Lesson 1. An Introduction to working with multispectral satellite data in ArcGIS Pro
In which we learn:

- How to unpack tar and gz files from USGS EROS
- The basic map interface in ArcGIS
- How to add image files
- What each individual band of Landsat spectral data looks like
- The difference between:
  - Analysis-ready data: surface reflectance and surface temperature
  - Landsat Collection 1 Level 3 data: burned area and dynamic surface water
  - Sentinel 2 data
  - ISRO AWiFS and LISS-3 data

The basic map interface in ArcGIS

1. If ArcGIS Pro is closed, use the Windows Start Menu to find the ArcGIS application folder under the letter A. Click the down arrow to open the folder and click on ArcGIS Pro. If prompted sign in to to the ArcGIS portal. Navigate to the workshop drive following the relative path *…\EO_SRS_ArcGISPro\ArcPro_RS_2019* and open the .aprx file ***ArcPro_RS_2019.aprx***.

2. With the ***ArcPro_RS_2019.aprx*** file open, locate the Map tab named **Lesson 1 Data Intro**.
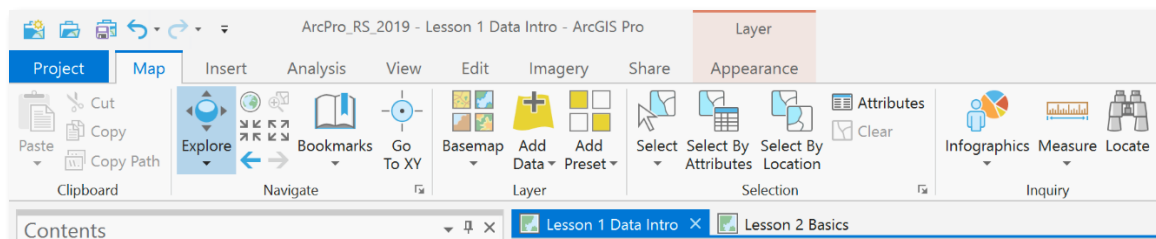

3. Click on the **Lesson 1 Data Intro** map tab to activate it. Notice the **Contents** pane, a dockable window. In this lesson, we will work with the **Drawing Orde**r view. If the Contents pane 'disappears', you can reopen the pane by clicking the **View** tab in the context ribbon.

4. In the **Contents** pane, check the empty box to the left of the **World Topographic Map** basemap. You can see the context of the ARD Conus grid. Whenever the basemap slows down map redraws, you can turn it off again.

5. Click on the hollow triangle to the left of the **Satellite data collection grid** group layer to expand the group and see its contents. To turn on all of the group layers at once, hold down the **CTRL** key and click in one of the unchecked squares. The layer files for the LISS-3, AWiFS and Sentinel data show each sensors collection extent, as distributed by the USGS. The purple outlined boxes show the extent of Landsat World Reference System-2 swath tiles.

6. Turn off the LISS-3, AWiFS and Sentinel layers.

7. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Big Bend National Park** bookmark. The map will zoom to the bookmark extent.

8. In the **Contents** pane under the **Search** window, click on the **List by Selections** icon.
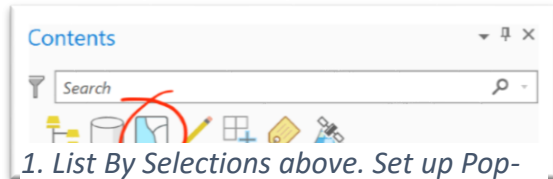
1. List By Selections above. Set up Pop-up options for "query/info" tool at right. Click on Explore icon in ribbon to activate.
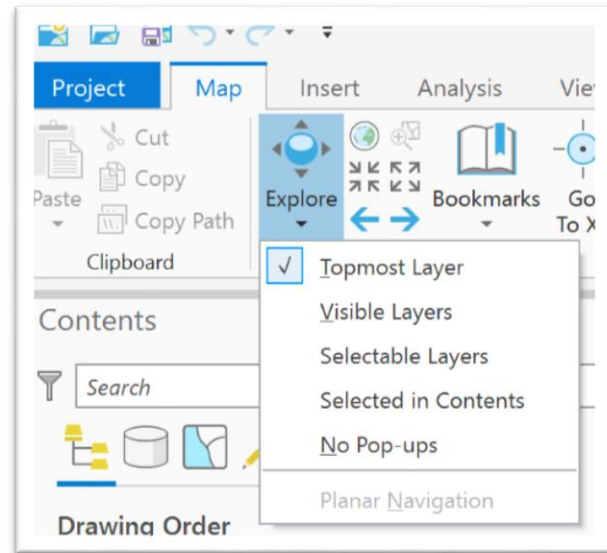
9. In the **Selection** view, unselect the LISS-3, AWiFS and Sentinel layers in the **Satellite data collection grid** group layer.

