NRES 241: Introduction to Geomatics for Natural Resource Management

Paul D. Pickell

2024-08-20

Contents

Welcome

These are the course materials for NRES 241 in the Bachelor of Natural Resources program (NRES) at the University of British Columbia (UBC). These Open Educational Resources (OER) were developed to foster the Geomatics Community of Practice that is hosted by the Faculty of Forestry at UBC.

These materials are primarily lab assignments that students enrolled in NRES 241 will complete and submit for credit in the program. Note that much of the data referenced are either public datasets or otherwise only available to students enrolled in the course for credit. Deliverables for these assignments are submitted through the UBC learning management system and only students enrolled in the course may submit these assignments for credit.

How to use these resources

Each "chapter" is a standalone lab assignment designed to be completed over one or two weeks.

Students enrolled in NRES 241 will submit all deliverables through the course management system at UBC for credit and should consult the schedule and deadlines posted there. The casual user can still complete the tutorials step-by-step, but the data that are not alreadyh publicly available are not hosted on this website and therefore you will not have access to them.

How to get involved

Because this is an open project, we highly encourage contributions from the community. The content is hosted on our GitHub repository and from there you can open an issue or start a discussion. Feel free to open an issue for any typos, factual discrepancies, bugs, or topics you want to see. We are always looking for great Canadian case studies to share! You can also fork our GitHub repository to explore the source code and take the content offline.

Chapter 1

Introduction to spatial data and map projections

Written by

Lab Overview

Raster and vector data form the foundation of GIS analysis. In this lab you will download spatial data relating to current and future climate scenarios in Canada. You will then learn the basics of navigating ArcGIS Pro to display this data and create graphical outputs. This lab is designed to help you understand the differences in raster and vector data and practice visualizing spatial data on a map using sound cartographic principles. You will also learn about geographic coordinate systems and how to apply ArcGIS Pro to view different map projections.

Over the past century, greenhouse gas emissions have driven rapid climatic changes across the globe. These changes can be understood by measuring changes in Mean Annual Temperature (MAT) and Mean Annual Precipitation (MAP). In this lab, you will use the Climate NA webmap to generate spatial data and examine how these variables are changing over time. You will also choose a specific location and discuss the implications of projected changes in climate at this place.

Learning Objectives

- Understand differences between raster and vector datatypes

- Visualize different map projections in ArcGIS Pro
- Display spatial data in ArcGIS Pro using appropriate projections and symbology

---

Deliverables

- Screenshots of spatial data displayed in a GIS
- Charts showing MAT and MAP plotted by elevation
- Answers to 9 questions throughout the lab
- Brief discussion of climate change impacts at Canadian location of your choice

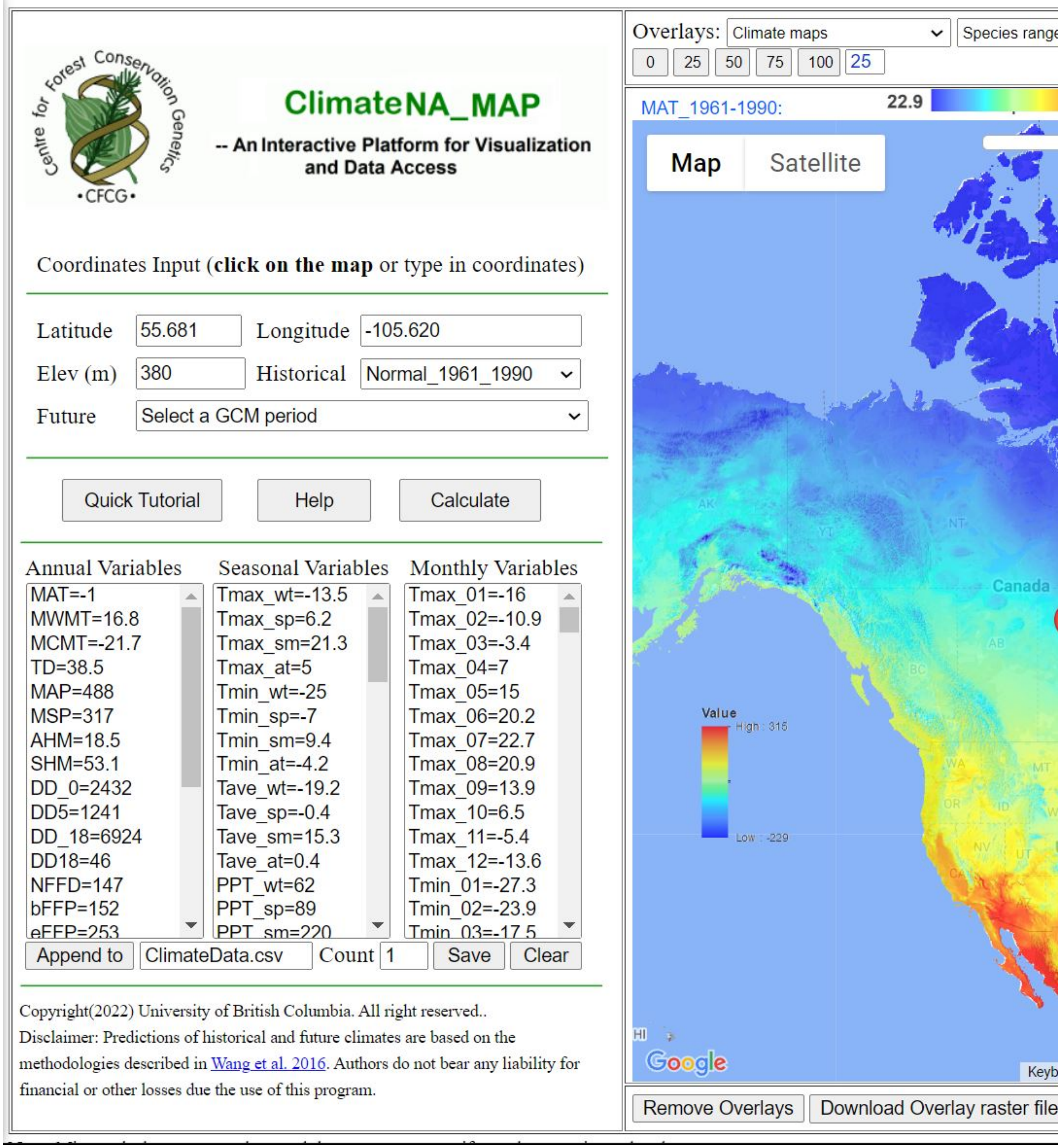
---

Data

- You will generate data for this lab using the Climate NA Webmap
- Shapefile of regularly spaced ellipses to explore map projection (ellipses.shp)

Task 1: Generate point data from Climate NA

Step 1: Go to Climate NA webmap using the following link: ClimateNA_Map (climatewna.com)


Centre for Forest Conservation Genetics
•CFCG•
ClimateNA_MAP
-- An Interactive Platform for Visualization and Data Access
Coordinates Input (click on the map or type in coordinates)
Latitude 55.681
Longitude -105.620
Elev (m) 380
Historical Normal_1961_1990
Future Select a GCM period
Quick Tutorial
Help
Calculate
Annual Variables
MAT=-1
MWMT=16.8
MCMT=-21.7
TD=38.5
MAP=488
MSP=317
AHM=18.5
SHM=53.1
DD_0=2432
DD5=1241
DD_18=6924
DD18=46
NFFD=147
bFFP=152
eFFP=253
Seasonal Variables
Tmax_wt=-13.5
Tmax_sp=6.2
Tmax_sm=21.3
Tmax_at=5
Tmin_wt=-25
Tmin_sp=-7
Tmin_sm=9.4
Tmin_at=-4.2
Tave_wt=-19.2
Tave_sp=-0.4
Tave_sm=15.3
Tave_at=0.4
PPT_wt=62
PPT_sp=89
PPT_sm=220
Monthly Variables
Tmax_01=-16
Tmax_02=-10.9
Tmax_03=-3.4
Tmax_04=7
Tmax_05=15
Tmax_06=20.2
Tmax_07=22.7
Tmax_08=20.9
Tmax_09=13.9
Tmax_10=6.5
Tmax_11=-5.4
Tmax_12=-13.6
Tmin_01=-27.3
Tmin_02=-23.9
Tmin_03=-17.5
Append to
ClimateData.csv
Count 1
Save
Clear
Copyright(2022) University of British Columbia. All right reserved..
Disclaimer: Predictions of historical and future climates are based on the methodologies described in Wang et al. 2016. Authors do not bear any liability for financial or other losses due the use of this program.
Overlays: Climate maps
Species range
0 25 50 75 100 25
MAT_1961-1990:
22.9
Map
Satellite
Canada
Value
High : 315
Low : -229
Google
Remove Overlays
Download Overlay raster file

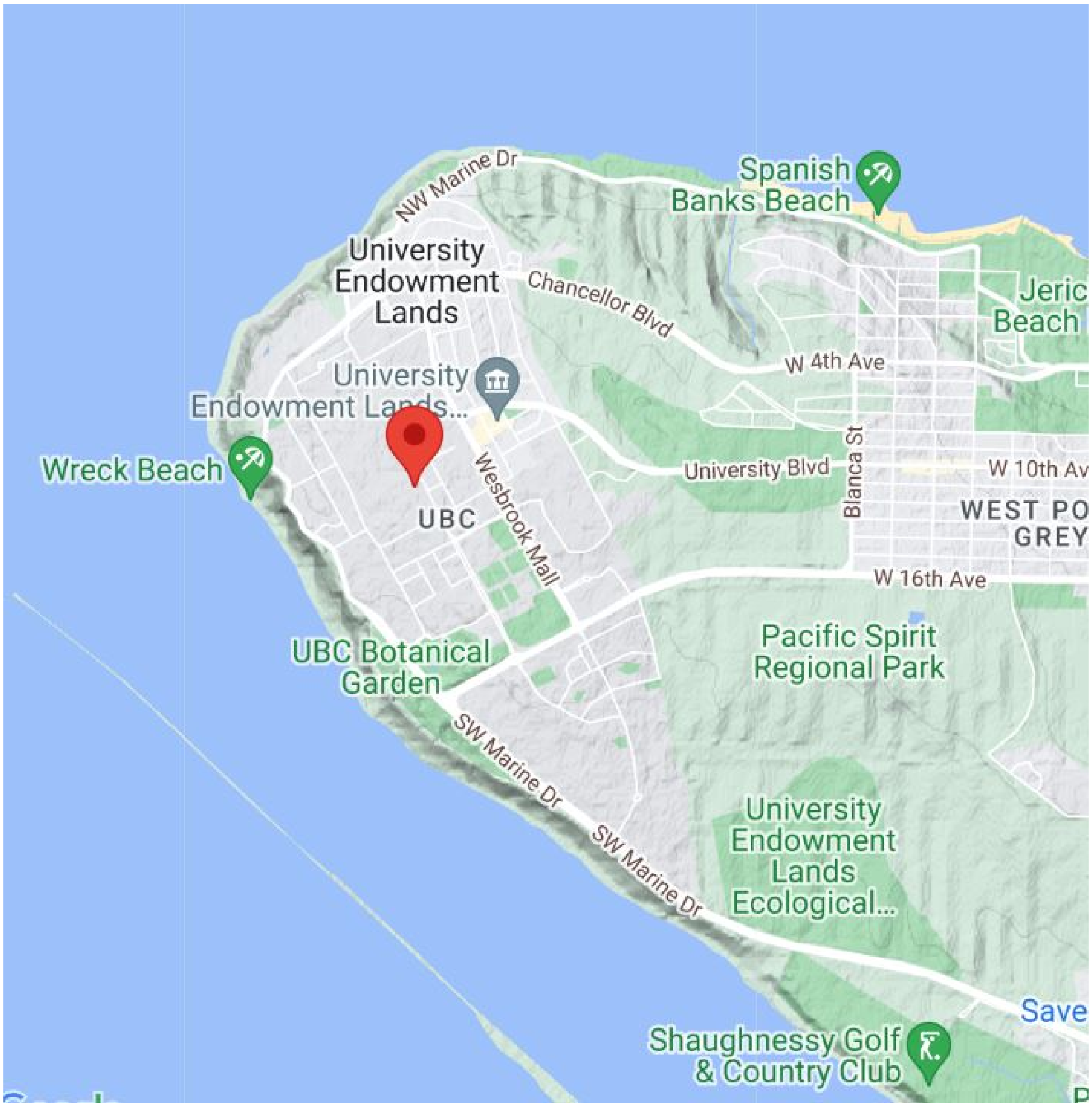
By clicking on the map on the right you can generate Annual, Seasonal and Monthly climate variables which will be displayed on the left. You can also select locations by typing in coordinates into the Latitude and Longitude boxes and hitting Enter on your keyboard.

Q1. What map projection does the climate NA webmap use? The Help button will take you to a page that describes what each of the climate variables mean. For this lab we will be focusing on two Annual variables: **MAT (Mean Annual Temperature)** and **MAP (Mean Annual Precipitation)**.

Use the **Historical** drop-down menu to generate climate normals from different decades and years. The **Future** drop-down menu will allow you to generate climate projections for different time periods and climate warming scenarios.

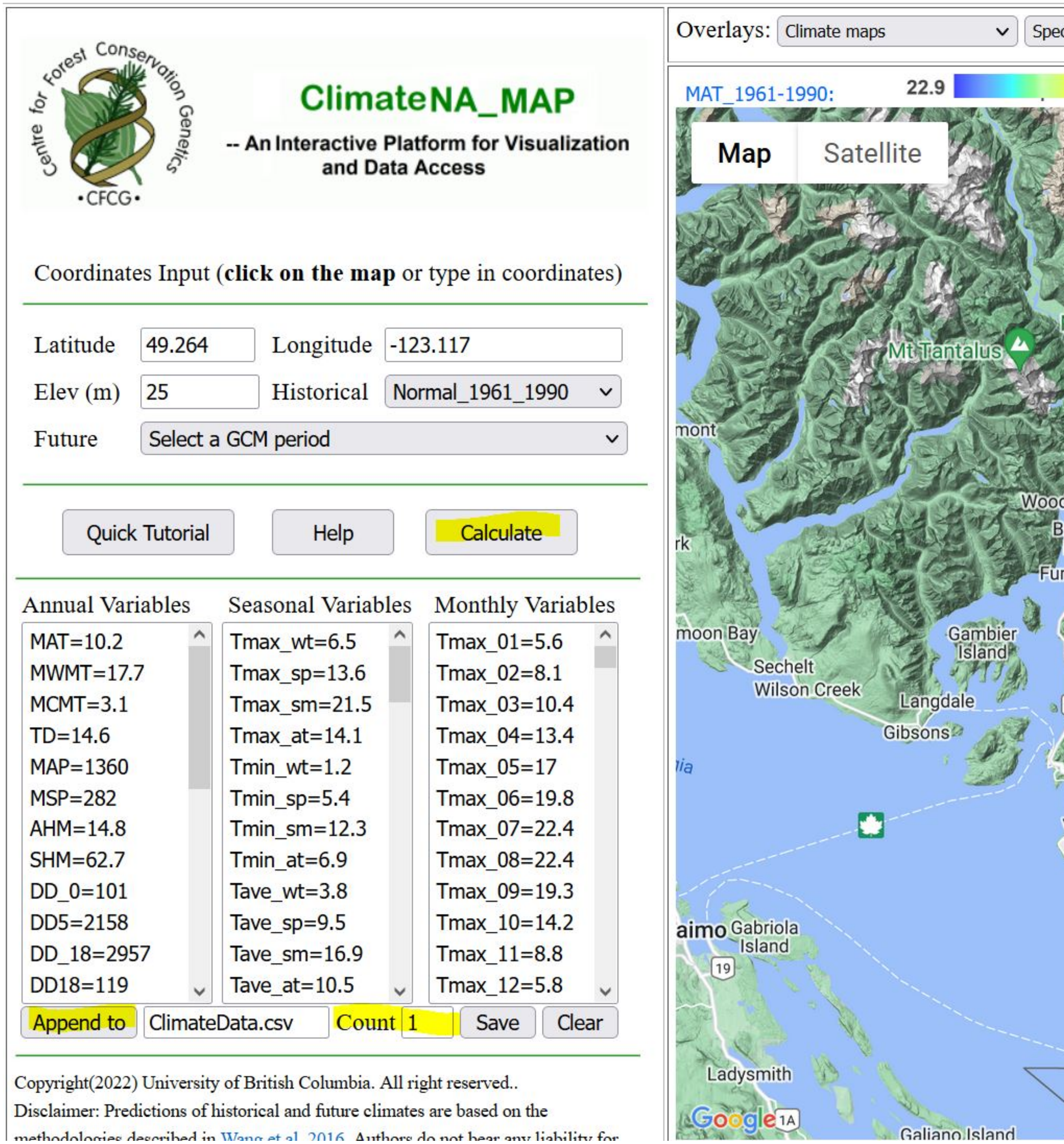
The Quick Tutorial button will give more explanation for other features of the webmap.

Q2. Zoom in to the UBC Vancouver campus, what is the MAT and MAP at this location for the normal period 1961_1990? (You do not need to click on the exact same point shown below, but make sure to click somewhere on campus).



Step 2: Next we will be generating climate data at varying elevations within Vancouver and the Coast Mountains. Set the Historical drop-down menu to **Normal_1961_1990**.

Q3. In two sentences describe what a climate normal is and why it might be important in understanding changes in climate. Zoom in to the following area showing greater Vancouver and the Coast Mountains.


Centre for Forest Conservation Genetics
•CFCG•
ClimateNA_MAP
-- An Interactive Platform for Visualization and Data Access
Coordinates Input (click on the map or type in coordinates)
Latitude 49.264
Longitude -123.117
Elev (m) 25
Historical Normal_1961_1990
Future Select a GCM period
Quick Tutorial
Help
Calculate
Annual Variables
Seasonal Variables
Monthly Variables
MAT=10.2
MWMT=17.7
MCMT=3.1
TD=14.6
MAP=1360
MSP=282
AHM=14.8
SHM=62.7
DD_0=101
DD5=2158
DD_18=2957
DD18=119
Tmax_wt=6.5
Tmax_sp=13.6
Tmax_sm=21.5
Tmax_at=14.1
Tmin_wt=1.2
Tmin_sp=5.4
Tmin_sm=12.3
Tmin_at=6.9
Tave_wt=3.8
Tave_sp=9.5
Tave_sm=16.9
Tave_at=10.5
Tmax_01=5.6
Tmax_02=8.1
Tmax_03=10.4
Tmax_04=13.4
Tmax_05=17
Tmax_06=19.8
Tmax_07=22.4
Tmax_08=22.4
Tmax_09=19.3
Tmax_10=14.2
Tmax_11=8.8
Tmax_12=5.8
Append to
ClimateData.csv
Count 1
Save
Clear
Copyright(2022) University of British Columbia. All right reserved..
Disclaimer: Predictions of historical and future climates are based on the
Overlays: Climate maps
MAT_1961-1990:
22.9
Map
Satellite
Mt Tantalus
Gambier Island
Sechelt
Wilson Creek
Langdale
Gibsons
Gabriola Island
Ladysmith
Galiano Island

Pick a location in the greater Vancouver area **(choose a location that is on land, i.e. not in the ocean)**, click on the map to add a pin then click **Calculate** to generate climate data for this location.

Next, click the **Append** to button to add the climate data to a .csv file that we will download later. The Count field should now show 1, indicating that one location has been added.

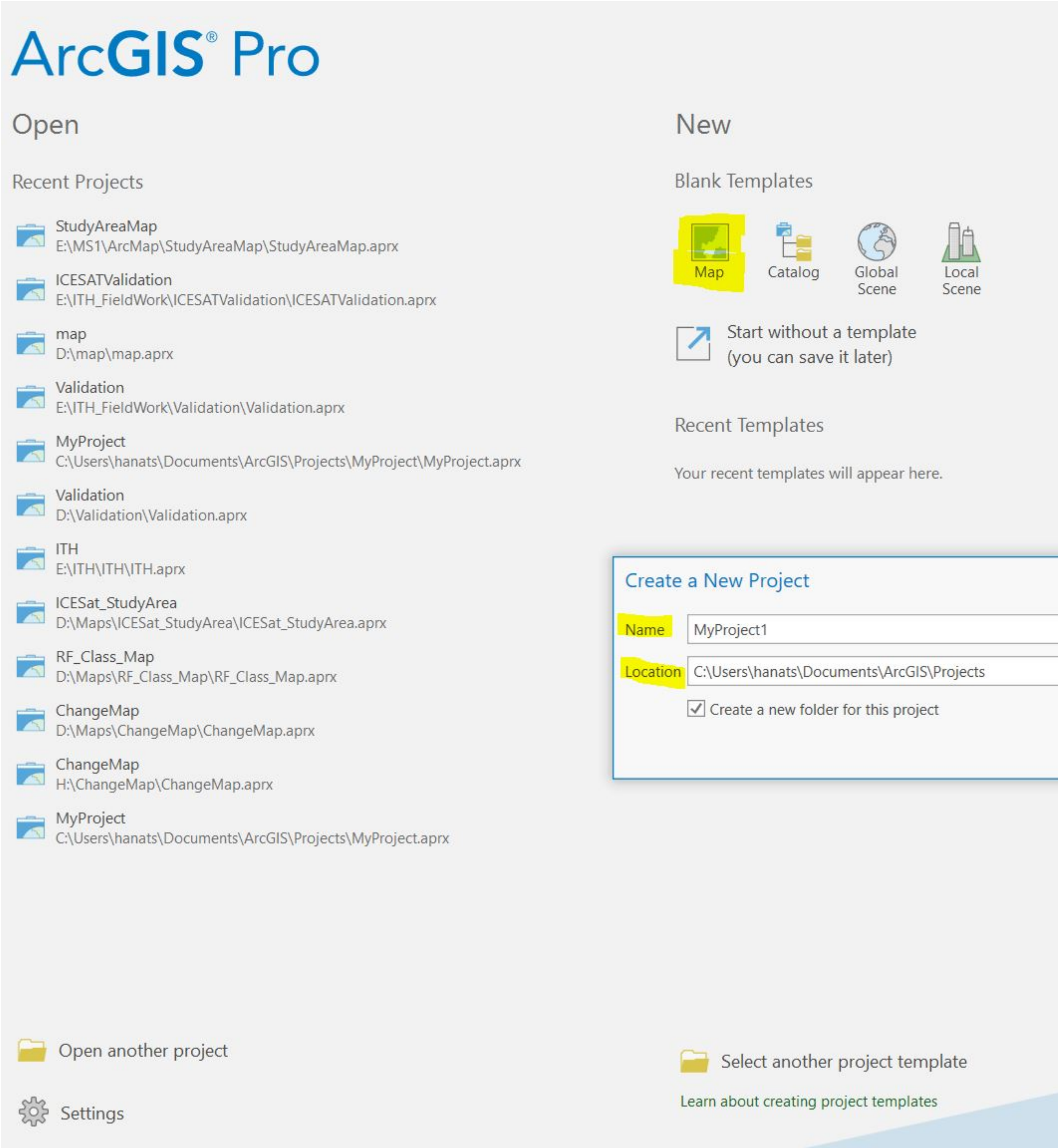
Next, click on 10-15 new locations on the map, click Calculate then Append to. Later, we will graph climate at different elevations, so **try to sample a range of mountain peaks, valleys and flat locations.** Again, choose locations on land and vary the distance to water bodies.

Calculate and append climate variables for 10-15 new coordinates.

