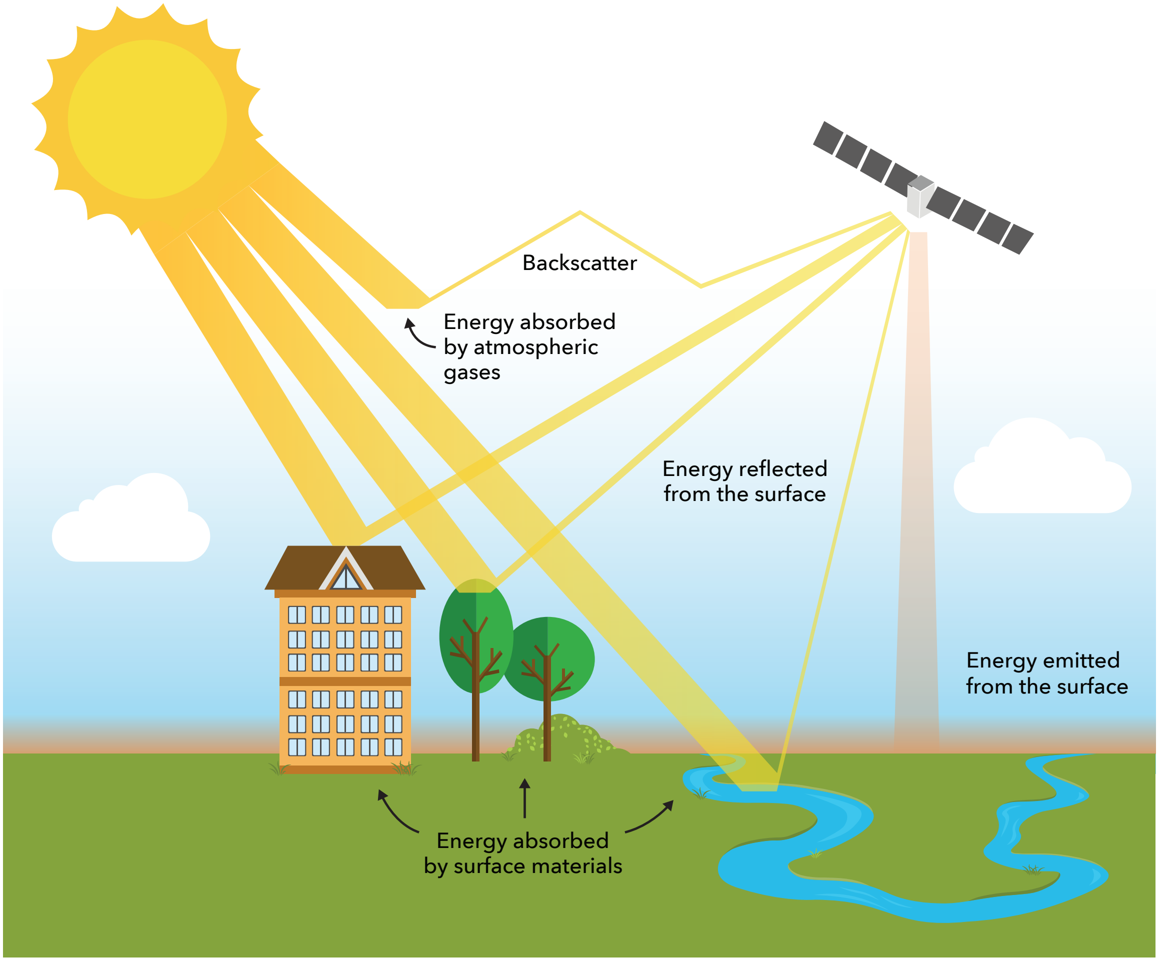


Figure 5-1. Satellite sensors collect reflected energy through a constantly changing atmosphere. Raster functions can be used to radiometrically calibrate images for use in different types of analysis, including change detection or image classification.

In this chapter, you'll learn how to perform this type of radiometric calibration of imagery. You'll use two raster functions to calibrate Landsat 8 imagery to surface reflectance values for use in further analysis. As you learned previously, imagery is often delivered as uncalibrated digital number (DN) values. Although imagery can be used and analyzed using this baseline radiometric resolution, for many scientific applications it is best to calibrate the image to a standardized radiometric resolution.