10. Return to the **Drawing Order** view of the **Contents** pane.

11. Click on the **Explore** icon in the **Navigate** group of the **Map** tab. Change option from *Topmost Layer* to *Selectable Layers*.

12. Hover the mouse over the Big Bend National Park area and verify that the icon is a little hand with pointed index finger. Click anywhere in the park area. You should see a green flashing dot momentarily and then the Pop-up window will appear. Verify that the attributes for conus_ard_grid are h = 12 and v = 17. The attributes for WRS2_descending are Path = 30 and Row = 40. You can use these grids to specify grid coordinates and/or Landsat path and row for EarthExplorer or GloVis data retrieval. Note that in order to see feature attributes you will need to expand the layer name and choose the displayed attribute value.

13. You can skip this step for the current exercise. There are two options for adding data layers:
    - With the Map tab selected on the context ribbon, click the Add Data icon in the Layer group and navigate to the desired folder. At the bottom right corner of the Add Data window, you have the option to change Default file type to Rasters (All Local Types).
    - Alternatively, with the View tab selected on the context ribbon, click on the Catalog Pane. With Project underlined in the Catalog Pane, open the Folders to find the EO_SRS_ArcGISPro folder than contains workshop datasets. You can select a single

file, a series of TIF files by depressing the Shift key during selection, or non-consecutive files by depressing the Ctrl key during selection. Right click and select Add to current map or drag the files onto the map.

- In either case, you may be asked if you want to generate pyramid files.

What each individual band of Landsat data looks like

14. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Surface Temperature in North Texas** bookmark.

15. Expand the **Landsat Spectral Bands** group layer, and then the **Landsat 8 Operational Land Imager** group layer.

16. Now we will review the gray scale OLI spectral bands. If all of the bands in the group layer are checked, press down the **Control** button on your keyboard, and click on one of the check marks. All of the checked layers in the group should turn off. Next turn on and off the spectral bands one by one. Which layers differ most from the others? Which appears darkest? Which appears brightest?
    - Surface Reflectance Band (SRB) 1: Coastal Aerosols
    - Surface Reflectance Band (SRB) 2: Visible Blue
    - Surface Reflectance Band (SRB) 3: Visible Green
    - Surface Reflectance Band (SRB) 4: Visible Red
    - Surface Reflectance Band (SRB) 5: Near Infrared (NIR)
    - Surface Reflectance Band (SRB) 6: Shortwave Infrared (SWIR 1)
    - Surface Reflectance Band (SRB) 7: Shortwave Infrared (SWIR 2)

A whirlwind tour
Composites and clipping

17. Turn off the **Satellite data collection grids** and **Landsat Spectral Bands** group layers.

18. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Big Bend National Park** bookmark.

19. Expand the **Landsat examples** group layer, then the **Clipped Big Bend NP** group layer.

20. One by one, make visible the **ETM+ Big Bend National Park** layer, the **OLI Big Bend National Park** layer and the **Clip OLI Big Bend National Park** layer. Notice the scan line error defect in the ETM+ data. These layers each contain three spectral bands and were derived using a raster function.

21. Turn the **ETM+ & OLI** layers on and off to see the clip effect.

Time series surface reflectance data

22. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Lake Meredith** bookmark.

23. Expand the **Landsat ARD Lake Meredith** group layer.

24. From top to bottom, turn on each layer to watch lake levels rise and fall. Note the Landsat sensors at the beginning of each layer name and the date at the end. Each composite layer comprises the visible red, green and blue spectral bands. Band numbers differ between OLI and TM data layers. Do you remember why? In a later lesson we will create composite layers and a time series mosaic dataset.

Provisional surface temperature data

25. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Surface Temperature in North Texas** bookmark.

26. Expand the **Landsat ARD DFW Heat maps** group layer. Then expand both ST layers to show each layer legend. One is from 2019 and the other from 1992.

27. Both layers, which consist of a single raster band, are symbolized using a built-in ArcGIS color ramp. Right-click one of the layers and choose **Symbology** from the menu. The **Symbology** pane will open on the right side of the map view. Notice that the layer min and max Values below the Color scheme are 4 digit integers, while the Labels are expressed as decimal values with K added to represent the value units. It is standard practice to store floating point continues values in integer format. The XML metadata and data product documentation indicate that a factor of 0.1 should be applied to pixel values. In another exercise, you will convert from degrees Kelvin to degrees Fahrenheit using raster algebra functions. You will also apply consistent classed symbology to assist comparison over time.