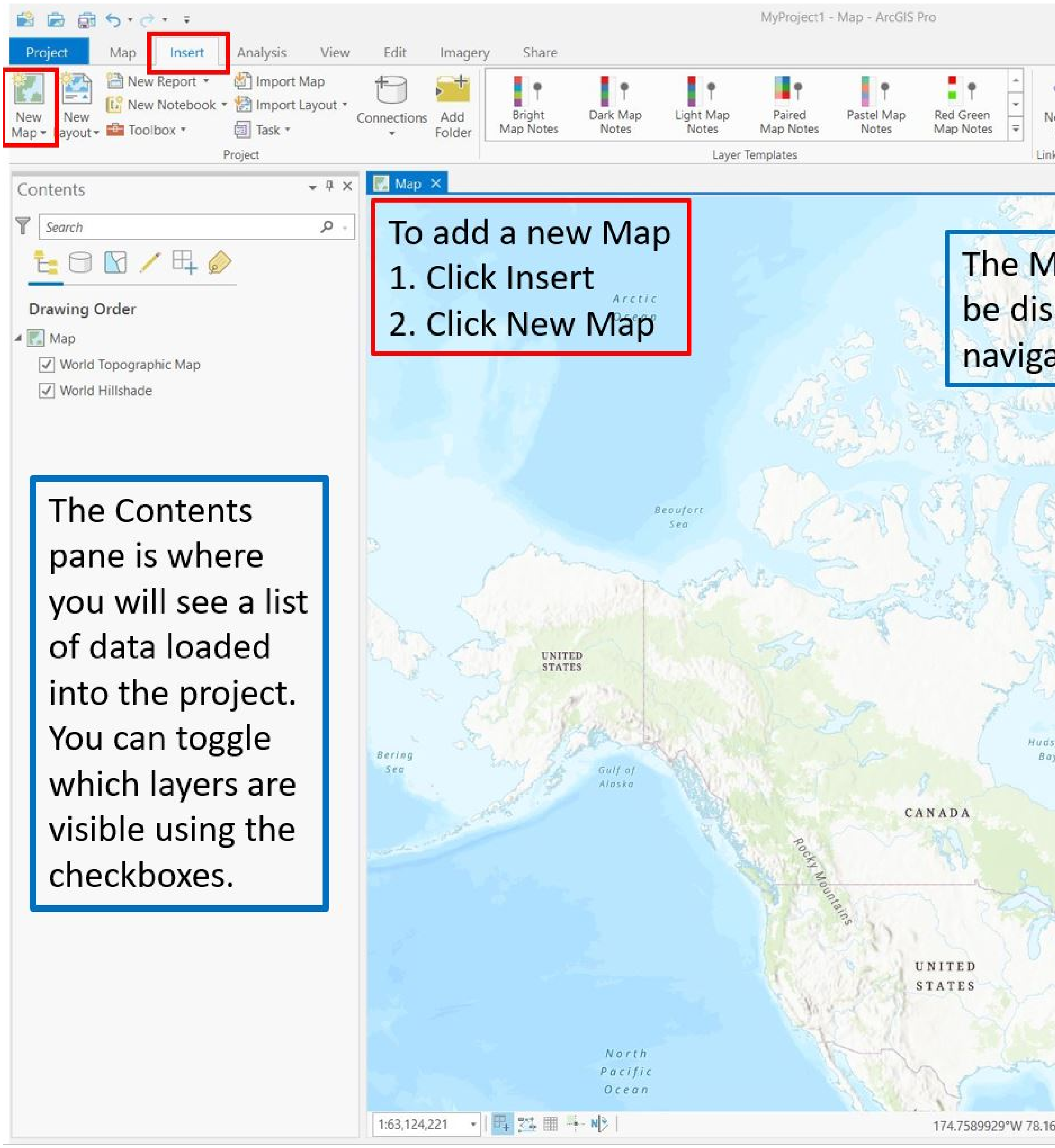
When you are done, hit the **Save** button to download the csv file to your Downloads folder (this will happen automatically).

Task 2: Import coordinates as spatial points in ArcGIS Pro

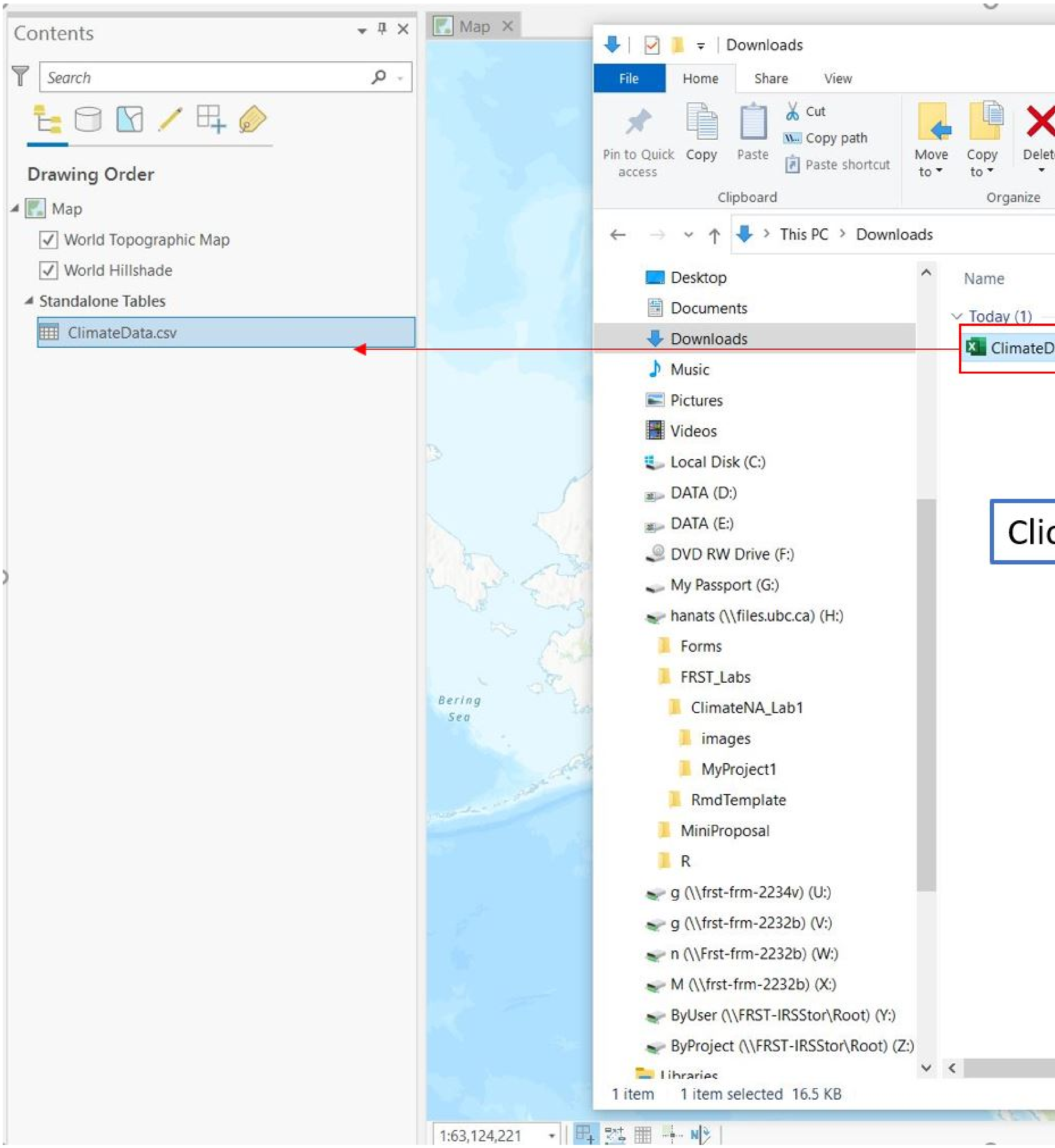
Step 1: Open ArcGISPro. Click on the Map button, then name your new project and save it as Lab 1 on your computer. The default filepath might look something like this: `C:\Users\YourUsername\Documents\ArcGIS\Projects\Lab1.`


ArcGIS Pro
Open
Recent Projects
StudyAreaMap
E:\MS1\ArcMap\StudyAreaMap\StudyAreaMap.aprx
ICESATValidation
E:\ITH_FieldWork\ICESATValidation\ICESATValidation.aprx
map
D:\map\map.aprx
Validation
E:\ITH_FieldWork\Validation\Validation.aprx
MyProject
C:\Users\hanats\Documents\ArcGIS\Projects\MyProject\MyProject.aprx
Validation
D:\Validation\Validation.aprx
ITH
E:\ITH\ITH\ITH.aprx
ICESat_StudyArea
D:\Maps\ICESat_StudyArea\ICESat_StudyArea.aprx
RF_Class_Map
D:\Maps\RF_Class_Map\RF_Class_Map.aprx
ChangeMap
D:\Maps\ChangeMap\ChangeMap.aprx
ChangeMap
H:\ChangeMap\ChangeMap.aprx
MyProject
C:\Users\hanats\Documents\ArcGIS\Projects\MyProject.aprx
Open another project
Settings
New
Blank Templates
Map
Catalog
Global Scene
Local Scene
Start without a template (you can save it later)
Recent Templates
Your recent templates will appear here.
Create a New Project
Name
MyProject1
Location
C:\Users\hanats\Documents\ArcGIS\Projects
Create a new folder for this project
Select another project template
Learn about creating project templates

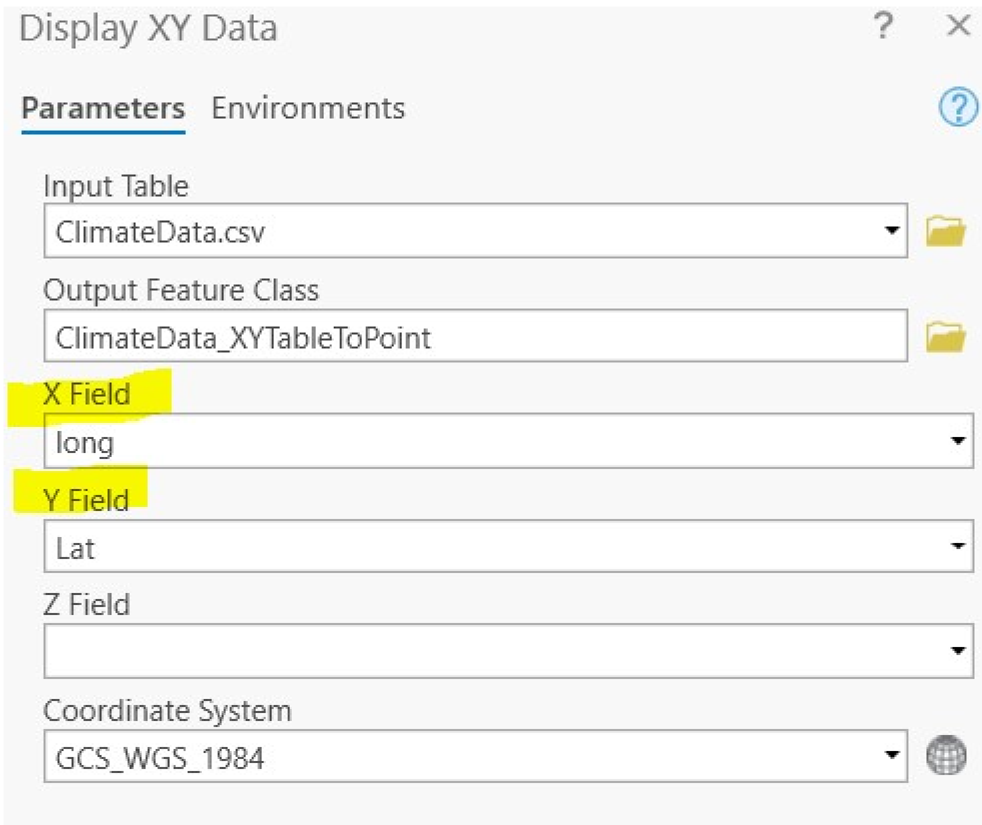
To get started, click the **Insert** button on the top ribbon, then the **New Map** button.


MyProject1 - Map - ArcGIS Pro
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
New Map
New Layout
New Report
New Notebook
Toolbox
Import Map
Import Layout
Task
Connections
Add Folder
Project
Bright Map Notes
Dark Map Notes
Light Map Notes
Paired Map Notes
Pastel Map Notes
Red Green Map Notes
Layer Templates
Contents
Search
Drawing Order
Map
World Topographic Map
World Hillshade
To add a new Map
1. Click Insert
2. Click New Map
The Contents pane is where you will see a list of data loaded into the project. You can toggle which layers are visible using the checkboxes.
Arctic Ocean
Beaufort Sea
UNITED STATES
Bering Sea
Gulf of Alaska
CANADA
Rocky Mountains
UNITED STATES
North Pacific Ocean
1:63,124,221
174.7589929°W

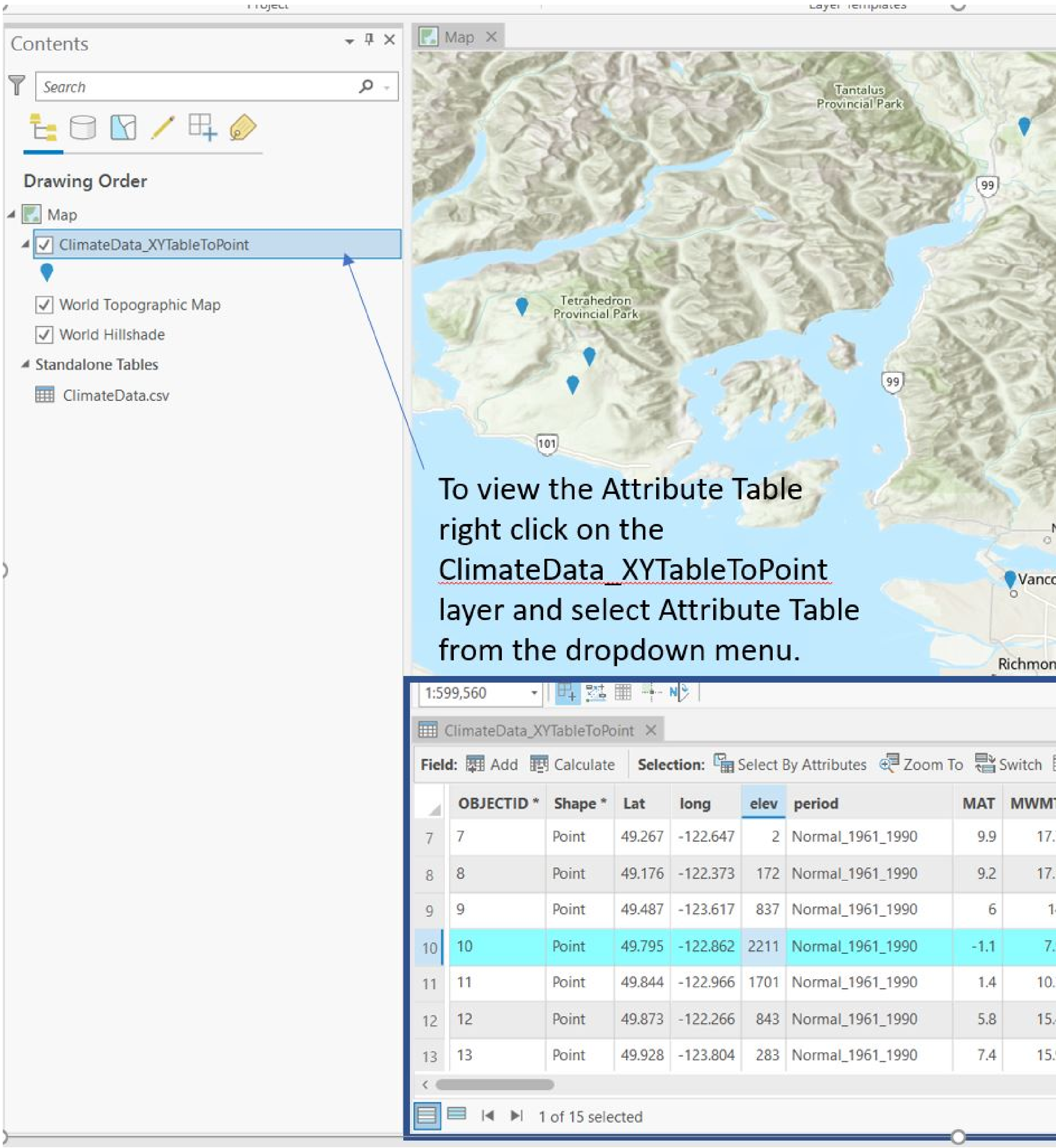
Step 2: To import ClimateData.csv to ArcGIS Pro open File Explorer and navigate to the Downloads folder. Click and drag ClimateData.csv to the Contents pane.


Contents
Search
Drawing Order
Map
World Topographic Map
World Hillshade
Standalone Tables
ClimateData.csv
Map
Downloads
File
Home
Share
View
Pin to Quick access
Copy
Paste
Cut
Copy path
Paste shortcut
Clipboard
Move to
Copy to
Organize
This PC
Downloads
Desktop
Documents
Downloads
Music
Pictures
Videos
Local Disk (C:)
DATA (D:)
DATA (E:)
DVD RW Drive (F:)
My Passport (G:)
hanats (\\files.ubc.ca) (H:)
Forms
FRST_Labs
ClimateNA_Lab1
images
MyProject1
RmdTemplate
MiniProposal
R
g (\\frst-frm-2234v) (U:)
g (\\frst-frm-2232b) (V:)
n (\\Frst-frm-2232b) (W:)
M (\\frst-frm-2232b) (X:)
ByUser (\\FRST-IRSStor\Root) (Y:)
ByProject (\\FRST-IRSStor\Root) (Z:)
Name
Today (1)
Bering Sea
1 item
1 item selected 16.5 KB
1:63,124,221

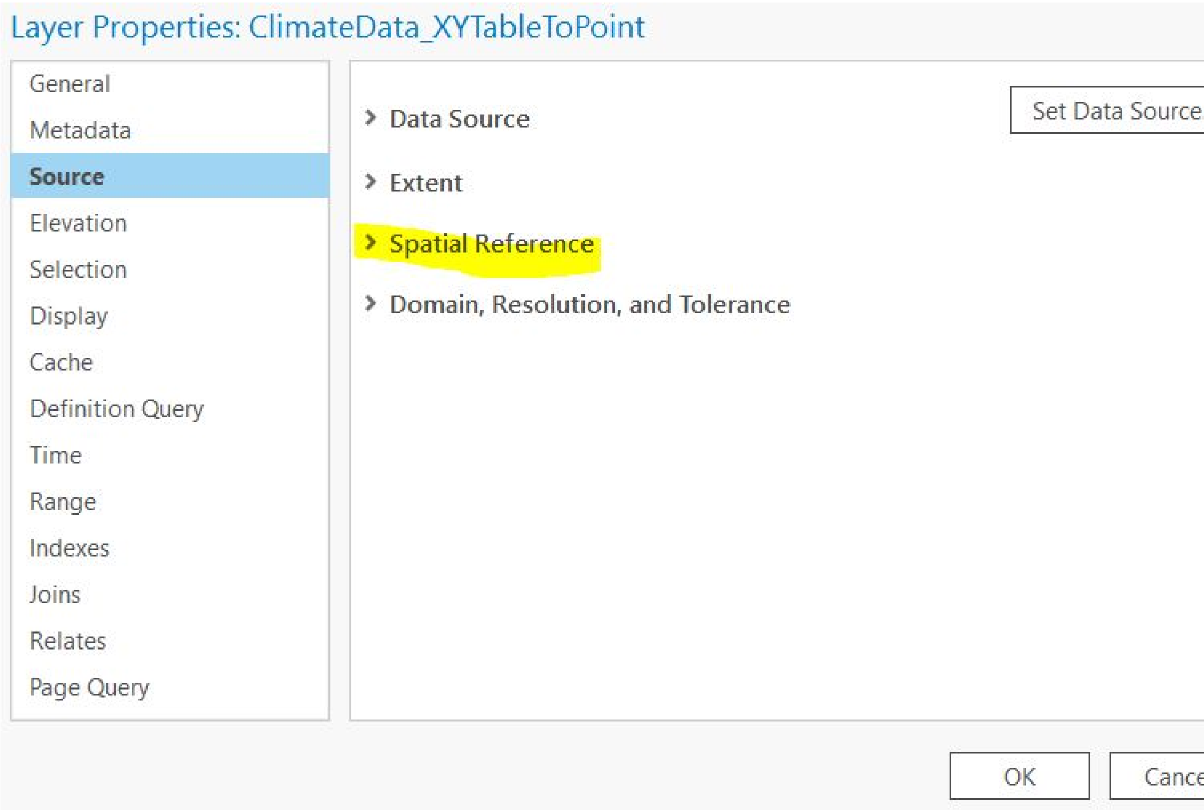
Step 3: Next, we will add data to the map using the lat/long coordinates from the csv. Right click on **ClimateData.csv** in the Contents pane then select **Display XY Data** from the dropdown menu. Ensure that the **X Field** shows the column corresponding to longitude (long) and the **Y Field** shows the column corresponding to latitude (lat). Leave the output feature class coordinate system as the default. Click OK.



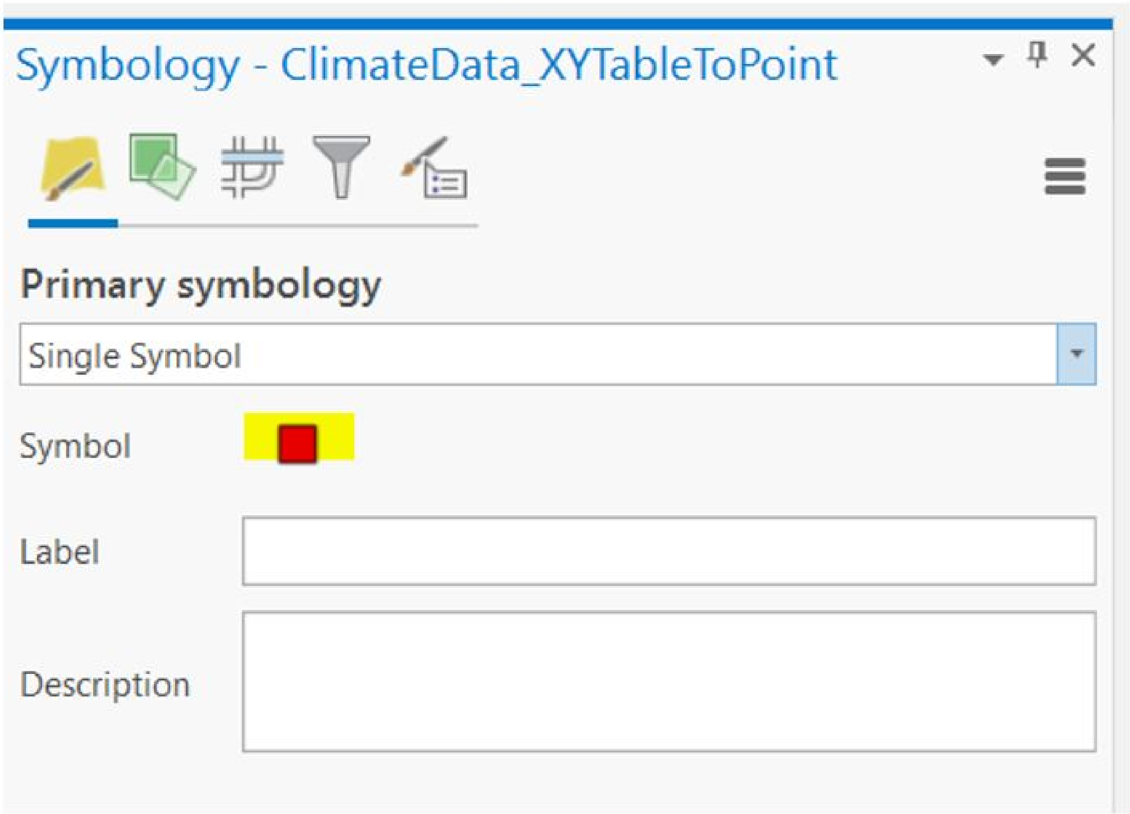
Step 4: Your point features should now be displayed in the Map pane. Right click on the **ClimateData_XYTableToPoint** layer and select Attribute Table. This is where you can view the climate data associated with each point.