Tutorial 5-1: Perform atmospheric calibration on an image

In this tutorial, you'll use the **Apparent Reflectance** function to calibrate a Landsat 8 image to top of atmosphere reflectance values. ArcGIS Pro reads key metadata from sensor information when loading a raster product, making it easy to use prebuilt raster functions. The **Apparent Reflectance** function uses published formulas to convert DN values to radiance values and then to reflectance, or albedo, values. To use this function, your image requires specific metadata:

- Acquisition date and sun elevation for the dataset
- Radiance gain, radiance bias, and sun irradiance for each band
- Reflectance gain and reflectance bias (for Landsat 8)

The **Apparent Reflectance** function can be used only with specific imagery (See "Information at Your Fingertips" at the end of this chapter).

Download the tutorial data and set up the project

1. Go to links.esri.com/Imagery20Data and download the data for chapter 5.

2. Unzip the folder to **C:\Top20Imagery**.

> **Note:** In the second chapter, you created a folder named **Top20Imagery** on your C: drive. If you haven't done that, create that folder now. Now and in subsequent chapters, you will download and unzip the data for each chapter to this folder.

3. Inside the **Top20Imagery_05** folder, double-click **Top20Imagery_05.aprx** to open the ArcGIS Pro project for this chapter.

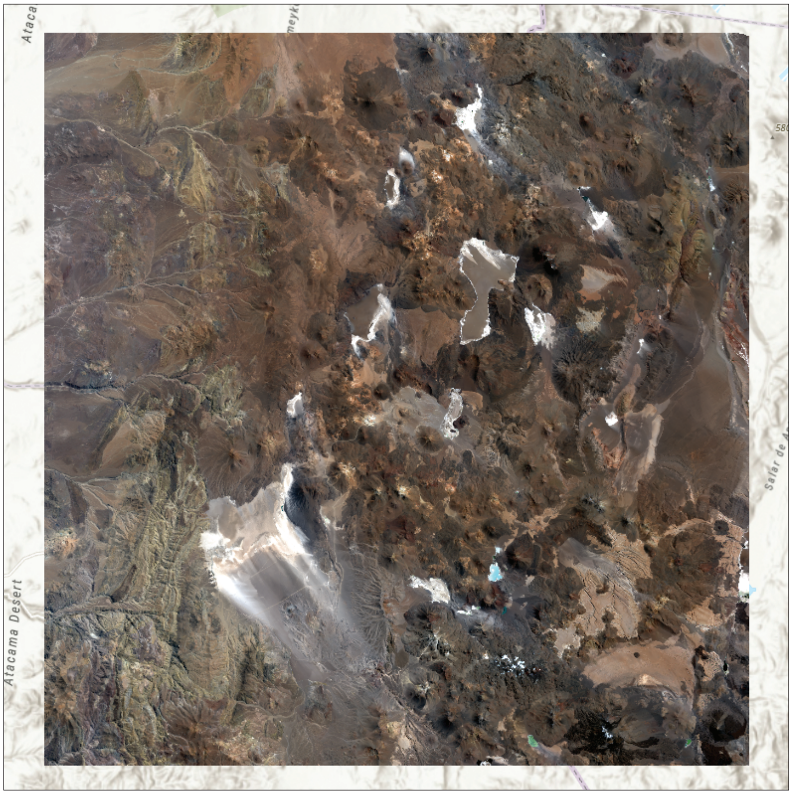
4. In the **Catalog** pane, expand **Folders** > **Top20Imagery_05** and then expand the **2025_0328-233_078_L1TP (Chile)** folder.

> ***Important:*** *Make sure you select the Level-1 Precision and Terrain Correction (L1TP) folder.*

This folder contains a Landsat 8 Operational Land Imager/Thermal Infrared Sensor Level-1, Collection 2 Precision and Terrain Correction Product (L1TP)[1] of the northern border between Chile and Argentina. This type of product has calibrated and scaled DN values. In chapter 2, you learned how the DN values relate to collected and measured intensity values from features on the ground.

In ArcGIS Pro, these values are represented as 16-bit unsigned data. This is the radiometric resolution of the image, the recorded and represented brightness of the image pixel values.

5. In the **Catalog** pane, right-click the **LC08_L1TP_233078_20250328_20250401_02_T1_MTL.txt** raster product and click **Add To Current Map**.



The new image appears in the **Contents** pane and on the map.

6. Using skills you've already learned, explore the image.

7. In the **Contents** pane, right-click the **Multispectral_LC08_L1TP_233078_20250328_20250401_02_T1_MTL** layer and click **Zoom To Layer**.

Several collection tiers are available from USGS. This image is a Tier 1 product. Tier 1 images have been corrected by USGS and contain well-characterized radiometry—that is, data values across the various multispectral bands. One advantage to this processing level is that you can use formulas and internal metadata related to the sensor settings to calibrate the image for some atmospheric effects.

Calibrate an image to apparent reflectance

You can radiometrically calibrate this image to reflectance values by using a raster function.