28. Close the **Symbology** pane and fold up the group layer.

Burned area data

29. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Mendocino CA wildfire** bookmark.

30. Expand the **Mendicino Burn scar** group layer. The four first layers are BC files from the Landsat Collection 1 Level 3 Burn Area product. Turn these four layers off momentarily.

31. The fifth layer is Band 5 from a Landsat Collection 1 full swath. Use what you learned about the Pop-up tool to determine which WRS-2 path row is shown. Compare to the file name.

32. Turn off the LC08_L1TP swath file and turn back on the 4 BC files.

33. Expand each of the four layers to see their legends. The BC image in the NW of the map (last of four in layer list) shows what the data look like when first added to the map. A gray scale stretch is applied.

34. The BC image in the SW of the map uses a different color scheme and displays integer values. This represents an interim step where the primary symbology has been set to unique values with default colors accepted.

35. Notice that the top two layers have the same meaningful legend. These are symbolized using the unique values option with proper labeling. You will apply symbology of your own to make a consistent map in a subsequent exercise. Close the **Symbology** pane and fold up the group layer.

Dynamic surface water data

36. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **Landsat ARD Surface Water** bookmark. The map will zoom in close to Memphis, Tennesee.

37. Expand the **Landsat ARD Mississippi Flooding** group layer. The **INWM** (end of file name) layer is open. This is the surface water map with a mask applied. It is symbolized using the same method as the burn scar maps.

38. Turn on the **SHADE** (end of file name) layer above. Each SW tar includes a single band hillshade of the DEM that was used to generate the dynamic water surface layer. Highlight the **SHADE** layer, and click on the **Appearance** tab on the ribbon.

39. Look for the Effects group in the ribbon. Use the Layer Transparency slider or text entry beside it to set the SHADE layer transparency to ~ 50%.

40. Finally, turn on the **SLOPE** (end of file name) layer. This raster a single band DEM-derived representation of Percent Slope, also used to calculate dynamic surface water extent. Values range from 0 to 45%. Like the surface temperature data, these data are stored in integer values that should be multiplied by a factor of 0.1. Consequently, the upper value in the example used is actually a percent slope of 14.6%. The highest possible value for the dataset is 45% or an integer value of 450. When you are done, fold up the group layer.

ESA Sentinel 2 multispectral 10m data

41. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **ESA Sentinel 2 and Lake Travis** bookmark. The map zooms to Lake Travis, northwest of the city of Austin.

42. Expand the **ESA Sentinel 2 example** group layer. There are two raster layers in the group. Note the different file name convention. The lower layer is named **T14RNU_20190907T171851_TCI.jp2**. **T14RNU** (*Txxxxx*) references the tile number field. **20190907T171851** denotes the data take sensing start time in the format *YYYY-MM-DD T HH:MM:SS*. **TCI** indicates that the JPEG 200 file is a True Color Image. Single band designations are B01 to B12.

43. Let's take a look at a Sentinel 2 data package:
    - Click on the **View** tab in the ribbon.
    - From the **Windows** group, click on the **Catalog Pane** which will open on the right side of the map view.
    - Expand the **Folders** folder.
    - Expand in turn the **EO_SRS_ArcGISPro** folder, the **RSdata** folder, and the **ESA_Snt2** folder.
    - Now expand the folder that begins **S2A_MSIL1C_20190907T**… and expand in turn the **GRANULE** folder and the **IMG_DATA** folder.
    - Resize the Catalog Pane so that you can see the full image names.
    - Select and right-click on the filename that ends in **_B08.jp2** and click on **Properties**. *
    - Expand the **Raster Information** property and look for Cell Size X and Y. What is it? *
    - Also expand the Spatial Reference to find the Projected Coordinate System, the WKID and the Authority.
    - Drag the file onto your map view and compare the new layer to the TCI layer. Bands 2 (blue), 3 (green), 4 (red) and 8 (near infrared) have 10 m resolution grid cells.
    - Repeat the * steps above for the filename that ends in **_B11.jp2**. In the Contents pane highlight the newly added layer, right-click it, and choose **1:1 Zoom to Source Resolution**. This is a SWIR band and has a 20 m resolution. Other bands with 20 m grid cells are bands 5, 6, 7, 8A, and 12.
    - Repeat the * steps above for the filename that ends in **_B09.jp2**. As previously, zoom to source resolution. This is a water vapor band and has a 60 m resolution. Other bands with 60 m grid cells are bands 1 and 10. Bands 1, 9, and 10 are used primarily for cloud screening and atmospheric correction.
    - Close the **Catalog Pane** if it remains open.
    - Use the **ESA Sentinel 2 and Lake Travis** bookmark to return to the starting map extent.
    - Notice that the B09 layer appears slightly pixelated. One by one, turn off the B09 layer and the B11 layer, noticing how the map view sharpens as pixel resolution increases.