Contents
Search
Drawing Order
Map
ClimateData_XYTableToPoint
World Topographic Map
World Hillshade
Standalone Tables
ClimateData.csv
Map
Tantalus Provincial Park
Tetrahedron Provincial Park
99
101
To view the Attribute Table right click on the ClimateData_XYTableToPoint layer and select Attribute Table from the dropdown menu.
Richmon
1:599,560
ClimateData_XYTableToPoint
Field: Add Calculate Selection: Select By Attributes Zoom To Switch
OBJECTID * Shape * Lat long elev period MAT MWMT
7 7 Point 49.267 -122.647 2 Normal_1961_1990 9.9
8 8 Point 49.176 -122.373 172 Normal_1961_1990 9.2
9 9 Point 49.487 -123.617 837 Normal_1961_1990 6
10 10 Point 49.795 -122.862 2211 Normal_1961_1990 -1.1
11 11 Point 49.844 -122.966 1701 Normal_1961_1990 1.4
12 12 Point 49.873 -122.266 843 Normal_1961_1990 5.8
13 13 Point 49.928 -123.804 283 Normal_1961_1990 7.4
1 of 15 selected

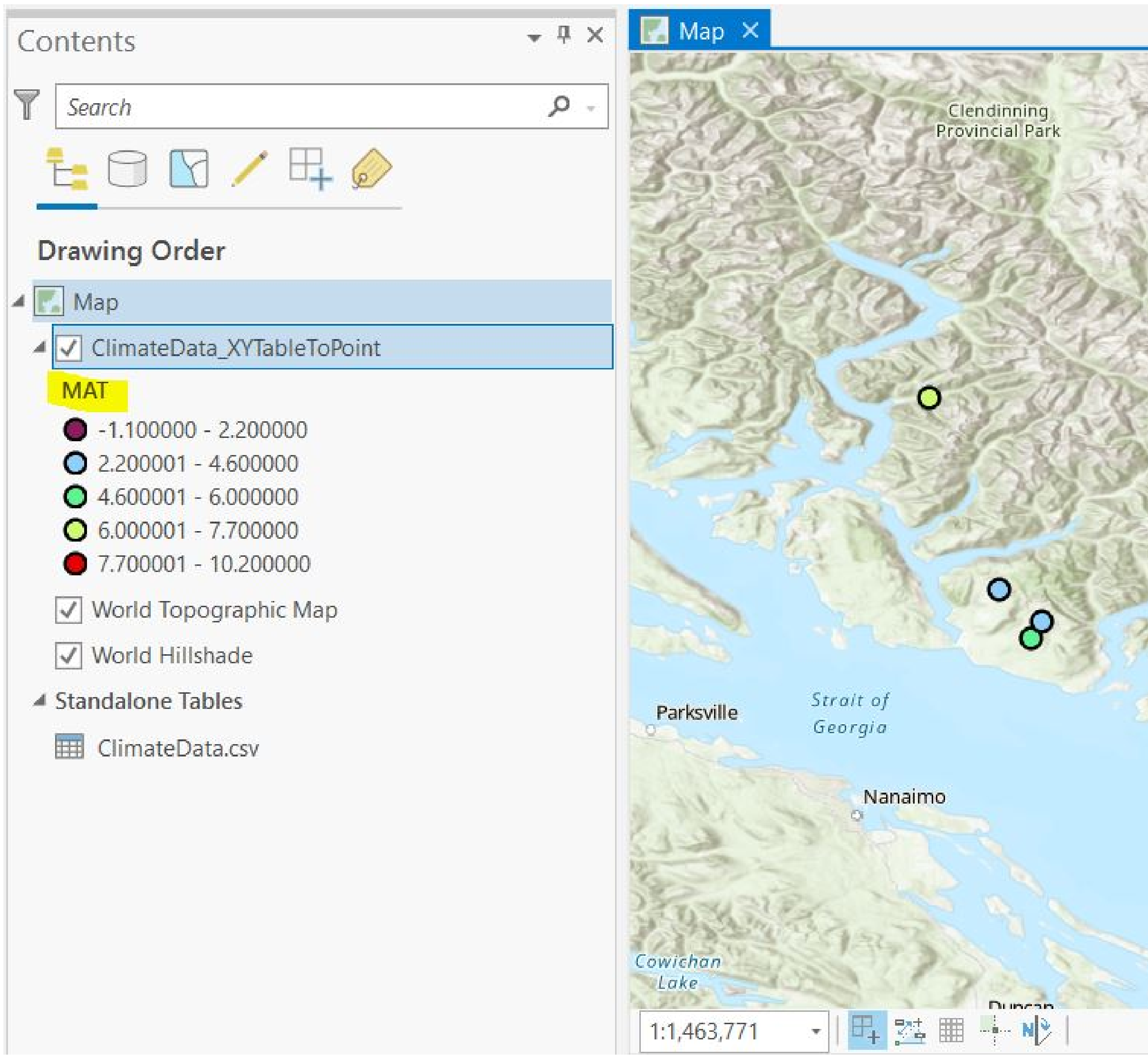
Right click on the **ClimateData_XYTableToPoint** layer in the Contents pane and select **Properties** from the dropdown menu. Navigate to **Source** and examine the **Spatial Reference** information by opening the menu.



Q4. What is the Geographic Coordinate System of the layer? What is the Angular Unit? **Step 5:** Next we will explore point symbology. Right click on **ClimateData_XYTableToPoint** layer and select **Symbology**. You can change the symbol of all the points by clicking on the Symbol button and selecting a new symbol from the Gallery tab.



We can also vary the color of each point by different variables in the Attribute Table. Right click on **ClimateData_XYTableToPoint** layer and select **Symbology**. Under Primary symbology, use the dropdown menu to change the symbology type to **Graduated Colors**.



Use the **Field** option to change which variable to classify points by. In this example we are using the Mean Annual Temperature (MAT) field and plotting colder points in purple/blue and warmer points in yellow/red. Explore the different color options in the Color Scheme menu.

You can also change the number of classes and the method of choosing the classes using the Method and Classes options.

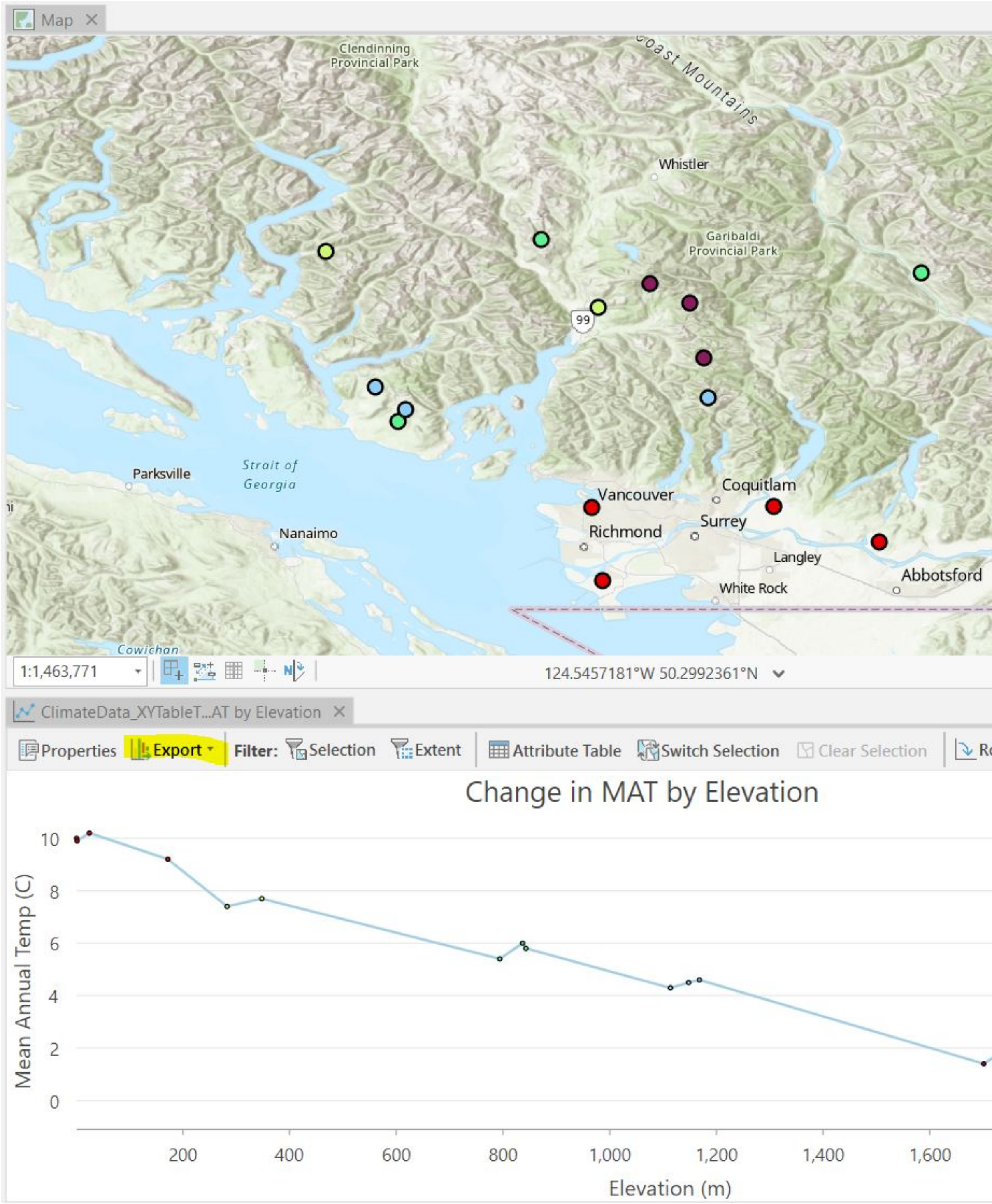
Plot your points and color code them by Mean Annual Precipitation (MAP). Take a screenshot of the points on the map and the symbology menu to include in your final deliverables.

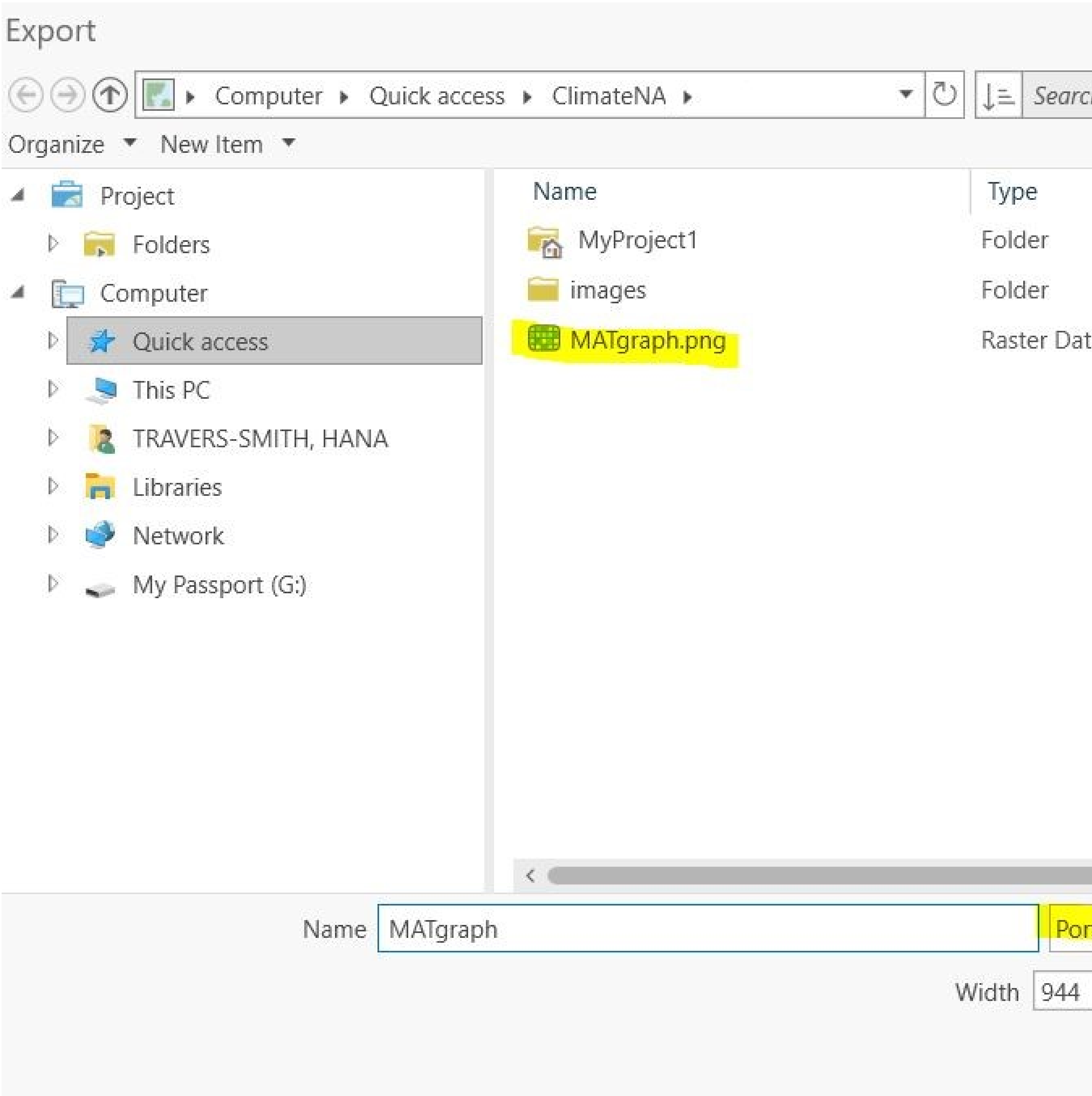
Step 6: Next, we will create a simple chart of our climate data. Right click on **ClimateData_XYTableToPoint** layer and select **Create Chart > Line Chart**.

In the Chart Properties pane set the **Date or Number** field to **elev**. This will plot elevation on the X-axis. Next, under Numeric fields select MAT, this will plot Mean Annual temperature on the Y-axis.

Go to the General tab and change the chart title and X and Y axis labels to something descriptive and include units of measurement. When you are finished click the Export > Export as graphic. Name the chart and save it as a .png.

Create charts of change in MAT and change in MAP by elevation. Include the images in your final deliverables.

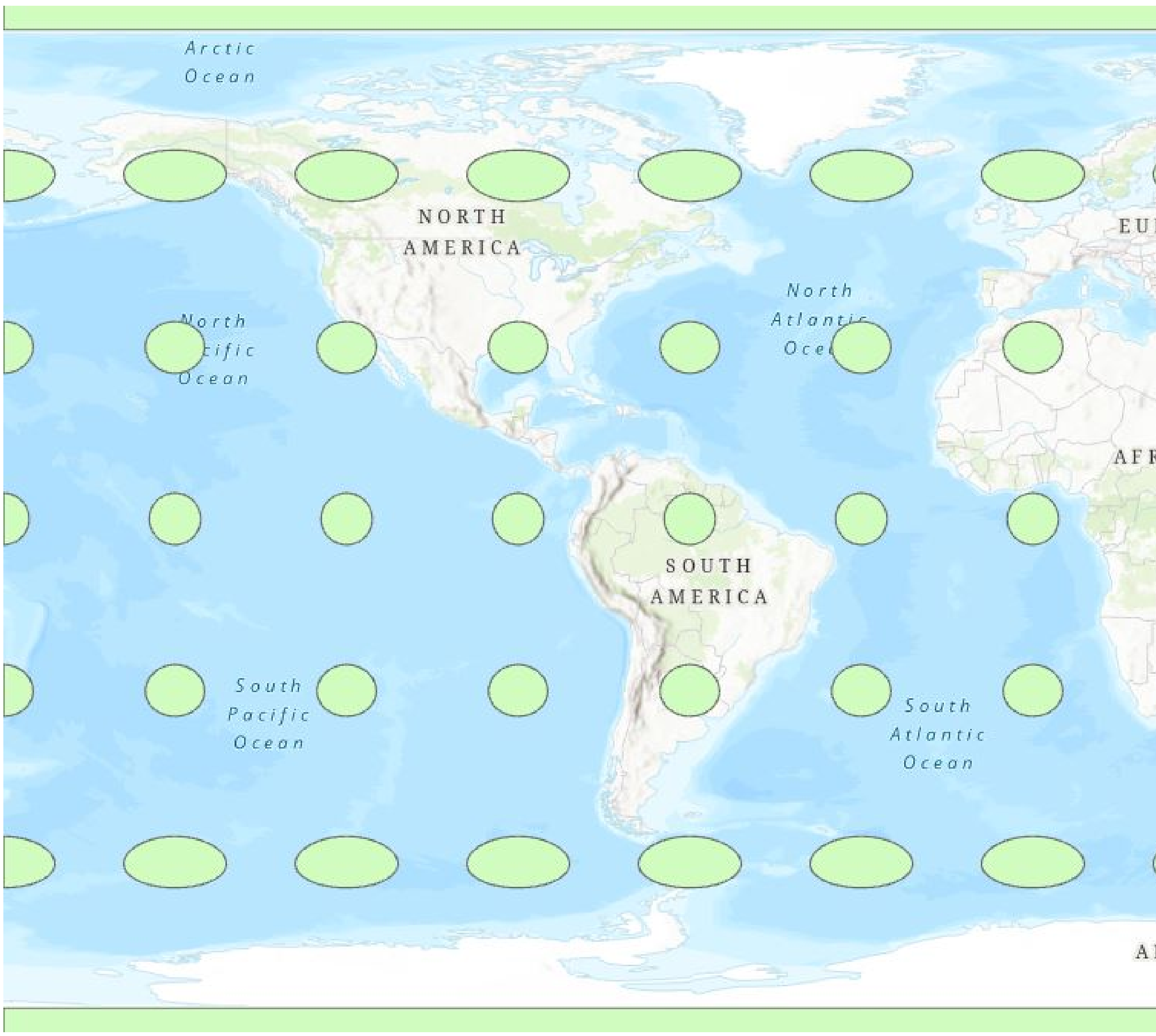

Map
Clendinning Provincial Park
Coast Mountains
Whistler
Garibaldi Provincial Park
99
Parksville
Strait of Georgia
Nanaimo
Vancouver
Coquitlam
Richmond
Surrey
Langley
White Rock
Abbotsford
Cowichan
1:1,463,771
124.5457181°W 50.2992361°N
ClimateData_XYTableT...AT by Elevation
Properties
Export
Filter:
Selection
Extent
Attribute Table
Switch Selection
Clear Selection
Change in MAT by Elevation
Mean Annual Temp (C)
10
8
6
4
2
0
200
400
600
800
1,000
1,200
1,400
1,600
Elevation (m)


Export
Computer
Quick access
ClimateNA
Searc
Organize
New Item
Project
Folders
Computer
Quick access
This PC
TRAVERS-SMITH, HANA
Libraries
Network
My Passport (G:)
Name
Type
MyProject1
Folder
images
Folder
MATgraph.png
Raster Dat
Name
MATgraph
Por
Width
944

Task 3: Exploring map projections

Step 1: Open ArcGIS Pro and insert a new Map.

To visualize how different map projections alter shape, area and distance of spatial data drag and drop the **ellipses.shp** shapefile to the Map. Note that the default projection in ArcMap is the pseudo-Plate-Caree projection.



Use the measure tool from the top ribbon (**Map > Measure**) to measure the length and width of the ellipses at the poles and at the equator. You will notice that the ellipses are actually perfect circles with a diameter of ~1000km.

Q5. What areas of the map show the most distortion? What properties of the circles are distorted? You can change the projection of the entire map in the **Map Properties > Coordinate Systems** tab. Any layers in the contents pane will be projected on the fly and displayed in this coordinate system. Note that changing the coordinate system of the Map does NOT change the underlying projection of the data itself.

Step 2: Compare the following three projections: **Mercator (world), Cylindrical Equal Area (world)** .

Q6: What properties are distirted or preserved in the Mercator and Cylindrical Equal Area projections? Where on the globe are the distortions most apparent?

Task 4: Import and display raster data

Step 1: Go to Climate NA webmap using the following link: ClimateNA_Map (climatewna.com)

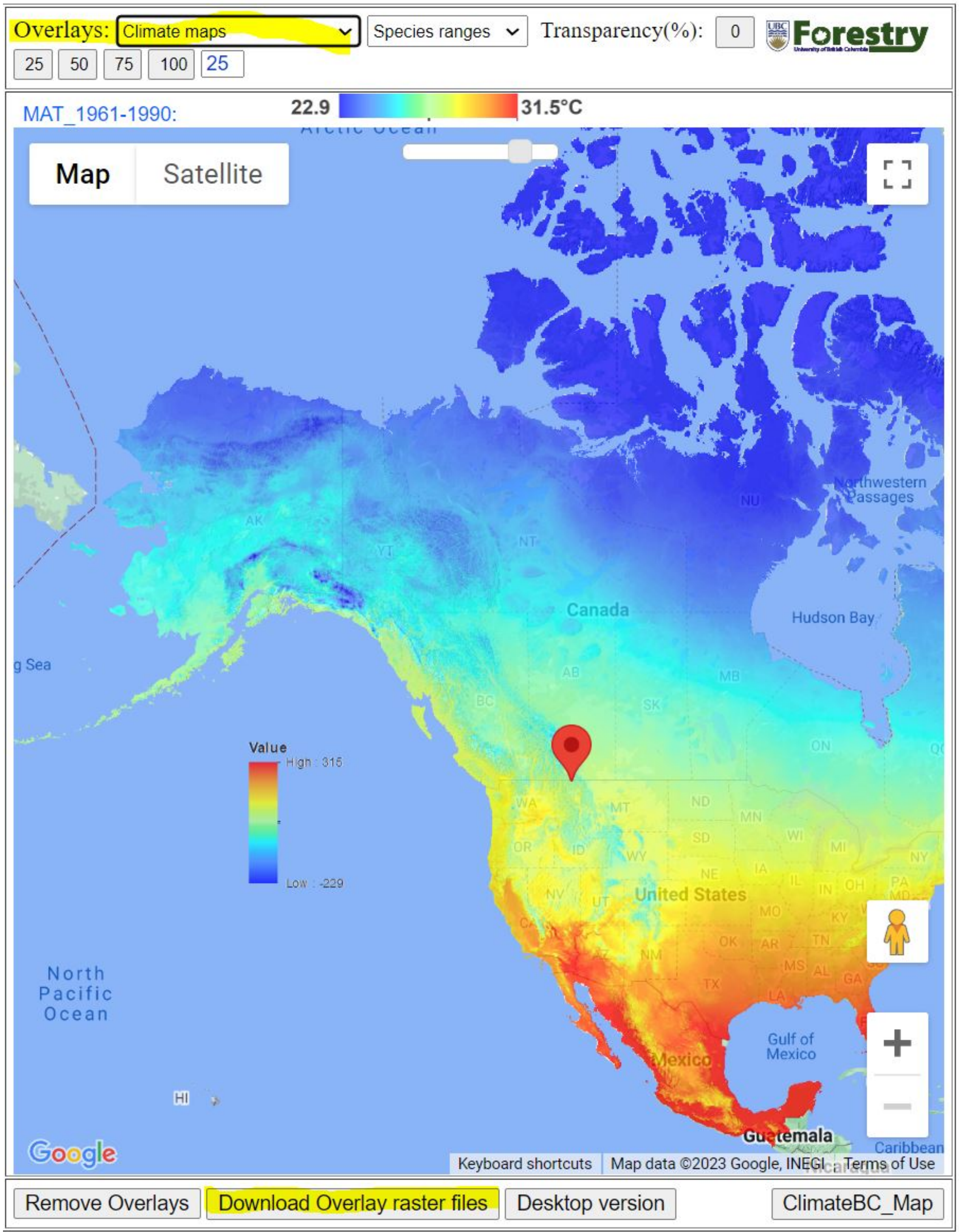
We will be downloading 4 raster datasets to calculate differences in current and future projections of MAT and MAP.

To download a raster overlay, look at the Overlays dropdown menu at the top of the screen (NOT the Coordinates Input that you used before), then select the layer you want and click Download Overlay raster files.