1. On the **Imagery** tab, in the **Analysis** group, click **Raster Functions** to open the **Raster Functions** pane.
2. At the top of the **Raster Functions** pane, in the search bar, type Reflectance.
3. Under **Correction**, click the **Apparent Reflectance** function.

   The **Apparent Reflectance** function is used to adjust the brightness values of some satellite imagery based on the scene illumination and sensor-gain settings. The calibration function uses sun elevation, acquisition date, and sensor gain and bias for each band to derive top of atmosphere reflectance from the DN values of imagery product types. The images are adjusted to a theoretically common illumination condition. One result of this adjustment is that there should be less variation between scenes from different dates and different sensors. This type of calibration is especially useful for analysis, such as image classification, indexes and ratios, and change detection.

   All the information required for the correction is extracted from the key metadata properties for each image when the function is initialized. If these metadata properties are present, selecting the image layer populates these values automatically.

4. In the **Raster Functions** pane, for **Raster**, select the **Multispectral_LC08_L1TP_233078_20250328_20250401_02_T1_MTL** layer.

   All the relevant information for **Reflectance Gain** and **Bias** values is added to the table for each band. In addition, the **Sun Elevation** in degrees is automatically added. The appropriate **Scale Factor** and **Offset** are similarly populated from the metadata.

5. Under **Sun Elevation (degrees)**, check the box for **Albedo**.

   You need to check the **Albedo** box to ensure that your calibration returns reflectance values. These values represent a brightness layer based on the proportion of radiation that is reflected by the surface. Albedo is expressed as a dimensionless 32-bit floating point number between 0 and 1. Zero corresponds to a black body that absorbs all incident radiation, such as wet coal, and 1 corresponds to a body that reflects all incident radiation, similar to fresh snow. These values can be thought of as a percentage of reflectance where zero is total absorption and 1 is 100 percent reflectance.

Note: Once calibrated, there are two ways to express radiometric signal return for imaging sensors: radiance values or reflectance values. For most remote sensing analysis, reflectance values are preferred and are used by scientific users for complex modeling and technical remote sensing applications.

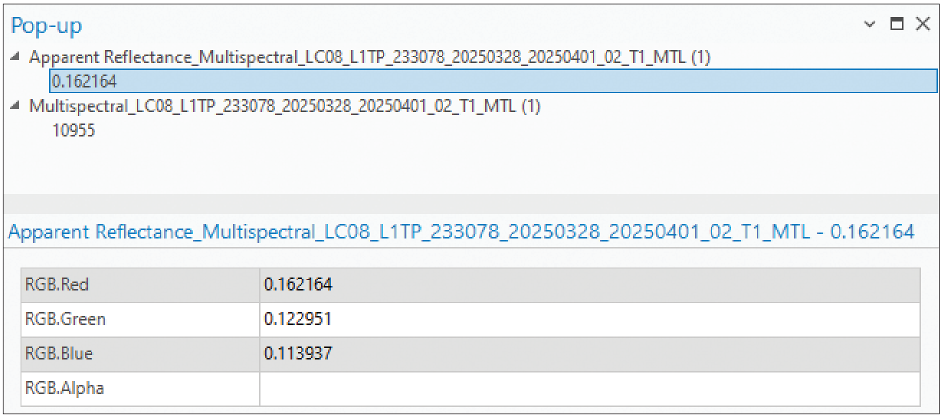
6. At the bottom of the pane, click **Create new layer**.

The new result layer is visible in the **Contents** pane and added to the map. This function modifies the image values—the radiometric resolution of the image—so previous statistics and histograms are no longer valid. As a result, a new symbology rendering is applied so the image may appear slightly darker.

Review the corrected image

1. On the **Map** tab, in the **Navigate** group, click **Explore** and select **Visible Layers**.

2. Click in the map to select a pixel.



Note: Your pixel values will differ from those shown, based on where you clicked in the image.

The new image is now radiometrically calibrated to a known standard: reflectance values.

3. In the **Contents** pane, uncheck the boxes for the **Apparent Reflectance_** and **Multispectral_ LC08_L1TP_233078_20250328_20250401_02_T1_MTL** layers to turn off their visibility.

Tutorial 5-2: Radiometrically calibrate an image using the Calculator function

In this tutorial, you'll use a different raster function to radiometrically calibrate an image already corrected to surface reflectance by USGS but not provided with surface reflectance values—that is, values between 0 and 1. First, you'll add a Landsat 8 Level-2 Science Product (L2SP)[2] of the same area in northern Chile.

Add a new image to your map

You'll now add a new folder containing a Landsat 8 Level-2, Collection 2 Science Product (L2SP) of the same area.