Notes on Sentinel 2 data products: Each Sentinel 2 Level-1C product is a 100 km x 100 km tile with a UTM/WGS84 (Universal Transverse Mercator/World Geodetic System 1984) projection and datum. The Sentinel-2 tiling grid is referenced to the U.S. Military Grid Reference System (MGRS). Data acquired after December 5, 2016 are distributed from ESA in a single tile basis with a shorter naming convention and include a full-resolution True-Colour Image (TCI), which is the image that is shown in the map.

New format Naming Convention for Sentinel-2 Level-1C products generated after the 6th of December, 2016: As of the above date, all newly acquired (NRT) Level-1C products from the DataHub are distributed in a new product format. This format has been introduced in order to overcome the 256 characters limitation on pathnames imposed by Windows platforms. This has been achieved by compaction of the filenames, including the naming of internal folders and files.

ISRO moderate resolution 56m AWiFS and 24m LISS-3 data

44. We end our tour in the High Plains of West Texas with two Indian sensors. In the **Navigate** group from the **Map** tab on the ribbon, click on **Bookmarks** and choose the **ISRO AWiFS & LISS data in West Texas** bookmark.

45. Expand the **ISRO ResourceSat** group layer. There are two raster layers in the group. Both were generated using the Composite Bands raster function. We have another file naming convention to parse. Look for clues in the metadata text file packaged in the zipped archive. The source LISS file basename is R2LS308292019266046_bX_l1t.tif. Let's parse it to R2 LS3 08-29-2019 266-046_bX_l1t where:
    • R2 = the satellite IRS-RS (ResourceSat)
    • LS3 = the sensor LISS-3
    • 08292019 = MMDDYYYY, date of pass
    • 266046 = path 266 row 046 in the ISRO system
    • bX = band number, where bands are b2 (green), b3, (red), b4 (NIR) and b5 (SWIR)
    • l1t = ProcessingLevel, which is L1T, Level 1 Terrain Corrected.

46. Note the many black background pixels. In order to make them transparent, one must determine their No Data value. To do so, activate the **Map** tab and click on the **Explore** icon to return to the **Pop-up** choices. Check on the *Topmost Layer* option. Return to the map view and click in a black area. Note the RGB.Red, RGB.Green, and RGB.Blue values.

47. Open up the **Symbology** pane. At the bottom of the pane, notice a **Statistics** tab (active by default) and a **Mask** tab. Click on the **Mask** tab to activate it. Check the box next to *Display background value*. The default numbers are 0. Accept them and close the **Symbology** pane. The map will redraw with No Data values set to transparent.

48. Zoom to Source resolution of the LISS-3 layer (R2 LS3). With 24m pixels, the spatial resolution is sharper than Landsat. An image tile is somewhat smaller than a full Landsat WRS-2 tile. The color composite, which includes all 4 bands is set to R = SWIR (band 5), G = NIR (band 4), and B = red (band 3). Such a band combination creates a false color combination in which vegetation appears green. Unfortunately, the IRS data is packed with a plain text metadata file, instead of the XML metadata file packaged with the Sentinel and Collection 1 Landsat data. Consequently, the Composite Bands raster function 'named' each

band Band_1. This makes it imperative to document layer order. In this case the Layer name references band order as bands 5, 4, 3, 2.

49. Turn off the LISS-3 layer (R2 LS3) and turn on the AWiFS layer (R2 AWF), The color composite in this case is V-NIR, or color infrared, where R = NIR (band 4), G = red (band 3), and B = green (band 2).

50. Zoom to Source resolution of the AWiFS layer (R2 AWF). Pan around the map to see the level of detail.

51. Now zoom back out to the full layer (right-click the layer and choose **Zoom to Layer**). Turn on the **World Topographic** base map to get a sense of how large the image tile is. Then turn the LS3 layer back on and compare the expanse of the AWiFS data swath to that of LISS-3. AWiFS is a valuable asset for covering a large area with reasonable fine grid cell resolution.

    Our tour is complete. Time for a break!