Download the following layers:

- **MAT_1961-1990**
- **MAT_ssp245_2071_2100**
- **MAP_1961_1990**
- **MAP_ssp245_2071_2100**

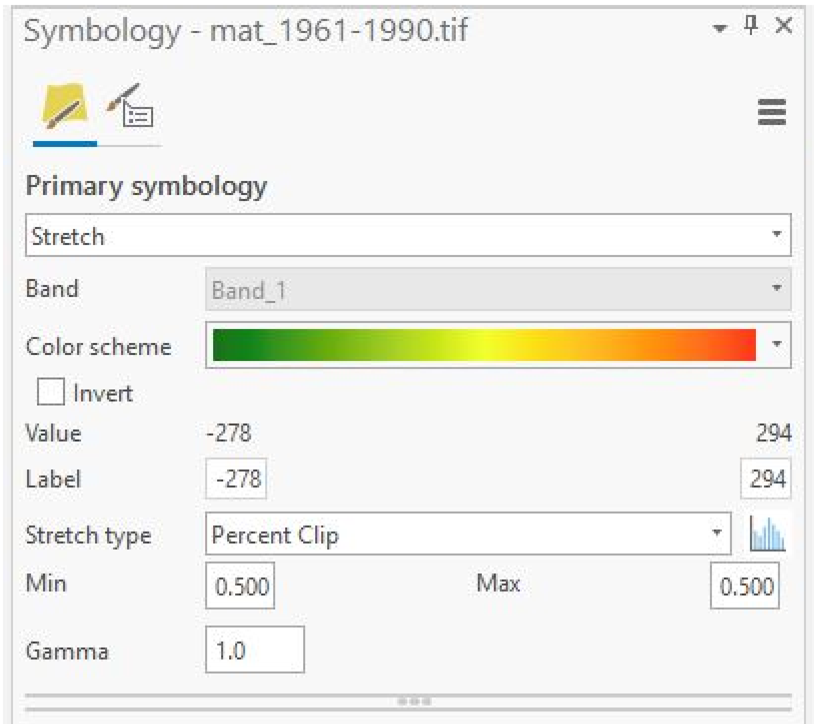
Q7. From the IPCC Sixth Assessment Report what does the SSP2-4.5 scenario represent? Answer in 2-3 sentences.


Overlays: Climate maps
Species ranges
Transparency(%): 0
Forestry
25 50 75 100 25
MAT_1961-1990:
22.9
31.5°C
Map
Satellite
Value
High : 315
Low : -229
Canada
United States
Mexico
Hudson Bay
Gulf of Mexico
North Pacific Ocean
Guatemala
Keyboard shortcuts
Map data ©2023 Google, INEGI
Terms of Use
Remove Overlays
Download Overlay raster files
Desktop version
ClimateBC_Map

Step 2: Drag and drop the 4 climate rasters from your Downloads folder to the Contents pane.

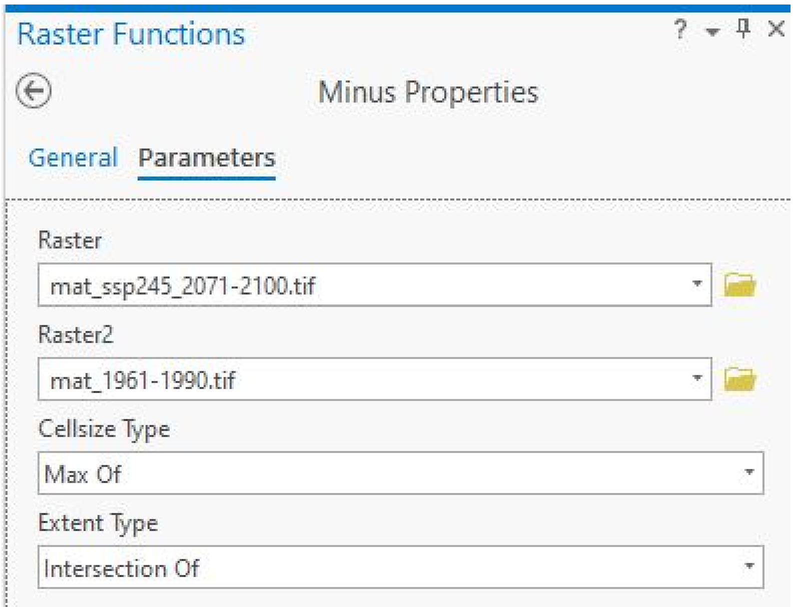
Change the coordinate system of the map to **NAD 1983 Statistics Canada Lambert**

Right click on the **mat__1961__1990** layer in the Contents pane > Symbology. Change the color scheme to better see the range of values.



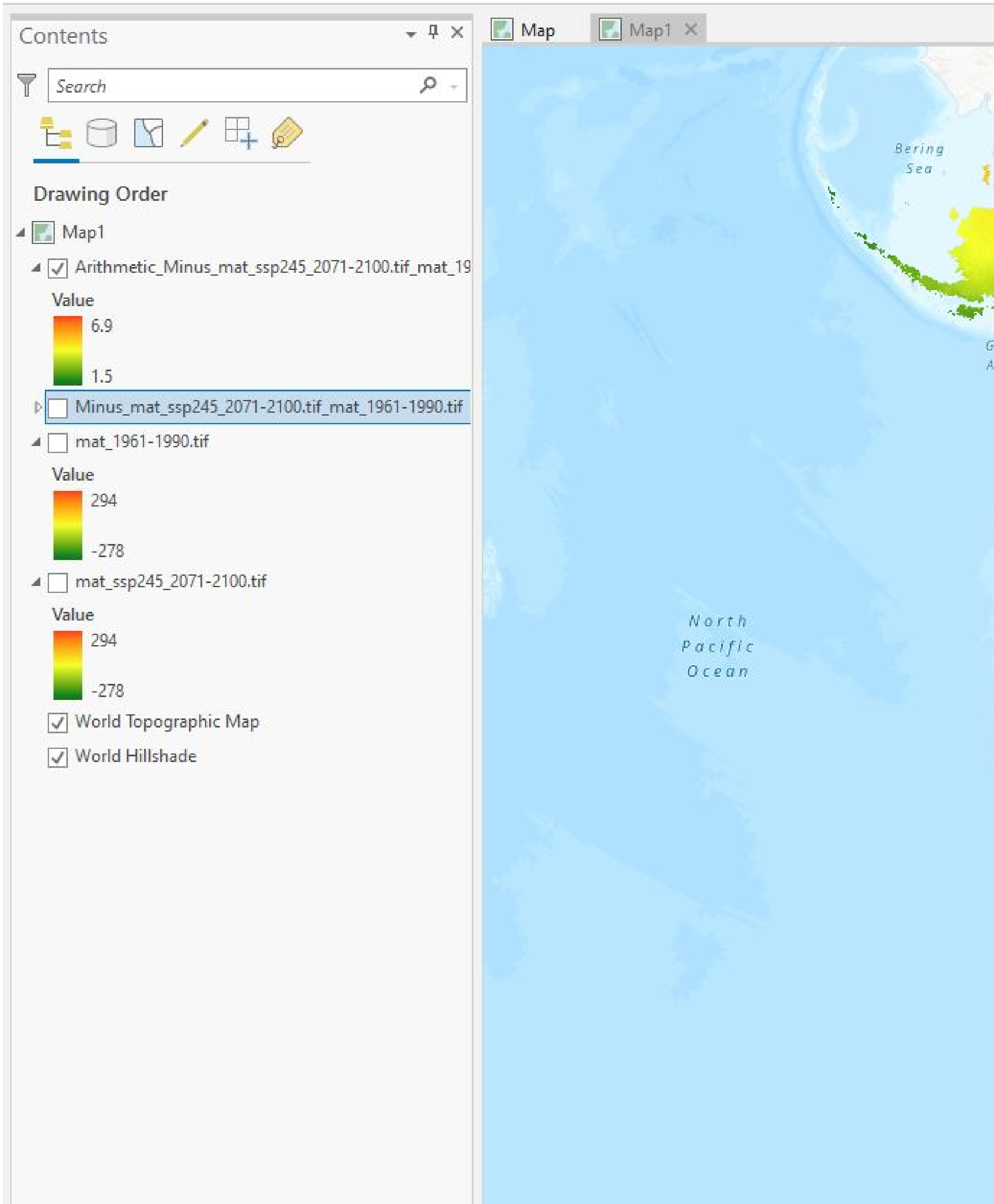
Step 3: Next we will calculate the **difference in historical and projected MAT**. First, navigate to the **Imagery** tab in the top ribbon > **Raster Functions.**

Under the Math tab click on the **Minus** tool. This tool subtracts cell values between two rasters and outputs a new raster whose values are the difference between the two inputs. In the Raster field input the **mat__ssp245__2071__2100** layer. In the Raster2 field input the **mat__1961__1990** layer. This will subtract the historical MAT values from the projected MAT values. Click **Create new layer.**



Notice that MAT values have been scaled by a factor of 10. Next, we will divide the cell values of the change in MAT raster by 10 to put values in units of $^\circ$C. Navigate back to the Raster Functions menu and select the Divide tool. Input the Minus_mat_ssp245_2071-2100.tif_mat_1961-1990.tif layer in the Raster field. In the Raster2 field type in **10**. Create new layer.

You should now have a layer that looks like the following:


Contents
Search
Drawing Order
Map1
Arithmetic_Minus_mat_ssp245_2071-2100.tif_mat_19
Value
6.9
1.5
Minus_mat_ssp245_2071-2100.tif_mat_1961-1990.tif
mat_1961-1990.tif
Value
294
-278
mat_ssp245_2071-2100.tif
Value
294
-278
World Topographic Map
World Hillshade
Map
Map1
Bering Sea
North Pacific Ocean

Q7: In 1-2 sentences comment on the pattern of change in MAT. Where are the greatest changes expected in Canada? Repeat Steps 2-3 with the MAP. Note that cell values need to be scaled by a factor of 100 to convert to mm.

Take a screenshot of the final change in MAP layer (similar to above) and include in the final deliverables.

Q8: What is the minimum and maximum change in MAP across the entire raster (in units of mm)? What does a negative change in MAP indicate?

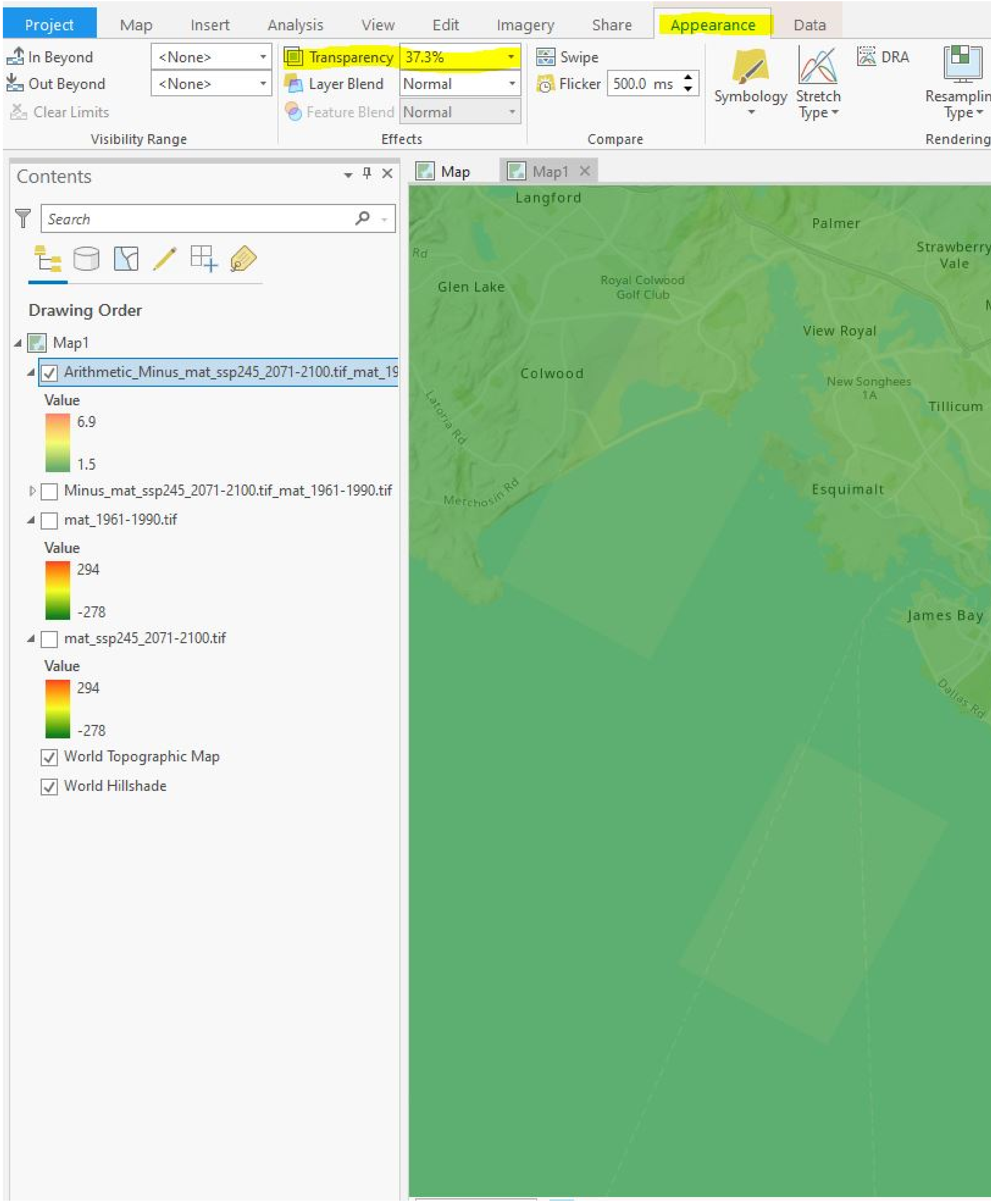
Q9: In 1-2 sentences comment on the pattern of change in MAP. Where are the greatest changes expected in Canada? Step 4: Now zoom into a place in Canada that is significant to you!

(Hint: you can adjust the transparency of the layers by clicking on them and navigating to the Appearance menu in the top ribbon > Transparency.

Turn on the change in MAT and MAP layers. Go to the Map tools on the top ribbon > Explore. Click on the map to open a pop-up window showing the lat/long of the point you clicked as well as the cell values from all the layers that are turned on in the Contents pane.

In the example below I have chosen Victoria, BC where the projected change in MAT is 2.7C.

For your chosen place, record the Lat/Long and the change in MAT and MAP. Include in your final deliverables.


Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Appearance
Data
In Beyond
Out Beyond
Clear Limits
<None>
<None>
Visibility Range
Transparency
37.3%
Layer Blend
Normal
Feature Blend
Normal
Effects
Swipe
Flicker
500.0 ms
Compare
Symbology
Stretch Type
DRA
Resamplin Type
Rendering
Contents
Search
Drawing Order
Map1
Arithmetic_Minus_mat_ssp245_2071-2100.tif_mat_19
Value
6.9
1.5
Minus_mat_ssp245_2071-2100.tif_mat_1961-1990.tif
mat_1961-1990.tif
Value
294
-278
mat_ssp245_2071-2100.tif
Value
294
-278
World Topographic Map
World Hillshade
Map
Map1
Langford
Palmer
Strawberry Vale
Glen Lake
Royal Colwood Golf Club
View Royal
Colwood
New Songhees 1A
Tillicum
Latoria Rd
Metchosin Rd
Esquimalt
James Bay
Dallas Rd

Step 6: For the place you chose in the previous step, discuss the following in 500 words or less:

-Describe the current and projected changes in MAT and MAP. What is the direction of change? How does the magnitude of change compare to other sites across Canada?

-Identify an environmental concern that could be intensified by the projected changes in climate. Is this region susceptible to wildfire? Flooding? Droughts? Why is this issue important? Use 1 peer reviewed source to back up your argument. (Provide the full citation for this reference at the end of the discussion).

-Briefly, what changes could help mitigate this concern? Is there a specific technology that could be developed or a change in lifestyle that you would like to see in the future?

Chapter 2

Geodatabases, data handling, and mapping

Written by

Lab Overview

The aim of this lab is to design and build a geodatabase, as well as organize spatial data within it. We will review tools for cleaning raster and vector data. Finally students will learn how to create and export a map using good cartographic principles.

Learning Objectives

- Learn how to design geodatabases based on topics and needs
- Familiar with building databases, organizing data, and linking data sets
- Create and export a map

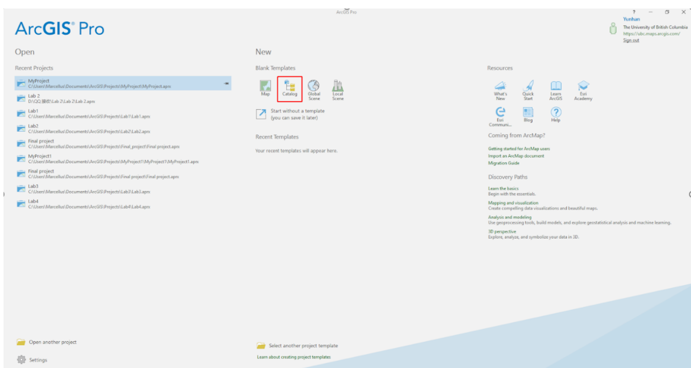
Deliverables

- Answers to 10 questions posted in the handout
- Map with good cartographic design

Task 1: Building a geodatabase and organizing data

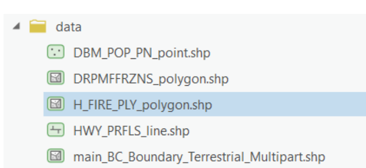
In this task, we will review what a geodatabase contains and learn how to design your own geodatabase based on project requirements and objectives in ArcGIS Pro. Geodatabases allow you to store many spatial data layers of different types in one place. You can edit data related to one project within a geodatabse and then easily share it with other people.

Step 1: Start ArcGIS Pro. Under the New header, select Catalog. Name the project “Lab2”. When ArcGIS Pro opens a new Catalog window, navigate to your Lab2 folder.



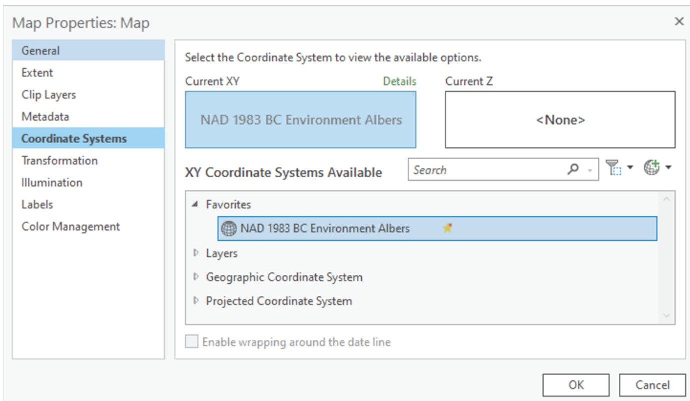
Step 2: Download the zipped (.zip) lab data from GitHub, unzip it, and move it into your Lab2 project folder, which by default is `C:\Users\YourUsername\Documents\ArcGIS\Projects\Lab2.`

Step 3: Open the Catalog pane by clicking View > Catalog Pane. Under the folders tab you should see the folder with your lab 2 project. You have six shapefiles in the data folder. Three different kinds of icons are shown in front of shapefile names. These indicate what type of data (point, line, or polygon) is stored within a shapefile. For example, the **DBM_POP_PN_points** shapefile is composed of points, the **HWY_PRFLS_line** shapefile is composed of lines, and the **main_BC_Boundary_terrestrial_multipart** shapefile is a polygon.

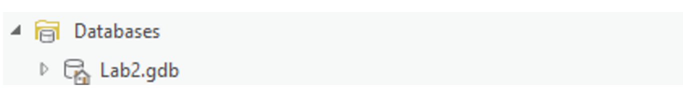


Step 4: Open a new Map. Under the Insert tab on the top ribbon, click New Map. Before adding any layer, you need to make sure that the coordinate system of the map gives an accurate projection of your study area. For this lab we will

focus on BC, so we will use the coordinate system that best reproduces BC. In the Map interface, right-click "Map" in the contents, select properties, and in the pop-up window, select Coordinate Systems. Change the coordinate system to **"NAD 1983 BC Environment Albers"**.

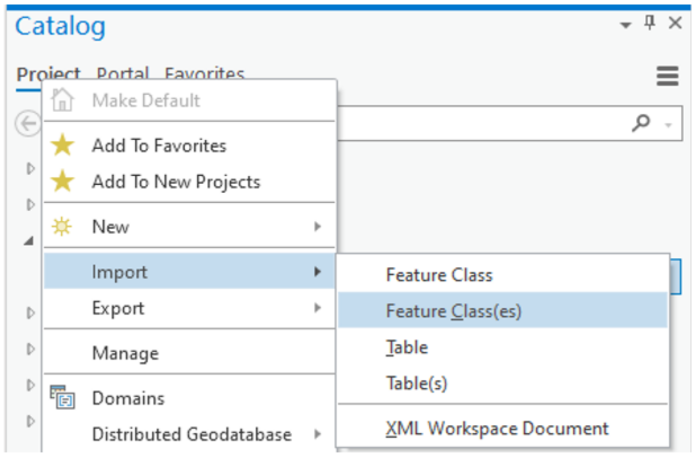


Step 5: By default, the Lab2.gdb geodatabase created with the new project is set as the "default geodatabase". This means that whenever you run a tool or search for data, ArcGIS Pro will automatically default to the location of this geodatabase unless you specify otherwise. If you navigate to Project > Databases in the Contents pane, you should see a geodatabase with a little house. The house indicates which geodatabase is set as the default geodatabase for the project. Only one geodatabase can be the default at any given time.

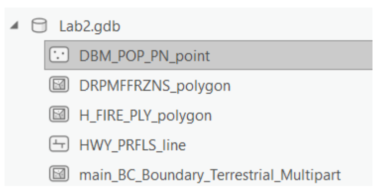


Next, we will import our data into the Lab2 geodatabase.

Step 6: Right-click the lab2.gdb in Catalog, select import, then select Feature Class(es). Click the folder button and navigate to the Lab 2 data folder and select each layer, then click "Run".



Once all the data is in the Lab2 geodatabase it should look like the following.



Step 7: Drag and drop all the data from the geodatabase to the map. You may notice that the names of these files are not in a uniform format, and some words may be abbreviated. This can cause some inconvenience when dealing with data from different sources. Therefore, it is necessary to format the data names to be processed uniformly to improve efficiency. In general, you can standardize the names of data according to your preferences and further explain the meaning of the names through a data dictionary or metadata.

You can rename layers in your map by right-clicking it in the Contents pane and selecting properties, then change the name in the general tab. Note that this does not change the name of the original data. Rename each of the layers to be more descriptive and for easier organization of your map.

When you name your data, it is good practice to use underscores (_) instead of spaces.

Q1: Based on the filenames and attributes of each layer, choose a name you think is most appropriate for each shapefile from the following list: Canada_Cities, Historical_fire, highways, BC_boundary, BC_fire_districts. Take a screenshot of the Catalog pane (right side of screen) showing your home folder and the Lab 2 geodatabase with all of the required layers

Task 2: Vector Data Processing

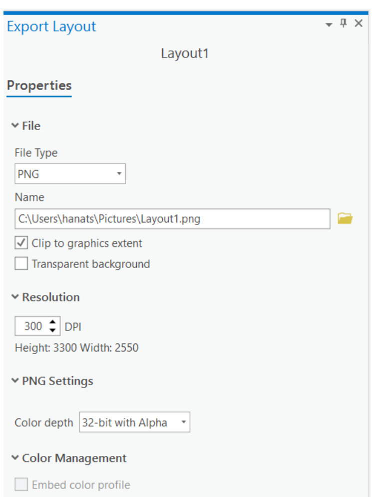
Step 1: Next we will practice processing vector data contained in the new geodatabase. It is good practice to copy and edit data within a geodatabase so that the original data does not get altered accidentally.

First, you will notice that the Canada_cities layer contains cities across all of Canada. We will clip this layer to the BC boundaries. On the top ribbon click View > Geoprocessing > search for the Clip tool. In the **Input Features or Dataset** field select the layer you want to clip. In the **Clip Features** field select the layer that you want to clip the input features to. Name the new layer **BC_cities** and save it to the Lab 2 geodatabse.

Q2: What layer did you use as the Input Features and Clip Features?
Step 2: Next, we will create a new shapefile of fires that occurred after 2010. Right-click on the "Historical_fires" layer in the Contents pane, select "Data" and then select "Export Features".

The first two lines in the opened dialog box are already filled in automatically. Name the exported file as "Historical_fires_2010". Then, select "FIRE_YEAR" in the drop-down list below, then select "is greater than or equal to", and select "2010". Click "OK".

A new point feature class appears in your geodatabase, which you may need to refresh to see. It is also automatically added to the contents pane, and you can right-click on it and select the attribute table to view the new data in detail.



Open the attribute table of the new 2010 fires layer. You can generate simple summary statistics for each attribute by right-clicking on a column > Statistics. You can also order attributes from largest to smallest by right clicking on a column > Sort Descending (Sort ascending sorts smallest to largest). Use these tools to answer the following questions.

Q3: How many polygons are included in the 2010 fires shapefile?

Q4: What is the most common cause of fire? How many hectares was the size of the largest fire?

Q5: What year had the most fires, and how many were there? We can also **Summarize** one attribute by another. Right-click on the **FIRE_YEAR** column in the Historical fires 2010 attribute table, then select **Summarize**. In the Field drop-down menu select **SIZE_HA** and set Statistic type to **Sum**. Click OK.

This will create a new attribute table at the bottom of the Contents Pane, that shows total burned area for each year in hectares.

Q6: What year had the highest burned area? How many hectares were burned? Step 3: Open the attribute table of the BC_fire_districts layer. The MFFRCNTRNM attribute (very helpfully named), contains the name of each administrative fire centre. In the next step, we will spatially join this information to the BC_Cities layer, so that each city has an attribute showing which fire district it is in.

Right click on the BC_Cities layer > Joins and Relates > Spatial Join. Set the fire districts layer as the **Join Features** and name the new feature class BC_cities_join. Set **Join Operation** to Join one to one. This will join one city to one fire district. Scroll through the **Match Options**. These determine how the target features are matched to the join features. Select **Within**, this will join cities with the fire district they are completely within. Click OK.

Q7: What fire centre and fire zone is the town of Merrit located in? Use the tools from this section to conduct your own analysis and answer the following questions:

Q8: Which fire centre instersects with the most fires from 2010 onwards? How many total fires were there? (HINT: Think carefully about the Join Operation and Match Options.)

Q9: Which fire centre had the highest total burned area in ha? The highest mean fire size? (Exclude the Null result, as this represents two fires that were mapped outside of the BC boundaries.)

Q10: Do you see any patterns in the total annual burned area between 1920 and the present day? Do some research and discuss what do you think could be driving these patterns. Include a Line Chart to support your answer. Answer in less than 200 words. (HINT: To answer this question first create a summary table, then review Lab 1 for instructions on how to create a Line Chart using the data from this table.)

Task 3: Create a map

In this task we will use the spatial layers we generated in the previous step to create a map showing good cartographic principles.

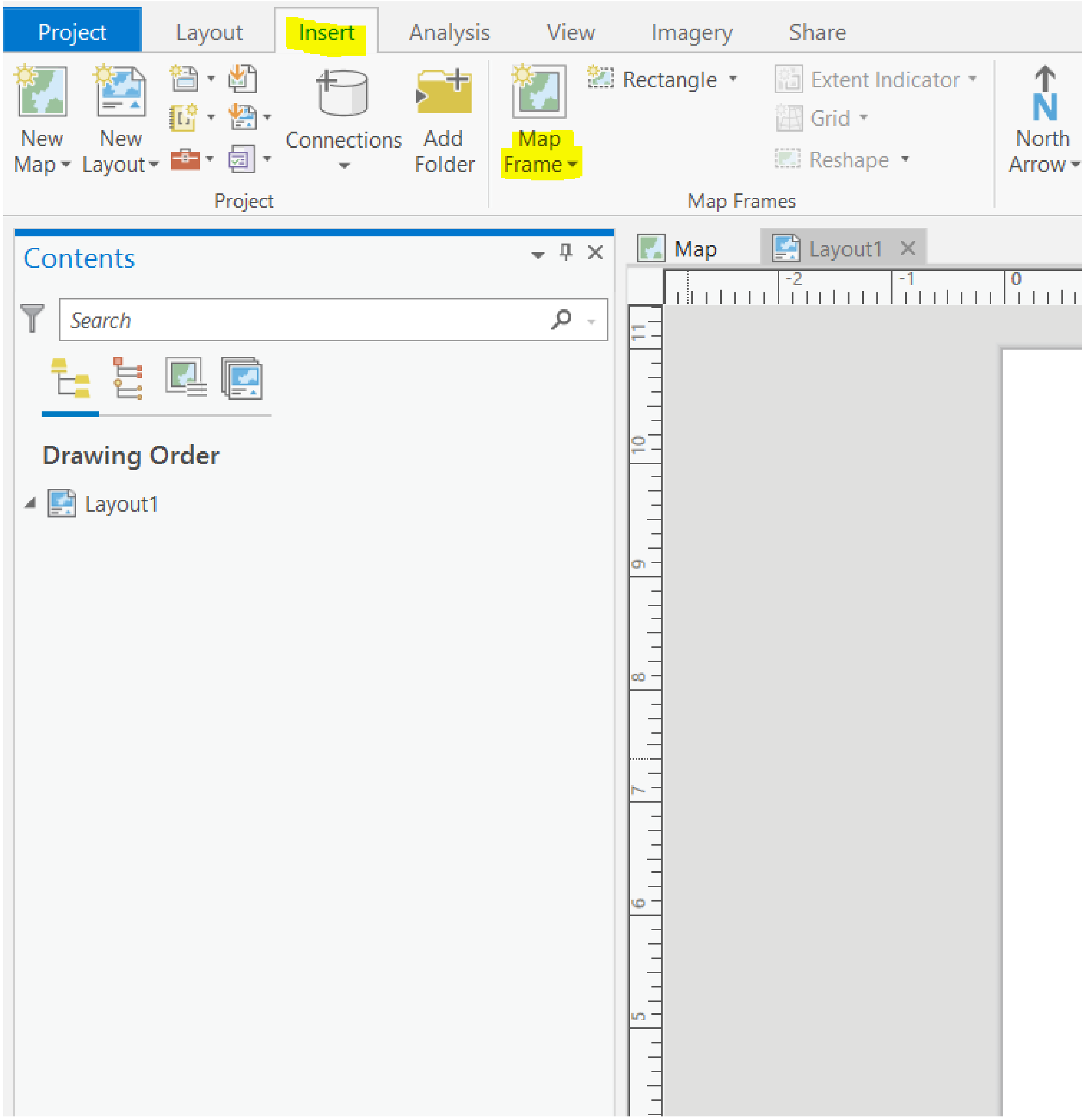
Step 1: First we will assemble all the required layers in the Map. Make sure you have the following layers loaded in the Contents pane (remove all other layers by right-clicking > Remove:

- Historical Fires (2010 onwards)
- BC highways
- BC cities

Change the symbology of the historical fires polygon so that fires are color coded by the **FIRE_YEAR** attribute. Choose an appropriate color scheme to show which fires are most recent. You may also change the symbology of the highwats and cities layers.

Next, change the basemap using Map (top ribbon) > Basemap. Experiment with the different options and pick one that is aesthetically pleasing to you.

Step 2: Once you have set the basemap and symbology for all the layers click **Insert** > **New Layout**. Then choose the size of the layout. For compatibility with most printers select **Letter 8.5x11**. This will open a new Layout window where you will construct your final map.



In the new Layout, select **Insert** > **Map Frame**. Select Map1, then drag and draw where the data will be displayed on the page. Leave room on the sides for latitude/longitude labels.

Once the map extent is drawn, you can zoom in/out and reposition the map within the map frame by right clicking on **Map Frame** in the Contents pane

> Activate. Adjust the Map Frame so that you can see the extent of BC. When you are done click the back arrow to go back to the layout.

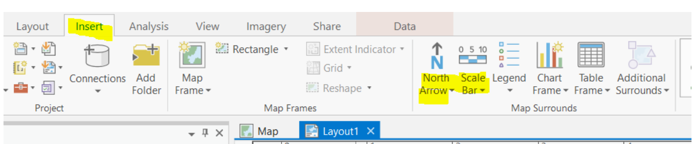
Step 3: Every map you create should have the following elements:

- Scale bar
- North arrow
- Legend
- Title

For this lab we will also include an inset map, although this is not always necessary.

Your final map will also be graded based on the clarity of the layout, so take your time to make a good looking map!

First, add a scale bar and north arrow in the Insert tab (top ribbon). Use the drop down arrows to select a style, you can also customize the map elements by right clicking on them in the Contents pane > Properties.

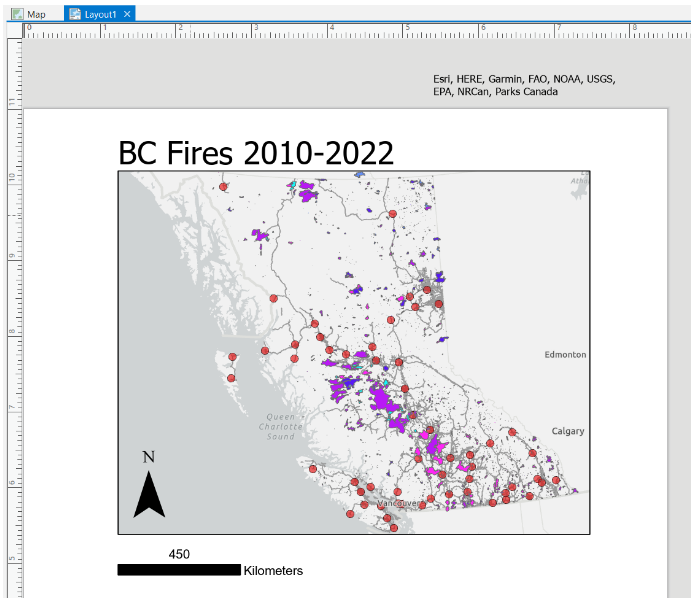


Open the scale bar properties and change the Map Units and Label Text from Miles to Kilometers. Examine the other options in this tab and experiment with changing font size, the color or the bar, etc.

Next, add a title using the add text button.

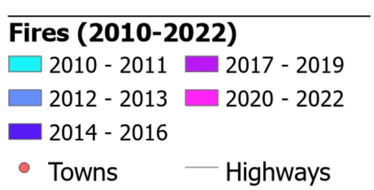
Next, we will remove the ESRI basemap credits from the map. ESRI does not let you remove them completely, but we can redraw them outside the layout so they don't get plotted. Insert > Dynamic Text > Service Layer Credits. Move the credits outside the layout extent.

Your layout should now look something like the following:



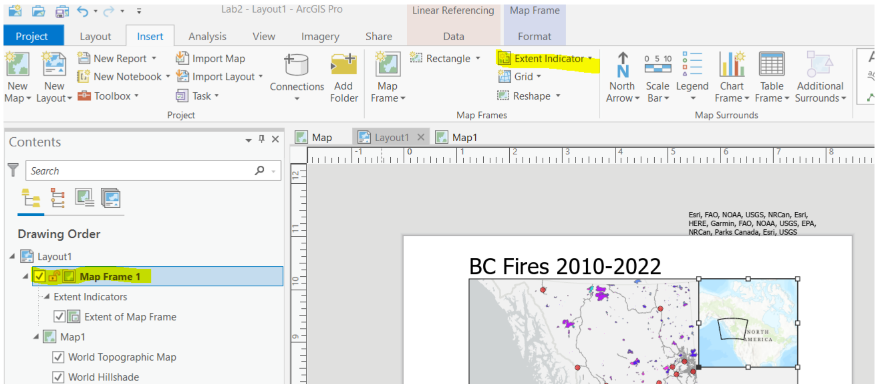
Step 4: Next, insert a legend. You can rename the items in the legend by renaming the layers in the Contents pane. Ensure all the layers are displayed in the legend and have descriptive titles. Open the Legend properties and experiment with the customization options. Here is a great resource for some of these options: https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/tips-and-tricks-for-working-with-legends-in-arcgs-pro/ Legend customization in ArcGis Pro can be confusing and unintuitive! If you are struggling to find the right box/menu to edit a specific part of the legend, you can right-click on the legend > convert to graphics. This will separate each part of the legend into editibale chunks, and can be helpful for adjusting text size of different headings and labels and for resizing elements of the legend.

Here is an example legend (note that yours does not have to look exactly the same):



Step 5: Finally, we will add an inset map to show where our data is in relation to the rest of Canada. Insert > **New Map**. Select a different basemap than the main map. Go back to the Layout , insert a new Map Frame and Select Map1. Rightclick on the new Map Frame 1 in the Contents > Activate. Re-position the inset map to show the extent of Canada.

Click on **Map Frame 1** then in the top ribbon select **Extent Indicator** > **Map Frame** (this is the BC fire map.) This will add a box on the inset map showing the extent of the BC fires data.



Step 6: You are now ready to export the final map! Go to **Share** on the top ribbon > **Export Layout**.

Save the map a PNG (easier to copy and paste in a Word document) or PDF in a folder you will be able to find. Make sure the Resolution is set to at least 300 DPI.

Include your map in the final deliverables.

Chapter 3

Spatial Overlay in QGIS

Written by Hana Travers-Smith

Lab Overview

Caribou are a keystone species in BC, and their presence indicates the health of boreal and mountain ecosystems. Habitat loss due to logging, mining, and climate change has led to significant population declines. Protecting caribou habitats helps preserve these ecosystems, supports the species' recovery, and protects important ecological services and cultural values.

In this lab you will practice using overlay tools in QGIS to explore caribou habitat availability in BC. You will learn about Structured Query Language (SQL) and perform a table and spatial join in QGIS.

Learning Objectives

- Become familiar with spatial overlay tools in QGIS
- Use Structured Query Language (SQL) to select features based on their attributes.

Deliverables

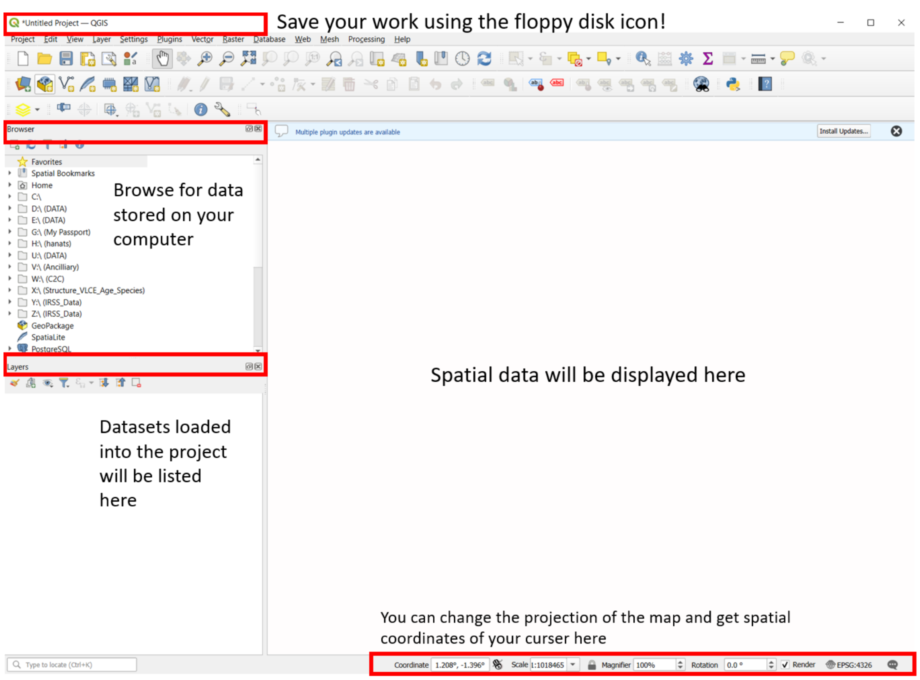
- Answers to questions posed in the lab handout

Task 1: Import Data

This lab introduces a new **open-source** software called **QGIS**. It has similar tools and operations as ArcGIS Pro, (which you used in the first two labs), but it is freely available to the public and does not require a paid subscription like ArcGIS Pro. Many consulting and NGO's prefer QGIS for this reason, so it is helpful to be familiar with how to use it!

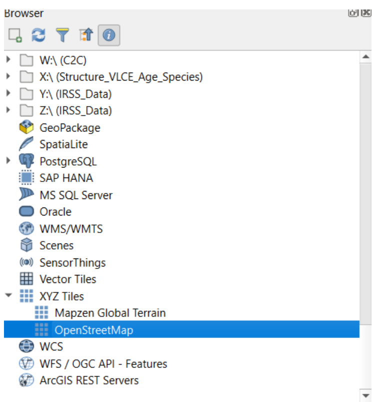
Step 1: Open QGIS and select "New Empty Project". To add data to the map use the **Browser** pane on the left to navigate to the directory on your computer where the lab data is saved. Your "Downloads" and "Documents" folders will be listed under the **Home** directory in the Browser. Double click on a layer to add it to the map.

Load the **Herds.shp** and the **Herd_area_forest.csv** datasets. Note that the Herd_area_forest dataset is not a spatial data set (it is just a table of attributes) - so it will not add spatial data on the map.

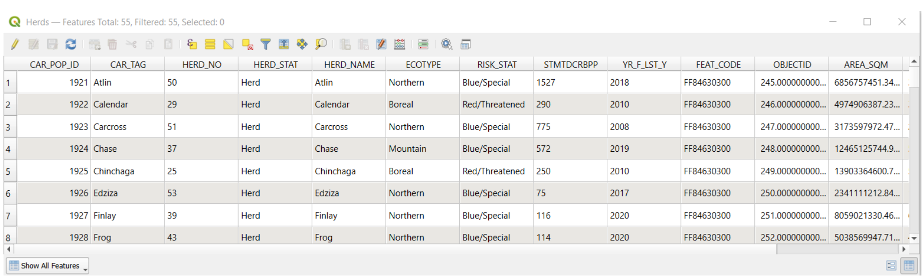


If you ever accidentally close the Browser or Layers panels you can reopen them from View > Panels > and toggling on the visible panels!

Step 2: Add a basemap by scrolling through the Browser panel and double clicking on **Open Street Map**. You may get a pop-up window asking which geographic transformation you want to apply to the basemap. Click the first one on the list > Okay. In the Layers panel you can change the order the layers plot in by dragging and re-ordering them. Put the basemap on the bottom and the herd layer on top. Practice zooming in and out and panning on the map.



Step 3: Open the **Herds** attribute table by right-clicking on it in the Layers panel > Open Attribute Table. Each polygon in this layer represents the range of a caribou herd. You can see attributes for things like the herd name, ecotype and risk status.



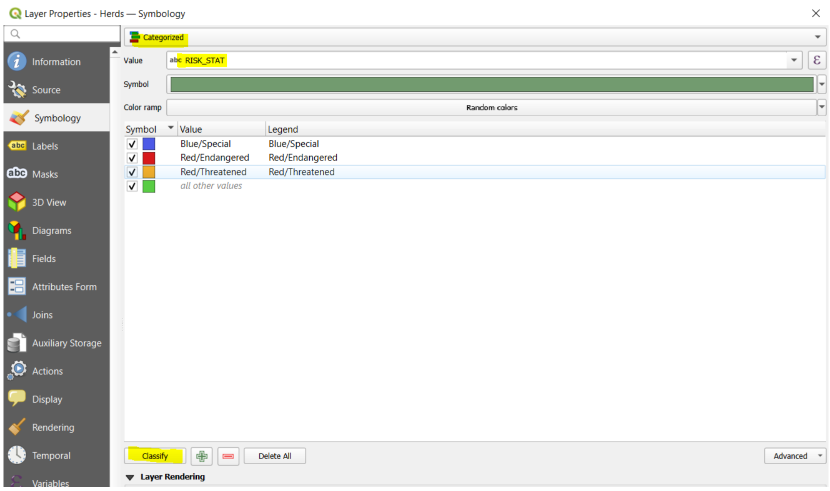
Herds — Features Total: 55, Filtered: 55, Selected: 0

	CAR_POP_ID	CAR_TAG	HERD_NO	HERD_STAT	HERD_NAME	ECOTYPE	RISK_STAT	STMTDCRBPP	YR_F_LST_Y	FEAT_CODE	OBJECTID	AREA_SQM
1	1921	Atlin	50	Herd	Atlin	Northern	Blue/Special	1527	2018	FF84630300	245.000000000...	6856757451.34...
2	1922	Calendar	29	Herd	Calendar	Boreal	Red/Threatened	290	2010	FF84630300	246.000000000...	4974906387.23...
3	1923	Carcross	51	Herd	Carcross	Northern	Blue/Special	775	2008	FF84630300	247.000000000...	3173597972.47...
4	1924	Chase	37	Herd	Chase	Mountain	Blue/Special	572	2019	FF84630300	248.000000000...	12465125744.9...
5	1925	Chinchaga	25	Herd	Chinchaga	Boreal	Red/Threatened	250	2010	FF84630300	249.000000000...	13903364600.7...
6	1926	Edziza	53	Herd	Edziza	Northern	Blue/Special	75	2017	FF84630300	250.000000000...	2341111212.84...
7	1927	Finlay	39	Herd	Finlay	Northern	Blue/Special	116	2020	FF84630300	251.000000000...	8059021330.46...
8	1928	Frog	43	Herd	Frog	Northern	Blue/Special	114	2020	FF84630300	252.000000000...	5038569947.71...

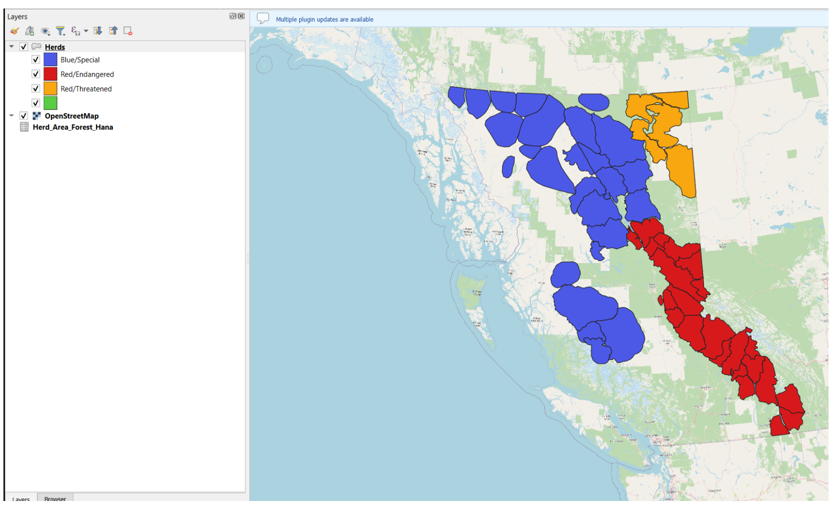
Show All Features

Q1) How many unique herds are there in BC?

Step 4: Next, symbolize the herds by risk status. Right click on the Herds layer > Properties > Symbology. hange the symbology type to “Categorized” and the value field to “RISK_STAT”. Click the “Classify” button to add the classes to the legend and adjust the colors as you see fit > OK.



Your map should look something like the following:



Step 5: Right-click on the Herds layer and navigate to **Information** in the Properties tab to answer the following questions:

Q2) What is the coordinate system of the data?

Q3) How many attributes (or fields) are in the dataset? How many attributes are a numeric data type?

Task 2: Join Tables

In this task we will join attributes from a table represented forested area to the Herds polygons.

Step 1: Right-click on the **Herd_Area_Forest** layer and open the attribute table. The attribute "Forest Area(Sqm)" represents the area of forests in m2 within each herd polygon. To perform a tabular join the two datasets both need to have a common attribute, or "key". A "key, indicates which rows from the first data set correspond to the rows in the second dataset. Rows that have the same value in the"key" will be joined together. In this case we will join the non-spatial tabular forested areas data to the herd polygons.

Inspect the attribute tables of the **Herd_area_forest** and **Herd** polygons.

Q4) What attribute could we use as a key to join these two datasets together?

Step 2: To perform a tabular join on the top ribbon navigate to Processing > Toolbox > Search for "join attributes by field value".

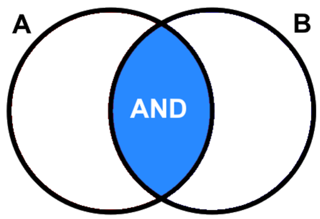
- Input Layer: **Herds**
- Table field: [input the key attribute from Q4 here]
- Input Layer 2: **Herd_area_forest**
- Table field: [key attribute]
- Join type: Take attributes of the first matching feature only
- **Run**

You should now see a new layer in the contents pane called "Joined layer". Open the attribute table and scroll through all the attributes - the information from the forested area dataset should be joined to each polygon feature.

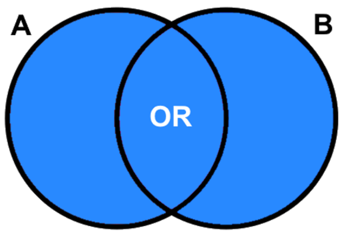
Task 3: Select Features Using SQL statements

The SQL statement is widely used in GIS to select target features. There are four basic conditional operators (i.e., Boolean operators): AND, OR, XOR, and NOT. Similar to the Set concept in mathematics.

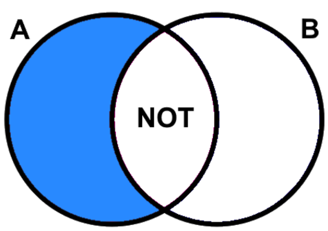
AND is an exclusive statement that needs the selected feature to meet both or multiple criteria to be passed. The tuple illustration for A AND B is listed below.



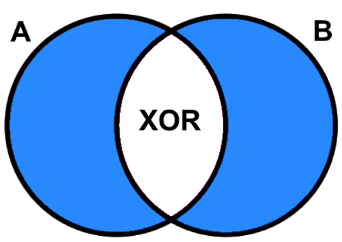
OR is an inclusive statement that will select all the features that meet any one of the criteria. As outlined in the shaded blue tuple, all the features that fall within this area will be selected (A OR B).



NOT is an exclusive statement. It is used to diminish the range of one desired characteristic. The tuple illustration for A NOT B is shown below.

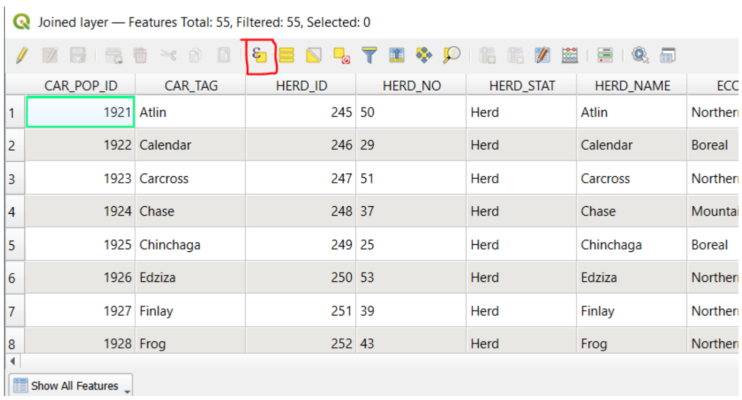


XOR is used to describe a relationship to exclude the common area in two tuples, but the areas that are true individually for both or multiple statements will be kept. (i.e. everthing but the intersection of A and B).



Step 1: Open the attribute table of the "Joined layer" polygon and click the "Select by Expression" button. (If you have closed QGIS between this task and

the previous task you may need to repeat the join operation with the forested area table).

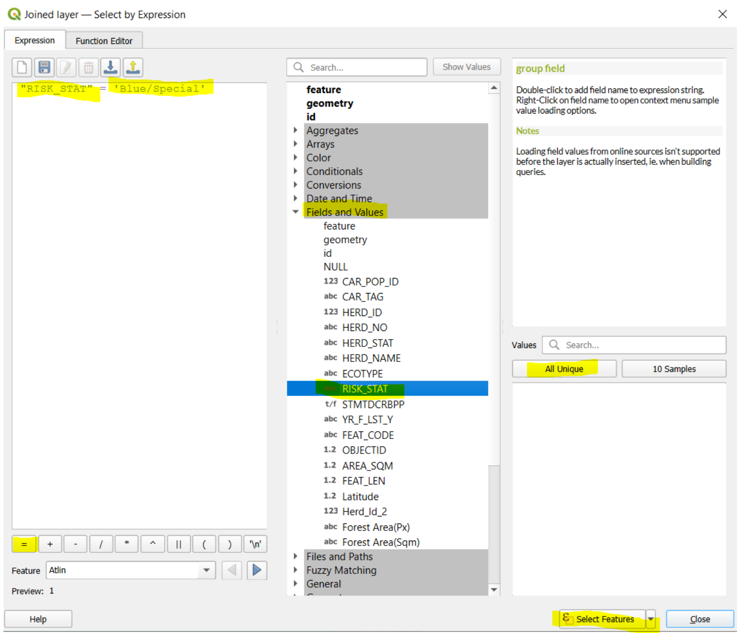

Joined layer — Features Total: 55, Filtered: 55, Selected: 0

	CAR_POP_ID	CAR_TAG	HERD_ID	HERD_NO	HERD_STAT	HERD_NAME	ECC
1	1921	Atlin	245	50	Herd	Atlin	Norther
2	1922	Calendar	246	29	Herd	Calendar	Boreal
3	1923	Carcross	247	51	Herd	Carcross	Norther
4	1924	Chase	248	37	Herd	Chase	Mountai
5	1925	Chinchaga	249	25	Herd	Chinchaga	Boreal
6	1926	Edziza	250	53	Herd	Edziza	Norther
7	1927	Finlay	251	39	Herd	Finlay	Norther
8	1928	Frog	252	43	Herd	Frog	Norther

Show All Features

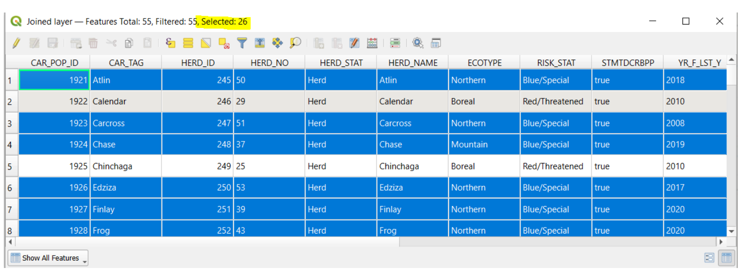
We will practice some basic queries using the attributes in the table. You can directly type a selection query into the Expression panel on the right or you can use the drop-down menus on the left to help build your queries.

Step 2: First, we will select the features where the RISK_STAT attribute is 'Blue/Special'. Expand the "Fields and Values" menu. Double click the RISK_STAT attribute - this will add it to the expression box on the left. Use the = sign button on the bottom (or type in in) to add the symbol to the expression. Finally, click the "All Unique" button to see the unique values of the RISK_STAT attribute and click *Blue/Special*. You should now see the completed expression on the left. > **Select Features**. The selected features should be highlighted in yellow on the map.



Notice the formatting style of the expression - the attribute RISK_STAT is enclosed in " " and the field value is enclosed in ' '. SQL statements must follow these formatting rules, otherwise you will get an error when you try and run the query. You can use the drop-down menus to select attributes, operators and values which will automatically apply the formatting for you.

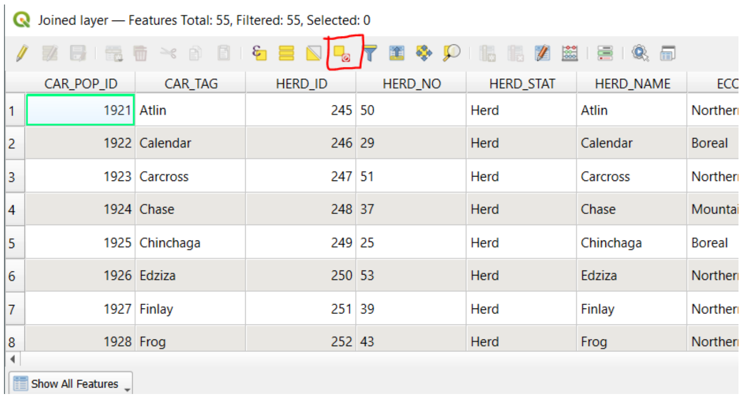
Step 3: Open the attribute table of "Joined layer" and notice that **26** polygons with 'Blue/Special' are highlighted.


Joined layer — Features Total: 55, Filtered: 55, Selected: 26

	CAR_POP_ID	CAR_TAG	HERD_ID	HERD_NO	HERD_STAT	HERD_NAME	ECOTYPE	RISK_STAT	STMTDCRBPP	YR_F_LST_Y
1	1921	Atlin	245	50	Herd	Atlin	Northern	Blue/Special	true	2018
2	1922	Calendar	246	29	Herd	Calendar	Boreal	Red/Threatened	true	2010
3	1923	Carcross	247	51	Herd	Carcross	Northern	Blue/Special	true	2008
4	1924	Chase	248	37	Herd	Chase	Mountain	Blue/Special	true	2019
5	1925	Chinchaga	249	25	Herd	Chinchaga	Boreal	Red/Threatened	true	2010
6	1926	Edziza	250	53	Herd	Edziza	Northern	Blue/Special	true	2017
7	1927	Finlay	251	39	Herd	Finlay	Northern	Blue/Special	true	2020
8	1928	Frog	252	43	Herd	Frog	Northern	Blue/Special	true	2020

Show All Features

Clear the selected features. Repeat the same query but this time use the "NOT EQUAL" operator `!=`. Now 29 polygons should be selected.



	CAR_POP_ID	CAR_TAG	HERD_ID	HERD_NO	HERD_STAT	HERD_NAME	ECO
1	1921	Atlin	245	50	Herd	Atlin	Norther
2	1922	Calendar	246	29	Herd	Calendar	Boreal
3	1923	Carcross	247	51	Herd	Carcross	Norther
4	1924	Chase	248	37	Herd	Chase	Mountai
5	1925	Chinchaga	249	25	Herd	Chinchaga	Boreal
6	1926	Edziza	250	53	Herd	Edziza	Norther
7	1927	Finlay	251	39	Herd	Finlay	Norther
8	1928	Frog	252	43	Herd	Frog	Norther

Step 4: Now we will combine two attributes in a query using the boolean (AND/OR/NOT) operators. Practice using the drop-down menus and typing directly into the expression panel to construct the following SQL statement: `"RISK_STAT" = 'Blue/Special' AND "Forest Area(Sqm)" > 3000000000`. (The AND operator and the > symbol can be found in the "Operators" drop-down menu below "Fields and Values".)

Q5: How many polygons are selected with this query?

Clear the selected attributes.

Step 5: Use what you have learned about SQL statements to answer the following questions:

Q6: How many herds are Endangered or Threatened? Include the SQL statement. (Hint: you will need to use the "RISK_STAT" attribute twice in your SQL statement)

Q7: How many herds with the Mountain ecotype are classified as Endangered? Include the SQL statement.

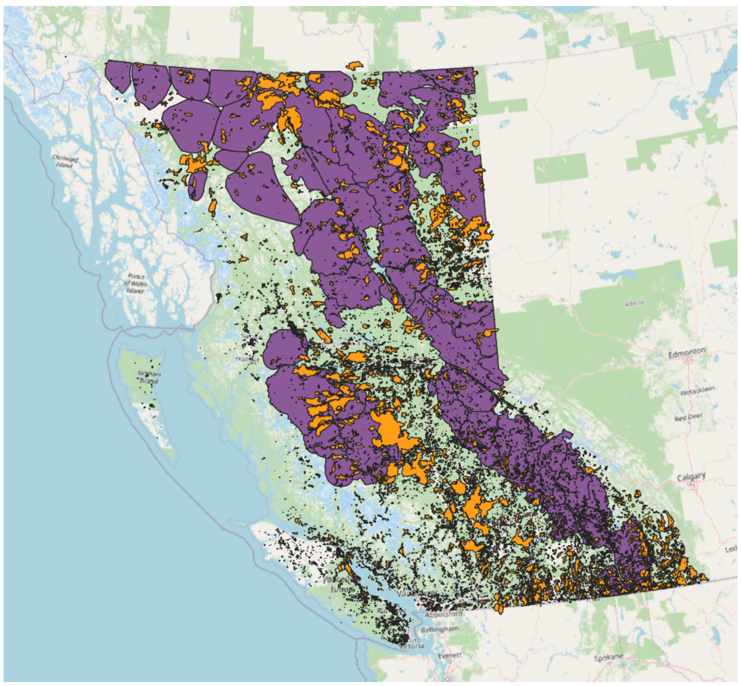
Q8: List the names of the herds in the Boreal ecotype with between 1000000000 and 5000000000 Sqm of forested area? Include the SQL statement.

Q9: How many herds have at least 5000000000 Sqm of forested area but are NOT Endangered or Threatened? Include the SQL statement.

Task 4: Data Analysis

In this task we will combine the herd polygons with spatial information of wildfire boundaries to understand which herds have experienced the most disturbance from wildfire.

Step 1: Load the wild fires polygon shapefile from **Lab 2** (fire_polys) and plot it on top of the caribou herds.



Step 2: We will use the **Intersection** tool to extract the overlapping area between the caribou herd boundaries and wildfire extents. The resulting layer will have attributes from both input layers.

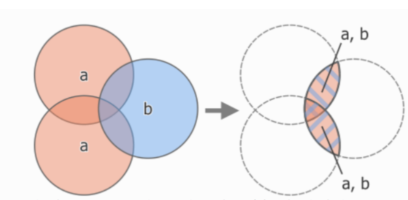


Fig. 28.124 *Intersection operation between a two-feature input layer 'a' and a single feature overlay layer 'b' (left) - overlapping areas become a new two-feature layer with both layers' attributes (right)*

https://docs.qgis.org/3.34/en/docs/user_manual/processing_algs/qgis/vectoroverlay.html

Search for the **Intersection** tool, Processing > Processing Toolbox.

- Input Layer: Herds

- Overlay Layer: fire_polys
- Leave defaults for all other options
- Hit Run. This operation may take several minutes.

At the end you should have a new layer called "Intersection". Turn off all other layers and inspect the output and its attribute table. Each polygon represents the area within the the caribou herds that **also** experienced fire.

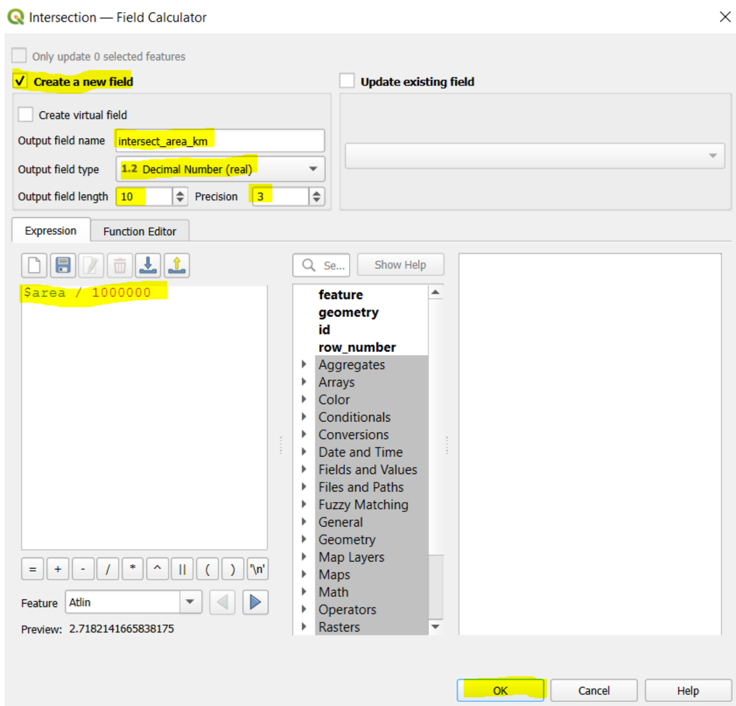
Notice that there are some attributes with duplicate names in both datasets (for example AREA_SQM and AREA_SQM2). The attributes from the caribou herds will be listed first and the attributes from the fire polygons will be listed second!

Step 3: Next we will calculate the area in km2 of each of the intersected polygons. Open the attribute table of the **Intersection layer** we just created.

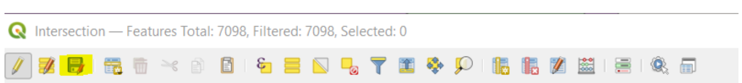
Click the "Field Calculator" button (it looks like an abacus).

We will use the $area command to calculate the area of each polygon - note that the default units are meters squared so we will divide by 1000000 to get km squared.

- Output field name: `intersect_area_km`
- Output filed type: Decimal Number (real)
- Output field length: 10
- Precision: 3
- In the Expression panel type: `$area / 1000000`
- Click OK.

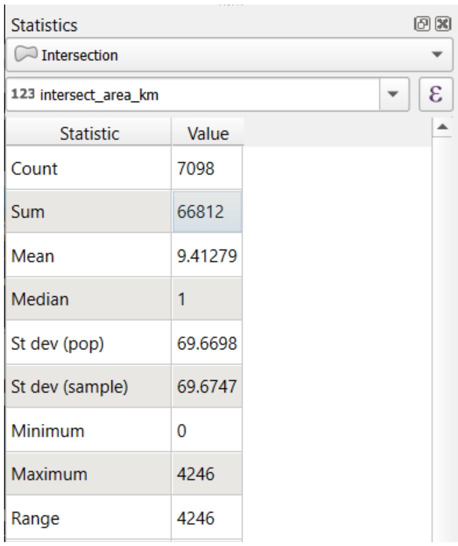


Click the "Save edits" button on the Intersection attribute table to save the new field.



Step 4: On the top ribbon click View > Statistical Summary to open the Statistics panel. We can use this tool to calculate summary statistics including the sum, mean, max and range for the features in our dataset.

Change the input layer to "Intersection" and the attribute to "intersect_area_km". You should now see summary statistics of the "intersect_area_km" field for all polygons in the dataset.



Statistic	Value
Count	7098
Sum	66812
Mean	9.41279
Median	1
St dev (pop)	69.6698
St dev (sample)	69.6747
Minimum	0
Maximum	4246
Range	4246

Q10: What is the total burned area within caribou herd ranges (report in km squared)?

Step 5: At the bottom of the Statistics panel check the “Selected features only” box. Open the “Intersection” attribute table and use the “Select by Expression” tool from previous Task to select polygons in the “Northern” herd ECOTYPE. The summary statistics should automatically update for the selected polygons.

Q11: What is the total burned area in the Northern herd ecotype?

Step 6: Use what you have learned about SQL statements and summary statistics to answer the following questions:

Q12: What is the total area of Endangered caribou habitat in km squared?

Q13: What is the total burned area of Endangered caribou habitat in km squared?

Q14: What proportion of Endangered caribou habitat was burned?

Chapter 4

Collecting and processing GNSS data

Written by Paul Pickell

Lab Overview

Oftentimes, you will need to collect and display your own data. There are many phone applications to collect your own GNSS data. In this lab, you will plan your own GNSS collection, collect data, and process the data.

Learning Objectives

- Learn how to plan for field data collection
- Use AvenzaMaps to collect GNSS readings
- Assess the accuracy and precision of GNSS coordinates

Deliverables

- Answers to 5 questions throughout the assignment
- Screenshots from the Timble Planning website
- A PDF map of your study area

- Pictures of your reference points in the field
- Screenshot of reference points and observed points in ArcGIS Pro

---

Task 1: Preparing for GNSS Data Collection

Field data collection is an important skill set to learn and practice. In this task, you will plan the collection of your GNSS data in a public park. The task for collecting GNSS data in a public park has nearly the same risks as if you collected the data on campus and you are expected to take similar precautions. This section is meant to inform you of the likely hazards and how to stay safe.

Planning Your Data Collection

Safety starts at the planning stage. When planning which park you will visit, consider somewhere nearby that is easily accessible by transit or walking. Avoid going somewhere that is unfamiliar to you. Ensure that you are visiting a public park and stay off of private or restricted property. You should only visit the park during daylight hours and plan to go out in sunny weather only. Check government websites for any recent animal sightings before you commit to going to your desired park. Do not plan to collect your GNSS data near bodies of water (e.g., oceans, lakes, ponds, rivers, streams). Do not plan to collect your GNSS data near cliffs or on steep terrain. Finally, ensure that you will have good cell phone coverage in case of an emergency.

Likely Hazards

At all times, you must be aware of possible hazards both overhead and underfoot. The main overhead hazard in a public park is going to be trees and falling branches. Do not collect your GNSS data during windy or stormy weather, which may cause tree branches to fall. Wet and slippery surfaces, steep angles, holes, logs, debris, and loose soil all pose fall hazards. Many of these hazards can be avoided with careful planning before you even step outside. Speaking of stepping, make sure you wear appropriate footwear, closed toed shoes are best for this work. Fauna are natural inhabitants of parks. Do not visit parks with recent sightings for large, predatory fauna such as bears or cougars. Even urban parks like Stanley Park in downtown Vancouver are known to have coyotes who have attacked people. As well, avoid areas with hazardous flora that may be thorny or poisonous. You may need to cross or transit streets to reach your park. Always follow local traffic laws and look for moving vehicles in and around your park. Always use designated crosswalks and do not look at your phone when walking near stopped or moving vehicles.

Do not collect your GNSS data while walking and looking at your phone. Always be aware of your surroundings.

Important: If you feel uncomfortable undertaking this task, please contact the instructor for alternative arrangements or accommodations for this particular assignment

All studies require a study area—for this lab, you will decide on your own study area through your own knowledge and simple remote sensing.

Your study area must:

- Be somewhere that you can legally and safely visit
- Be a park or a greenspace
- Have at least a portion of its ground visible using aerial imagery (e.g. Google Earth or an ArcGIS Pro basemap)

Step 1: Open ArcGIS Pro and turn on an imagery basemap (Map > Basemap > Imagery). Navigate to your proposed study area. You can do this by (a) dragging around your map, (b) putting coordinates into Go To XY, (c) typing in an address or park name into the Locate tool.

Before physically visiting your study area, you will need to verify that there are usable reference points in your chosen park. The reference points should be immovable, viewable from the sky and ground, and not tall (not trees or buildings). Additionally, you will be walking to your points – so they should be somewhere safely accessible and not too close or too far from each other.

Step 2: Find at least four possible reference points (all at least 10 m from each other). You will create a new shapefile and populate it with these reference points. In Geoprocessing, find the Create Feature Class tool by searching for "Create Feature Class". Save it to a findable location and give it a meaningful name (for this lab, it will be called "refpoints"). For the other options:

- **Geometry Type:** Point
- **Has M:** No
- **Has Z:** No
- **Coordinate System:** –Local UTM–
- Click **"Run"**

Your new shapefile should now be in the "Contents" Pane, but it has no points.

Choose Edit from the top ribbon, then select "Create." On the right, a "Create Features" pane will appear. In there, click refpoints, then select "Create a Point Feature." Zoom in closely on the basemap before creating point features so that the points are more accurate. Click on (at least) four reference points, then select "Save" from the Edit ribbon. If you need to Move a reference point, you can select Move from the Edit Tools.

Open the attribute table of refpoints and add three new columns: Name, East, North. Populate the columns for each reference point: Name – a unique name.

East – Easting. North – Northing. Easting and Northing can be populated using "Calculate Geometry." For more relatable measurements in your precision and accuracy assessment (Task 3), use your local UTM for the geometry. Be sure to save your edits.

Step 3: You will be exporting a georeferenced map of your study area. Zoom in (or out) to an extent that contains at least the entire park.

INCLUDE THE MAP IN YOUR FINAL DELIVERABLES - BE SURE TO INCLUDE THE FOLLOWING ELEMENTS ON THE MAP (10)

Elements to include on the map: - Reference points - Inset map showing location of study area within Vancouver - Scale bar, north arrow, legend, title.

Q1: Provide a description of each reference point - what is it?(2) Using the top ribbon, select Share > Export Map. A pane will pop up on the right-hand side of your screen. The file type is PDF, and make sure that it is saved somewhere you will be able to find it.

Toward the bottom of the pane, make sure that the box under "PDF Settings" that says "Export georeference information" is selected. Then select export. This will be used when you are collecting data with Avenza.

Step 4: Now that you have established a study area, you need to decide when you will be collecting your data. There are times in the day where you are more likely to get accurate GNSS readings. Find the coordinates of your study area so that you can use them in the Trimble GNSS Planning Online website (http://www.gnssplanning.com/).

Go to the Trimble GNSS Planning Online website and enter your study area's coordinates (one set of coordinates from anywhere within the study area) and elevation. If your coordinates are not in the proper units, either convert them to the proper units. Choose the day that you plan to visit your field site and collect data.

After you have input your information into Settings, click "Apply" and look through the other tabs (Satellite Library, Charts, Sky Plot, World View).

On the Charts tab take a screenshot of the Number of Satellites and Iono Information charts - INCLUDE IN FINAL DELIVERABLES (2)

Q2: Use these plots to determine the ideal time to collect GNSS points and briefly explain why. (2)

Task 2: Collect GNSS Data

You will need either an Android or iOS smartphone capable of installing the Avenza Maps App. If you do not have an Android or iOS smartphone, then please contact the instructor for alternative arrangements or accommodations

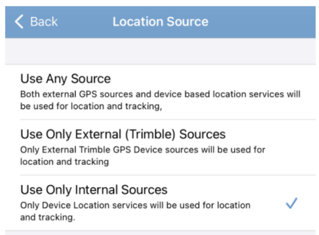
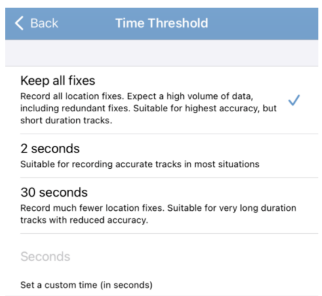
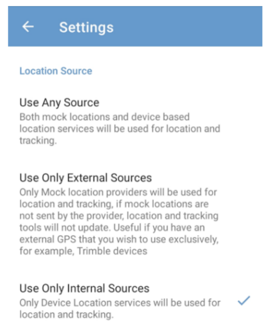
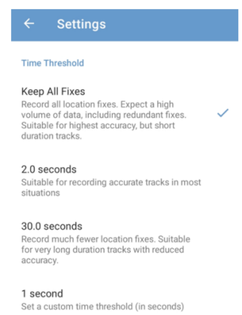
Step 1: To start you will need to install Avenza Maps App on your phone. There is an Android version as well as an iOS version so just go to your app store and download it. It's free!

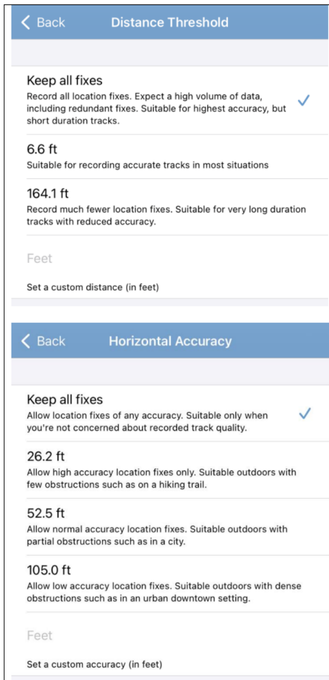
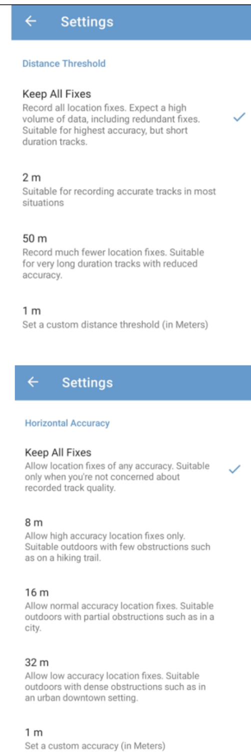
Step 2: Once you have the app installed on your phone, you need to sign up for a free account. If you have concerns about your privacy, you can use a pseudonym and your student UBC e-mail address.Avenza Maps is a widely used mobile mapping application, so chances are you might continue to use it in the future for other projects or hobbies. If you want to ensure future access to your Avenza Maps account and assets, then choose an e-mail account that you will continue to have access to (i.e., not your UBC student e-mail).

Step 3: Now that you are registered and logged in, you will change some settings in the Avenza Maps app. Navigate to the Settings in the bottom right corner (for iOS) and in the top right corner (for Android). Scroll down and click "GPS settings". Use the following settings:

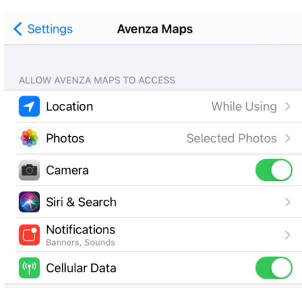
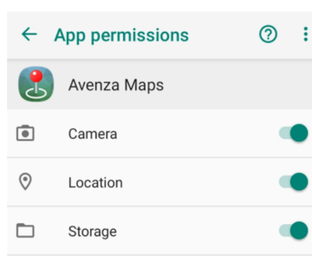
- **Location Source:** "Use Only Internal Sources". This ensures that we are only using the phone's internal GNSS receiver.
- **Horizontal Accuracy:** "Keep all fixes"
- **Distance Thresholds:** "Keep all fixes"
- **Time Threshold:** "Keep all fixes"
- **Ignore Suspicious Fixes:** Toggled Off

Next, we will set the units to metric. In Settings, navigate to "Units of Measurement" and select "Metric" at the top. Under "Coordinates", ensure that the "Format" is set to a workable coordinate system.

Your <u>Avenza Maps App Settings</u> should look something like below	
iOS	Android
 	 

Step 4: Ensure that the Avenza Maps App is allowed to access your location, camera, and photos in your *phone's settings.*

Your Phone Settings for the Avenza Maps App should look something like below	
iOS Settings > Avenza Maps • **Location:** "While Using" ○ **Precise Location:** Toggled On • **Photos:** "Selected Photos" • **Camera:** Toggled On 	Android Settings > Apps (sometimes Apps & Notifications, or something similar) > Avenza Maps Permissions: Camera, Location, and Storage 

Important: Personal location is very sensitive information. You should not undertake this exercise at your home or share the coordinates or screenshots of *your home location in Avenza Maps with anyone, including the instructor, TA, or other students in this course. Treat personal location information as any other private sensitive information and handle with respect and care.*

Step 5: Avenza Maps requires you to load a map before being able to use the location service of your phone. You will import the georeferenced PDF map that you created in Task 1. There are several ways to do this in Avenza Maps, but probably the easiest is to download the PDF to your phone and then import directly from your phone. *Be aware that map size can be large and will consume cellular data if you are not connected to a wifi network.* A video on Canvas shows how to accomplish this on iOS using an iPhone and an example georeferenced map of the world.

If you ran into problems creating your georeferenced PDF, then you can use the provided georeferenced PDF on Canvas for the world. In the end, the actual map that you use is not important for collecting your GNSS data, but Avenza Maps requires a georeferenced map be loaded in the app.

Step 6: Travel to your study area!!! Open the Avenza app, and select the Georeferenced PDF under "My Maps." Go to one of the reference points you selected in ArcGIS. On the bottom right of the app, there is a button that will bring the map to your current area. Press that button, then press the placemark button directly to the right of it. Create a placemark and name it something meaningful (for example: placemark 1, location 1). Stay exactly where you are, and create a placemark every 10 seconds for the next minute by pressing the location button then the placemark. You should have a total of 6 placemarks. Take a picture of the area you are trying to geographically capture. Go to two more of your designated locations and do the same procedure (create 6 placemarks, each 10 seconds apart, and take a picture.

INCLUDE PICTURES OF ALL YOUR REFERENCE POINTS (IN THE FIELD) WITH YOUR FINAL DELIVERABLES (3)

Step 7: Now you can return back to your workstation (after taking a nice walk!). In Avenza, go back to "My Maps," then select Layers (at the bottom). Select the layer you created, then the icon with three lines at the bottom right. Choose export layers. Export the layer as a KML by pressing the EXPORT option at the top right. A list of export applications should pop up—choose whichever one you would prefer.

Step 8: Find your exported file and bring it into ArcGIS Pro. You can drag and drop it from the Catalog Pane into the main map. From there, you should export the kml file to layer using the tool "KML to Layer."

Task 3: Assess Precision, Accuracy, and Possible Errors

For this lab, we will consider the initial ArcGIS-created reference points as the "true" values and perform an accuracy assessment with that in mind.

Step 1: Visually compare the Avenza-created Placemarks (called "Observed values" for the rest of the lab) with each other and ArcGIS reference points. How close/far are they from one another? You can use the measure tool to add values to this visual assessment.

TAKE A SCREENSHOT OF YOUR REFERNCE POINTS AND OBSERVED POINTS IN ARCGIS PRO AND INCLUDE IN YOUR DELIVERABLES (5)

When you are comparing the observed values Page 10 of 12 to each other, you are assessing **precision**, when you are comparing them to the "True" locations, you are assessing **accuracy**.

Step 2: Quantitatively determine the accuracy of the points. Add two columns in the Observed attribute table and populate them with the east and north values for each point using the Calculate Geometry tool. You should have the True east and north values from your reference points attribute table.

Export both tables as a CSV and bring them into excel.

In excel, we will calculate the horizontal accuracy for each placemark using the following equation:

$$\sigma_{H_{acc}} = \sqrt{(\overline{E} - E_{true})^2 + (\overline{N} - N_{true})^2}$$

Excel is a convenient place to use this equation. Breaking down the equation – get the mean observed East value, then subtract the "True" East value. Square this difference. Do the same for North. Add the north and east results, then take the square root of them. In excel, you can do this with the equation:

```
=SQRT((average(observed east values)-true east value)^2+((average(observed
north values)-true north value)^2))
```

The resulting value represents how accurate the GNSS measurements were – a lower value represents greater accuracy.

Q3: Is there a noticeable difference in accuracy between your placemarks? Why do you think this is? (3) To assess the precision, you will use the following equation:

$$\sigma_{H_{pre}=\sqrt{\sigma_E^2+\sigma_N^2}}$$

Calculate the standard deviation of the observed East and North values, square them, then add them and take the square root of the sum. In excel, you can do this with the equation:

```
=SQRT((STDEV(observed east values)^2 + STDEV(observed values)^2))
```

The resulting value represents how precise the GNSS measurements were – a lower value represents greater precision.

Q4: Is there a noticeable difference in precision between your placemarks? Why do you think this is? (3)

Q5: In 300 words or less, discuss potential errors and what may have affected accuracy and precision – be sure to reflect on the validity of the "True" values. (10)

Chapter 5

Remote Sensing Imagery Analysis

Written by Nicholas Coops

Lab Overview

The aim of this lab is to learn about the electromagnetic spectrum (EMS), understand spectral properties of different surfaces, and get comfortable using ArcGIS Pro to load and explore different types of remotely sensed images, display individual spectral bands, make different colour composites, and view spectral signatures. In addition, you will calculate two difference spectral indices representing built up areas and green vegetation.

Learning Objectives

- Understand the electromagnetic spectrum
- Use Landsat 5 spectral reflectance to map vegetation and urban areas
- Analyze spectral signatures of different land cover types

Deliverables

- Answers to 17 questions throughout the handout

- A map of reclassified urban/vegetated land cover

Data

We will be working with a multispectral image of Vancouver from the Landsat 5 satellite **(LT05_047026_20000823_subset.tif).**

Task 1: The EMS

The **electromagnetic spectrum (EMS)** is the distribution of electromagnetic radiation according to wavelength/frequency, and includes radio waves, visible and infrared light, x-rays, gamma rays, and more. In remote sensing, we use the reflective, absorptive, and emissive properties of terrestrial features to identify and measure them (i.e. how do different wavelengths in the EMS interact with the surface of the Earth?).

Note: It is important to recognize that the **visible** part of the EMS is the only section that humans can see. ***All colours in the visible spectrum are wavelengths, but not all wavelengths in the EMS are colours.***

Spectral Reflectance

Figure 1 shows the reflective characteristics of various features of the earth's surface. Use this figure to answer **Q1 − Q4.**

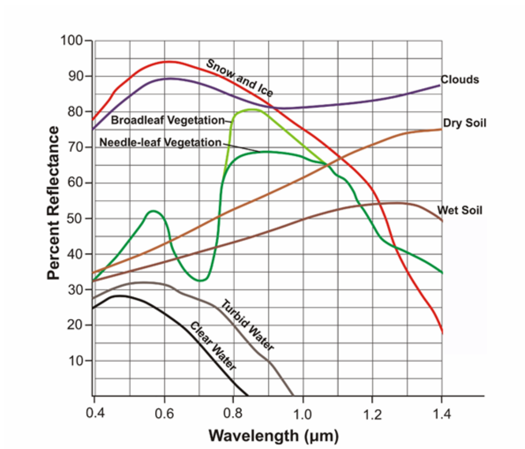


Figure 1: Reflectance characteristics of various features at different wavelengths.

Q1. For broadleaf and needle-leaf vegetation, what is the approximate wavelength that is reflected most, and what section of the ems does this range belong to??

Q2. TRUE/FALSE. Do soil and vegetation reflect roughly the same proportion of blue light.

Q3. Give a wavelength (in microns) at which snow and ice, dry soil, and vegetation are indistinguishable by their reflectance. In other words, at which wavelength is the proportion of radiation reflected the same (+/- 10%) for these features?

Q4. Broadleaf and needle leaf vegetation reflect the same amount at 0.7 microns. What causes this? Is there something contained in the foliage of both types of vegetation which causes identical spectral signatures? How does this pattern in spectral reflectance affect how we see live vegetation?

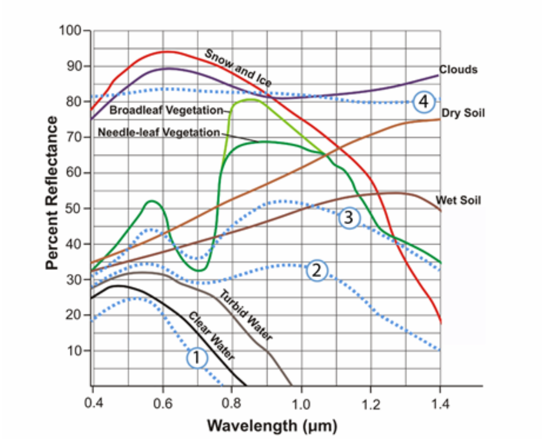


Figure 2: Reflectance characteristics of unknown features.

Q5. Figure 2 contains 4 additional spectra, belonging to unknown surface features. Hypothesize about what these spectra might be and provide your reasoning. Use the known features (broadleaf vegetation, wet soil, etc.) and what you have learned from class/readings to inform your choices. This is a difficult task, and educated guesses are all that is asked for. Do a bit of research, put some thought into it, and explain the reasoning for your guesses. These spectra do not represent the features which are already labeled. You must think of new features which could be observed with remote sensing.

Task 2: Landsat 5 Bands, the EMS & ArcPro Software

Table 2: Parameters of Landsat 5's Enhanced Thematic Mapper (ETM+) sensor

Band	Wavelength Range (microns)	Spectral Region	Spatial Resolution (meters)	
1	0.45-0.52	Blue	30	Coas
2	0.52-0.60	Green	0	
3	0.63-0.69	Red	30	
4	0.76-0.90	Near Infrared	3	
5	1.55-1.75	Middle Infrared	30	Vegetation a
6	10.40-12.50	Thermal Infrared	60	Thermal
7	2.08-2.35	Middle Infrared	30	

Q6: Each pixel of landsat's thermal infrared band (band 6) covers _____ pixels of the other bands. If it helps, draw a picture of the two pixel resolutions.

Q7: Band 6 is recorded with a coarser resolution because thermal radiation has a very _____ wavelength. Therefore, there is _____ energy available to sense. Step 1: Starting ArcGISPro

To start the lab, Open a new ArcPro map project and open the the L5057026subset_19990922_7B.dat file into the map window. At this point, you should see an RGB satellite image of the city of Vancouver (Figure 3) if the mapview does not immediately pan to the image right click **L5057026subset__19990922__7B.dat** in the Contents pane and press Zoom to Layer .

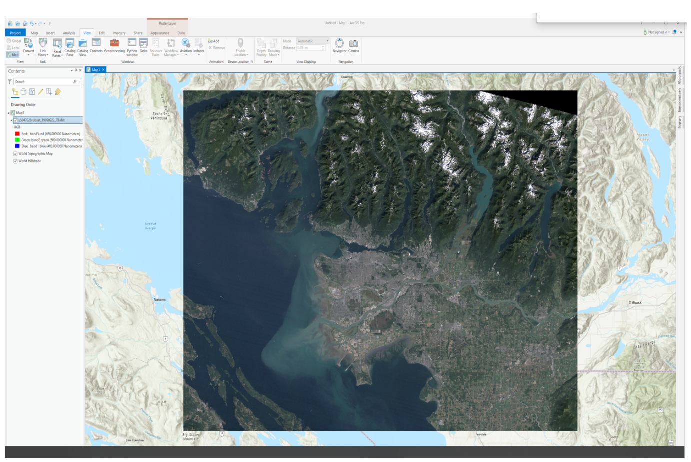
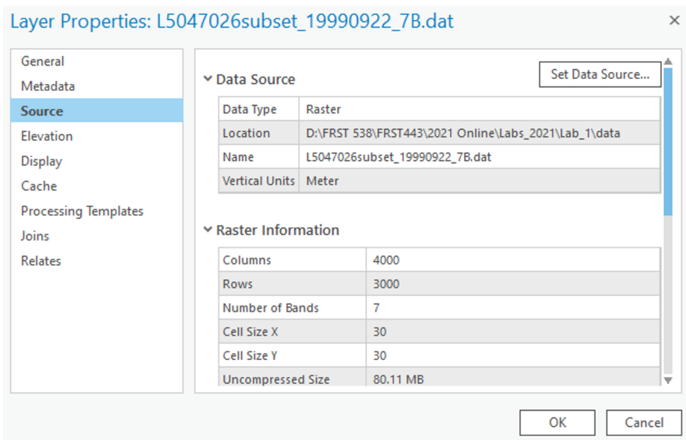


Figure 3: True colour composite of Vancouver.

Step 2: Exploring the data

It is now time to explore your imagery. Right click the box beside the **L5057026subset__19990922__7B.dat** file in the Contents pane and select "Properties". Use the menu on the left-hand side and select the Source page and the Raster Information drop down.



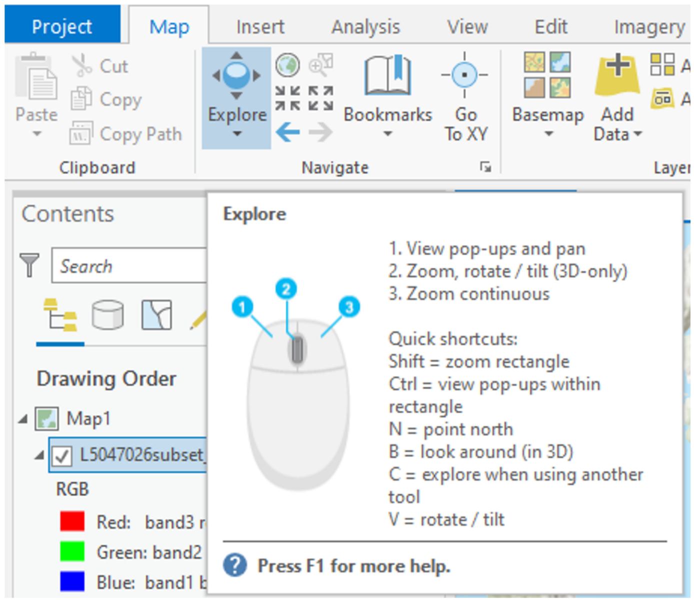
After clicking on the Raster Information, the tab should open up, and display important information about the image, such as dimensions (number of pixels in the X or Y directions), data types, projection, and resolution (listed as Projection/Pixel). This information can be useful when examining an image!

From the **Raster Information** you can see that the spatial resolution of this image is approximately 30 m by 30 m, square. That means that each pixel in the image represents an area of approximately 30 x 30 m on the ground, or 900 square meters. Furthermore, it is a Landsat 5 Thematic Mapper image of Vancouver and its surroundings taken at 22 September 1999 - Wow! Even more details are apparent – its size is 4000 by 3000 pixels, and has seven bands.

Scroll down and press on the **Spatial Reference** to see the projection information.

We will now use ArcGIS pro to zoom and pan our image.

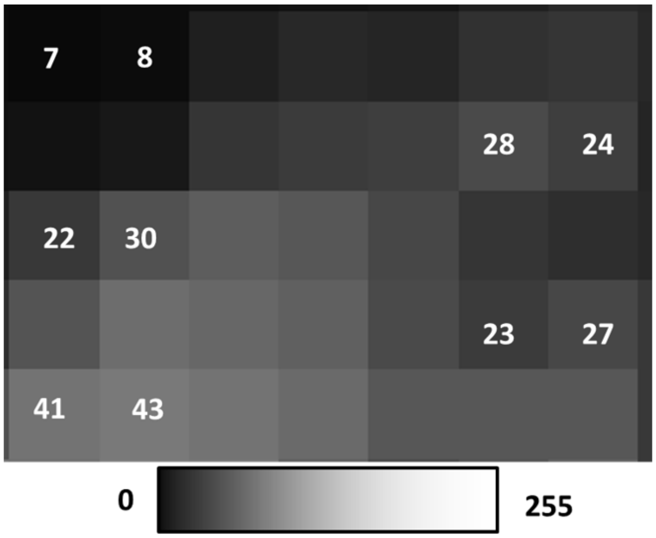
Notice the **Map** ribbon at the top, navigate to it and hover you mouse of the **Explore** tool:



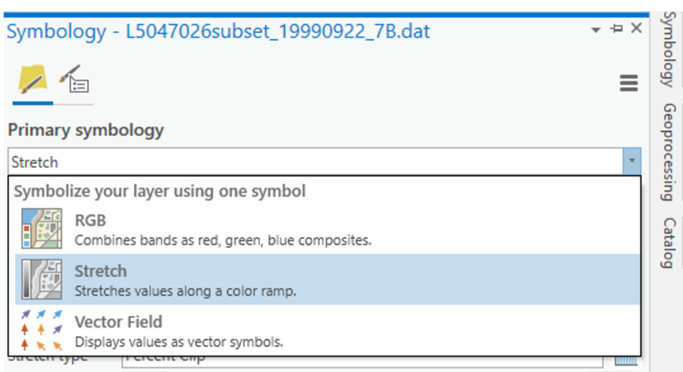
Use these controls to zoom in and out of the image and to pan around, try to zoom into the Fraser estuary and navigate upriver. Included in the Navigate pane there are also the fixed zoom tools the previous extent arrows and the small globe which will zoom to the full extent of your data.

Step 3: Displaying Greyscale, True Colour, & False Colour Imagery

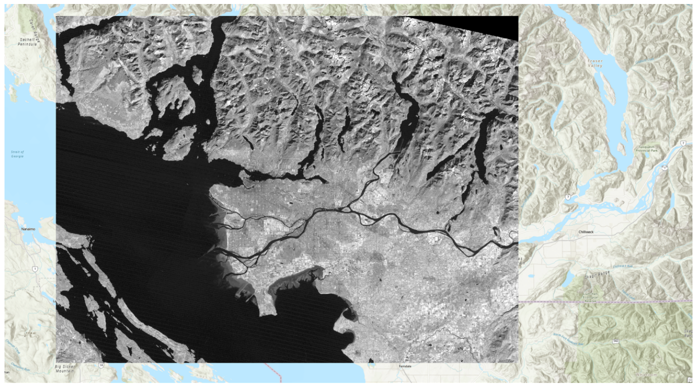
Traditionally, single bands of imagery are shown in greyscale, with dark areas shown in black, and light areas shown in white, with anything else shown in shades of grey. Think of each pixel representing a number between 0-255 (byte data type range, the same one of this very imagery!), with areas colored pure black representing the number 0, and areas colored pure white representing the number 255, and everything else is a shade of grey increasing in lightness from 1-254. The figure below displays this concept.



Right click on you data in the Contents pane and select “Symbology”. The symbology pane should appear on the side of you window. Press the drop down menu and select “Stretch”.



In the next dropdown menu labeled “Band” select “Band 4 NIR” you should see the same image as below.



You have now displayed a single band of greyscale imagery. Pixels that are bright/light/white have high amounts of light being reflected back to the sensor in this section of the EMS. Pixels that are dark/black have high amounts of absorption in this section of the EMS. Behind the shades of grey are actual numeric values indicating how much reflected light the sensor detected (from 0-255), that indicate what shade of black/grey/white should be shown. This is a critical component to understand about remote sensing data sets.

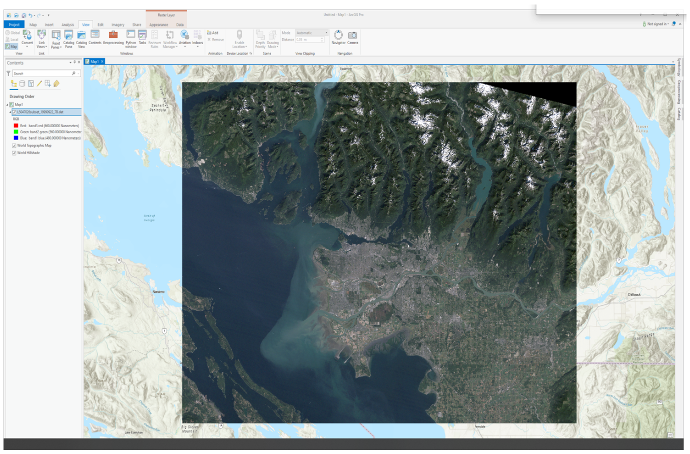
When more than 1 spectral band is available for a given image (like the Landsat data provided), colours can be used for visualization. Computer monitors display visible light as combinations of red, green, and blue using the RGB colour model.

Remember that the colours we see are also a wavelength in the EMS. e.g. Red – 660 nm, Green – 560 nm, Blue – 480 nm

In a true colour image, the computer display visualizes objects the way we see them in real life. In other words, in a true colour image, Landsat band 1 (Blue – 480 nm) is displayed as blue, band 2 (Green – 560 nm) is displayed as green, and band 3 (Red – 660 nm) is displayed as red.

Any combination where this is not the case is a **false color composite**, where the colours chosen to visualize the data are not true to life, i.e. Landsat band 1 (Blue – 480 nm) is displayed as red, band 2 (Green – 560 nm) is displayed as blue, and band 3 (Red – 660 nm) is displayed as green. Visualizing wavelengths outside of the visible spectrum (Landsat bands 4-7) automatically apply as false colour composites. False colour composites are necessary because many remote sensing devices can measure a broader range of wavelengths than humans can see. As a result, in order to display these data visually for humans, they must be displayed using a part of the spectrum that humans can see (Red, Green, Blue).

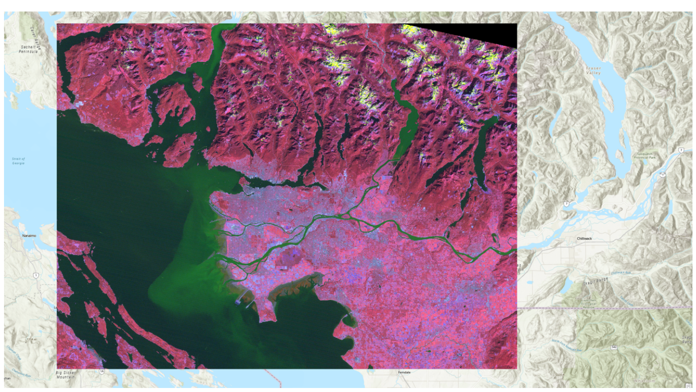
In the Symbology pane navigate back to “RGB” in the first dropdown list. Your image should change back into a True Colour Landsat image where band3 red is visualised as red, band 2 green is visualised as green and band1 blue is visualised as blue.



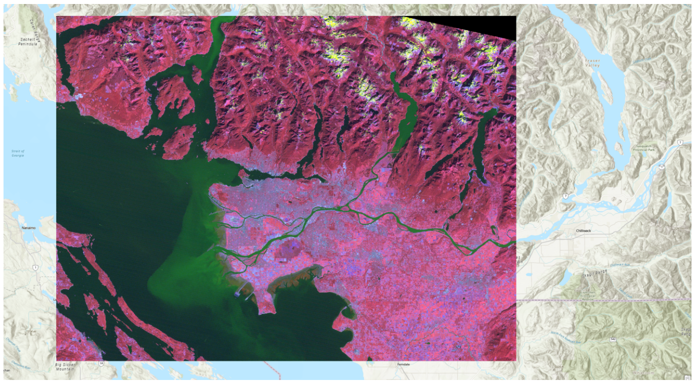
By displaying false colour composites it is possible to display many band combinations of the image on our screen. This time you will create a false colour composite by selecting different wavelengths (bands) to be visualized using red, green and blue colours.

In the Symbology pane under their respective drop done lists visualize the following band combination.

Band 4 using Red Band 2 using Green Band 7 using Blue You should see the following:



You can experiment with different band combinations by visualizing different bands using Red, Green and Blue. A standard false colour composite, for instance, has Band 4 visualized using Red, Band 3 visualized using Green and Band 2 visualized using Blue, as shown below:



Right click the bands in the Contents pane, turn different layers on and off by clicking the check mark off and on in the IsVisible section. Zoom and pan around and investigate different areas of Vancouver that you may know. Feel free to use google maps or google earth to help you orient yourself.

Q8. IIn a standard false colour composite healthy vegetation appear ________. Vegetation is more reflective in the ________ part of the spectrum than in the green part of the spectrum, so ________ appears brightest

Q9. Experiment with many different false colour composites. Which 3 bands would you combine if you wanted to analyze vegetation? Do some light research on spectral properties and the applications of different landsat bands and write a sentence or two justifying each of your choices. Then, append a screenshot of your chosen composite to your response.

Q10. Experiment with many different false colour composites. Which 3 bands would you combine if you wanted to analyze water quality? Do some light research on spectral properties and the applications of different landsat bands and write a sentence or two justifying each of your choices. Then, append a screenshot of your chosen composite to your response.

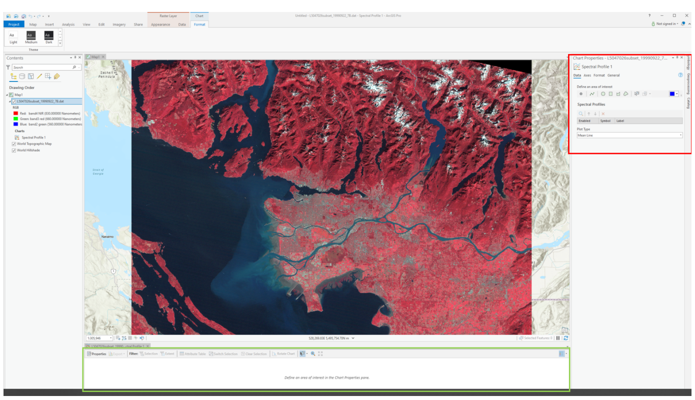
Q11. Experiment with many different false colour composites. Which 3 bands would you combine if you wanted to analyze agriculture? Do some light research on spectral properties and the applications of different landsat bands and write a sentence or two justifying each of your choices. Then, append a screenshot of your chosen composite to your response.

Q12. Experiment with many different false colour composites. Which 3 bands would you combine if you wanted to analyze urban areas? Do some light research on spectral properties and the applications of different landsat bands and write a sentence or two justifying each of your choices. Then, append a screenshot of your chosen composite to your response.

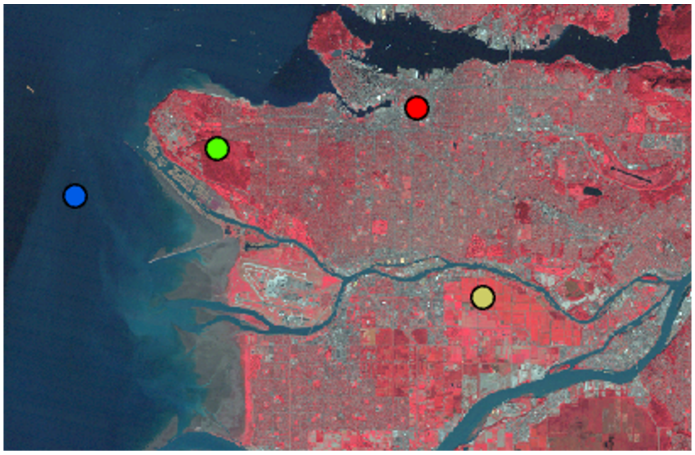
Task 3: Viewing Spectral Signatures

Step 1: Now it is time to examine your data set more thoroughly. At the beginning of this lecture we examined the spectral signatures of different materials. We will now do the same thing for the different sections of our Vancouver Landsat image.

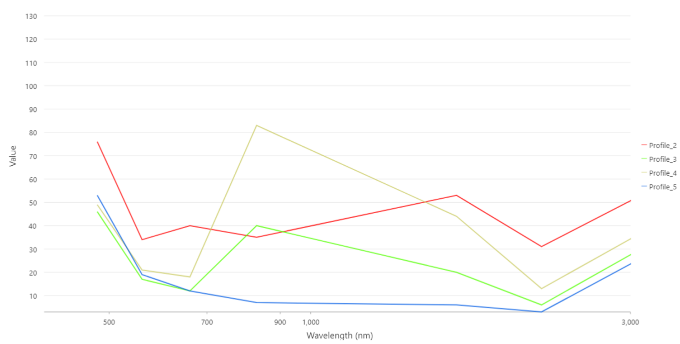
Right click on the **L5057026subset_19990922_7B.dat** file in the Contents pane and select Create Chart -> Spectral Profile. The Chart Properties pane should appear on the right side of your screen and the spectral chart on the bottom.



In the Chart properties pane under "Define an Area of Interest" select "point" and then click a pixel on your map. Change the colour and select a variety of different points representing different land cover types (Urban, forest, water, crops, snow).



You might have to resize the spectral chart at the bottom of your screen in order to see the different profiles. Your chart should look something like this.



Q13. Examine your new spectral profile chart, compare the different profiles you created to the spectral profiles in figures 1 and 2. What is different between them? Why might your spectral curves look different than the ones above?

Q14. Take a screenshot of your spectral plot and points in ArcGIS and paste them in your final report.

Chapter 6

Working with Air Photos

Written by Andres Varhola and Hana Travers-Smith

Lab Overview

The Geographic Information Centre at (GIC) (http://gic.geog.ubc.ca/) at UBC hosts the largest collection of aerial photos from British Columbia, and provides the public with services for accessing those aerial photos. It is also home to the University Aerial Photograph Collection, which consists of over 2 million air photos. In our labs will be using some photos from the GIC.

For this lab it is recommended that you download Google Earth to your laptop or tablet.

Learning Objectives

- Understand map scales and relation to ground area
- Learn techniques for identifying land use and land cover on aerial photography
- Practice georeferencing imagery in ArcGIS Pro

Deliverables

- Answers to the questions posed in the handout
- Photos of the topography recreated in the Virtual Sandbox
- A georeferenced air photo displayed in a GIS

Data

Data for this lab includes historic air photos given to you in class. Note you cannot take the air photos home with you, so be sure to use your time in class wisely to complete all tasks. You will also be given a digital air photo, which you will georeference in ArcGIS Pro.

Task 1: Measurements from air photos

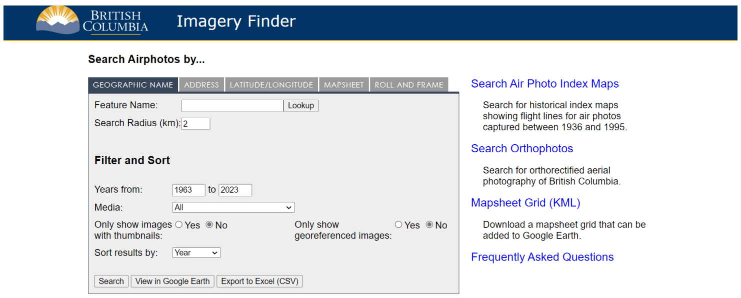
The GIC aerial photo collection includes federal, provincial and private air photos dating from 1922 for many areas in BC and some parts of the Yukon. The photos form a historical collection, mainly covering urban areas, although many rural regions have some coverage. While the majority of the air photos held by the GIC are vertical black and white photos, some color and oblique air photos (from the mid-1940s) are available for selected areas in BC. The standard format for a vertical aerial photo-graph contact print is 25 cm x 25 cm (10” x 10”). Photos obtained by the government for regular inventory programs are typically provided at scales of 1:15,000 to 1:40,000. Each photo is cross-referenced to an index map or flight report that indicates the flight path, flight altitude, date, and time of exposure. The air photographs are filed according to air photo roll numbers and are located in compact storage units.

Each file is coded by flightline following this format:

- **BC** or **BCB** (B added after 1989) = British Columbia government, black and white
- **BCC** = BC government color (after 1970’s)
- **A** = Federal government

and then by a 4 or 5 digit number (after 1977, the first two numbers correspond to the date of the photography), then a roll number circled for every 5th or 10th photo. All photos are numbered se-quentially, usually from 001, and increase in the direction of the flight. Sequential numbers (e.g. 009, 010) along a flight line indicate stereo pair coverage, meaning that the photos have 60% overlap and can be viewed in 3D.

Step 1: First, we will practice finding air photo metatdata (i.e. information relating to location, map scale, year of acquisition etc..) from the GIC website: http://a100.gov.bc.ca/pub/wimsi/AirphotoSearch



Pick one of the air photos from the "Urban" category.

Navigate to the **Roll and Frame** tab and search for the photo using the photo roll frame series and frame number found on the top right of the photo. Select **View in Google Earth -** this will automatically download a kmz. file to your computer. Click on the file to open it in Google Earth. The .kmz will show you the location of the air photo. Clicking on the camera icon will show metatdata related to the photo.

If you do not have access to Google Earth you can get the lat/long of the photo using the Search button instead. You type these into Google or Bing Maps on your device to get the location of the photo.

Q1. What year was the photo taken? What is the nominal scale of the photo and focal length of the camera?

Q2. What town is shown in the photo?

Q3. For each of the following scales, what is the equivalent ground area in hectares (ha) for a region covering 5"x 5" on the map 1:10,000. 1:12,000, 1:30,000? For full makrs show your work. (Hint: 1" = 2.54 cm; 1 ha = 10,000 m^2) **Step 2:** The following equation is used to calculate the nominal scale of an air photo.

$S_p = f/(H - h_{avg})$

where f is the focal length of the camera, H is the height of the aircraft above sea level and H_{avg} is the average elevation of the terrain in the photo. Note that the scale will change slightly at any given point if the terrain is hilly or mountainous!

For example: If f = 305 mm, H = 7000 m, h_{avg} = 700 m

$S_p = 0.305/(7000 - 700)$

$S_p = 0.00004841$

Note for the above calculation we first convert focal length in mm to m.

Next to get the nominal scale in terms of 1:XXXX we need to convert 0.00004 to a ratio.

First, rewrite 0.00004 as **4:100000**. (i.e. put the 4 on the left side and then a 1 with the same number of 0's as decimal places on the left).

Then divide 100,000 by 4 to get the nominal scale of 1:25000.

Answer the following questions for the air photo pair: **BCB93024 124** and **BCB93024 123**

Q4. What year were the photos taken? What is the focal length of the camera? What is the scale of the photos?

Q5. What is the name of the mountain range in the photos?

Q6. The scale given in the image metadata uses the average elevation of the photo. Why would a single number representing photo scale be problematic in this terrain?

Q7. The highest peak in the photo is at 2030 m. What is the nominal scale for a point located at the summit, assuming the aircraft flew at an altidue of 6393 m above sea level? Show your work. (Hint: Remember to convert the focal length of the camera in mm to m!)

Task 2: Interpreting air photos

Step 1: Select an air photo pair with mountainous topography. Get your TA to help you view them in 3D using the stereoscope.

Q8. Using the air photos and Google Earth as a reference, try to recreate the topography in the Virtual Sandbox. Include a photo of one of the air photos and a photo of the sandbox in your final deliverables. **Step 2:** Select an air photo with urban/natural features. Note the roll and photo numbers.

Q9. On your selected photo list at least 4 land cover types and 2-3 specific urban features present in the photo.

Q10. For each of the land cover types and features you listed in the previous question, describe how you can identify them in the air photos. How do they vary in terms of texture, shade and shape?
Step 3: Next, we will use a dot-grid to estimate the ground area covered by features in the air photo. Get a transparent dot-grid from your TA and measure the distance between the dots.

Select one of the forest or urban air photos and place the dot-grid on top of the air photo. **Take a photo of the air photo and overlaid dot grid.**

Select 3 irregularly shaped features in the photo, these could be lakes, cut-blocks, parks, property lines etc…

Step 4: Use the dot-grid to estimate how many cells cover each feature. Then look up the photo scale on the GIC website.

Use the following example to help you calculate the ground area of each feature in m2.

In this example imagine the dots are spaced 5 cm apart. A single cell on the dot grid would cover 5x5cm = 25cm^2. If you estimate that a feature on the air photo covers 10.5 cells and the scale of the photo is 1:20,000 then we would convert 10.5 cells to ground area as follows…

First calculate the area of the cells:

$10.5 * 25cm^2 = 262.5cm^2$

Next, convert this to ground area in m using the scale of the air photo:

$262.5cm^2 * 20,000 = 5,250,000cm^2/10,000 = 525m^2$

Step 5: Record the ground area of each feature you selected. On the photo you took of the air photo and dot grid use a photo editing program (ie MS Paint) to outline the features you chose. Add labels A,B,C to each feature.

Include the image in your final deliverables along with the estimated ground area of each feature and its associated label.

Task 3: Georeferencing

In this task you will learn how to integrate air photos with other spatial layers in a GIS. To do this we need to add **spatial reference information** to the digital image so that it can be displayed correctly on a map and be overlaid with other data sets. In this process you will identify common features between a base map which has spatial reference information, with the air photo, which does not. A geographic transformation will be used to align the points in the basemap with the air photo and assign a spatial reference. Because the air photo was taken in the 19XX's some landscape features are expected to change, so we will have to carefully select features that have not changed over time! Some good examples of stable control points might be:

- intersections of major roads
- airport runways
- buildings, piers, bridges, other permanent structures
- the centres of deep lakes
- easily identifiable natural features, islands, spits

Some examples of not so good control points might be river banks, trees or the shorelines of shallow lakes, as these features are more likely to change or be difficult to identify in two images.

You can read more about the process of georeferencing here: https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/overview-of-georeferencing.htm

Step 1: The file BurnsLake.tif is a high-resolution digital scan of photo **BC7739 No 188**. Create a new project in ArcGIS Pro and open a New Map. Drag and drop the air photo into ArcGIS Pro. Notice that because there is no coordinate information associated with the image, ArcGis plots the photo at the coordinates 0.0S, 0.0.0E.

You may also have to change the Symbology from RGB to greyscale strech.

First, set the cooridnate system of the Map to **NAD 1983 UTM Zone 10**. Right click Map in the Contents Pane > Properties > Coordinate Systems.

Step 2: In the Map Pane navigate to the corresponding region shown in the air photo (Burns Lake). We will be using the basemaps in ArcGIS Pro as the reference imagery. In the top Ribbon select Map > Basemap and change the basemap to Imagery or Imagery Hybrid.

There is a cloud over parts of the image, however, you should be able to see enough detail to georeference the image.

On the top ribbon go to Imagery > Georeferencing > Fit to Display. This will plot the air photo in the Map pane.

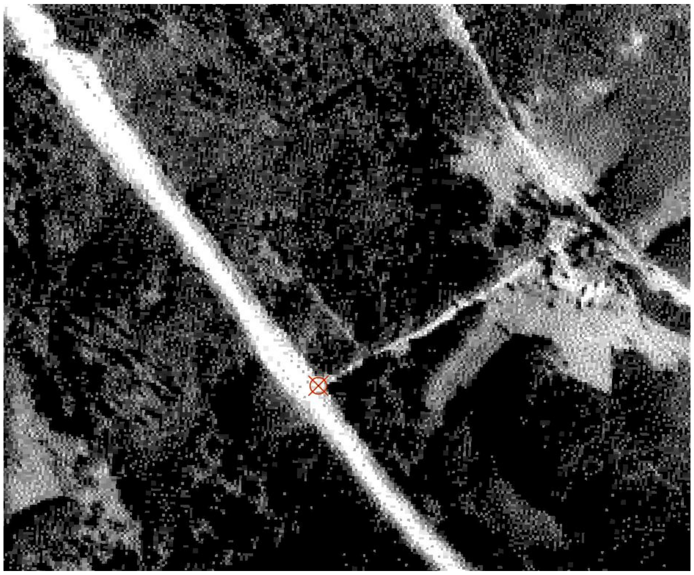
Next, use the Move, Scale and Rotate tools to approximately line up the air photo with the underlying basemap. Be sure to zoom in and try and identify common features between the air photo and the basemap. Note, this will not result in a perfect fit, but try and get reasonably close. When you done, click on the map outside the air photo to close the Move, Scale, Rotate tools.

Step 3: To georeference the image we will be adding **control points** in the reference basemap and finding the corresponding points in the air photo. In the example below we will use an intersection on the Trans Canada highway as the first control point.

Turn off the air photo layer in the Contents pane. Zoom in on the basemap to the control point. On the top ribbon choose Add Control Point. Click on the **scanned airphoto** to set the **source location**, next turn on the **basemap** and click on the corresponding location on the air photo to set the **target location**.

Remember, Source = airphoto and Target = reference basemap.

Control point on source image



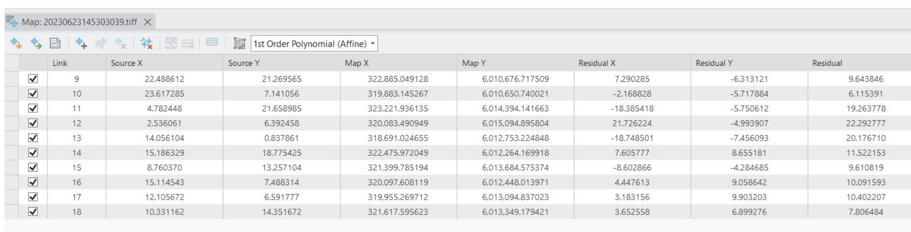
Corresponding control point on target image

Repeat this process and set 6-10 more control points. Try to distribute them across the entire image, a good practice is to try and choose points in each of the four corners and one or two in the centre of the image.

Step 4: You need a minimum of three points to apply a geographic transformation. The transformation will automatically warp the air photo to try and minimize the distance between the source and the target locations of each control point.

Click Transformation on the top ribbon and select **First Order Polynomial** > Apply.

Examine the Control Point table. For each control point, **Residual X** indicates the difference in meters between the source and target in the X direction after applying the transformation, and **Residual Y** indicates the difference in the Y direction.

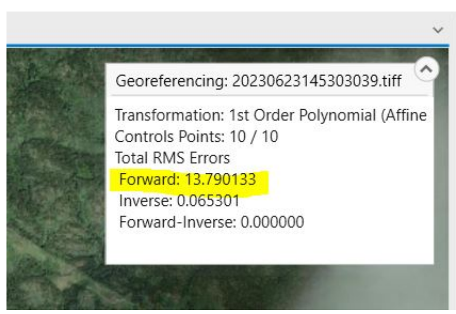

Map: 20230623145303039.tiff

1st Order Polynomial (Affine)

Link	Source X	Source Y	Map X	Map Y	Residual X	Residual Y	Residual
9	22.488612	21.269565	322,885.049128	6,010,676.717509	7.290285	-6.313121	9.643846
10	23.617285	7.141056	319,883.145267	6,010,650.740021	-2.168828	-5.717884	6.115391
11	4.782448	21.658985	323,221.936135	6,014,394.141663	-18.385418	-5.750612	19.263778
12	2.536061	6.392458	320,083.490949	6,015,094.895804	21.726224	-4.993907	22.292777
13	14.056104	0.837861	318,691.024655	6,012,753.224848	-18.748501	-7.456093	20.176710
14	15.186329	18.775425	322,475.972049	6,012,264.169918	7.605777	8.655181	11.522153
15	8.760370	13.257104	321,399.785194	6,013,684.575374	-8.602866	-4.284685	9.610819
16	15.114543	7.488314	320,097.608119	6,012,448.013971	4.447613	9.058642	10.091593
17	12.105672	6.591777	319,955.269712	6,013,094.837023	3.183156	9.903203	10.402207
18	10.331162	14.351672	321,617.595623	6,013,349.179421	3.652558	6.899276	7.806484

The overall error is shown in the pop-up menu on the Map where Forward error is average difference across all control points in meters and Inverse is the difference in terms of the pixel units.

To reduce error we can add more control points to the map, and delete points with high error and replace them with new points. Add 8-10 control points (total), **aim for Forward RMS less than 15 m.**



Q11: Once you have achived a Forward RMS < 15 m. Take a screenshot of your Control Point table that includes the error for each point and include it in the final deliverables. **Step 5:** To save the georeferenced air photo click **Save** and close the Georeferencing menu. You will now be able to overlay the air photo with the reference basemap and any other spatial data.

Find a region on the air photo where land cover has changed over time, this could be through urbanization, clear cuts etc. Zoom in and adjust the transparency of the air photo in the Appearance menu so that you can see the modern imagery underneath.

Q12: Take two screenshots, one of the historic air photo and another of the modern imagery showing changing land cover or land use. In 2-3 sentences briefly describe the change taking place in the two images.