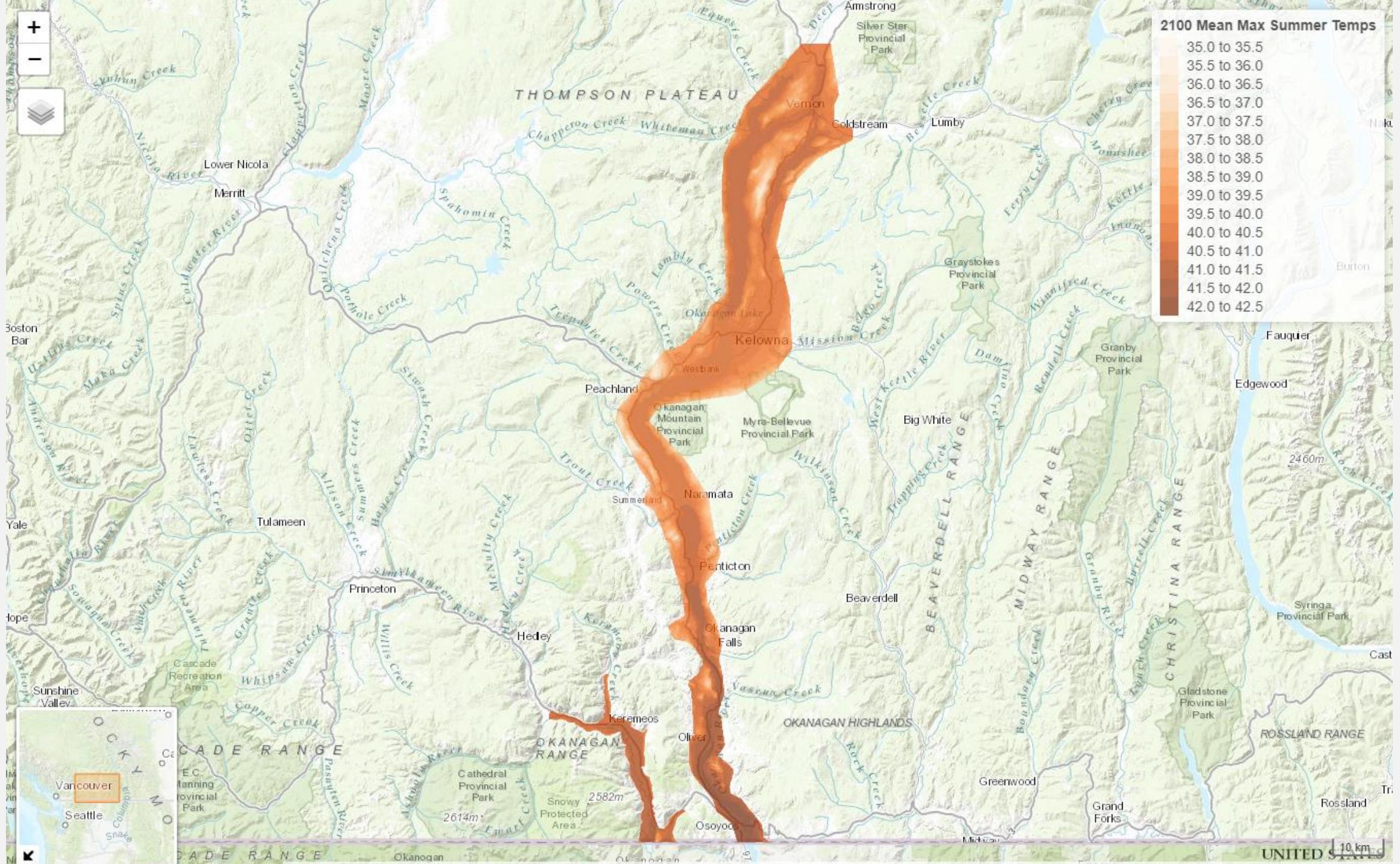
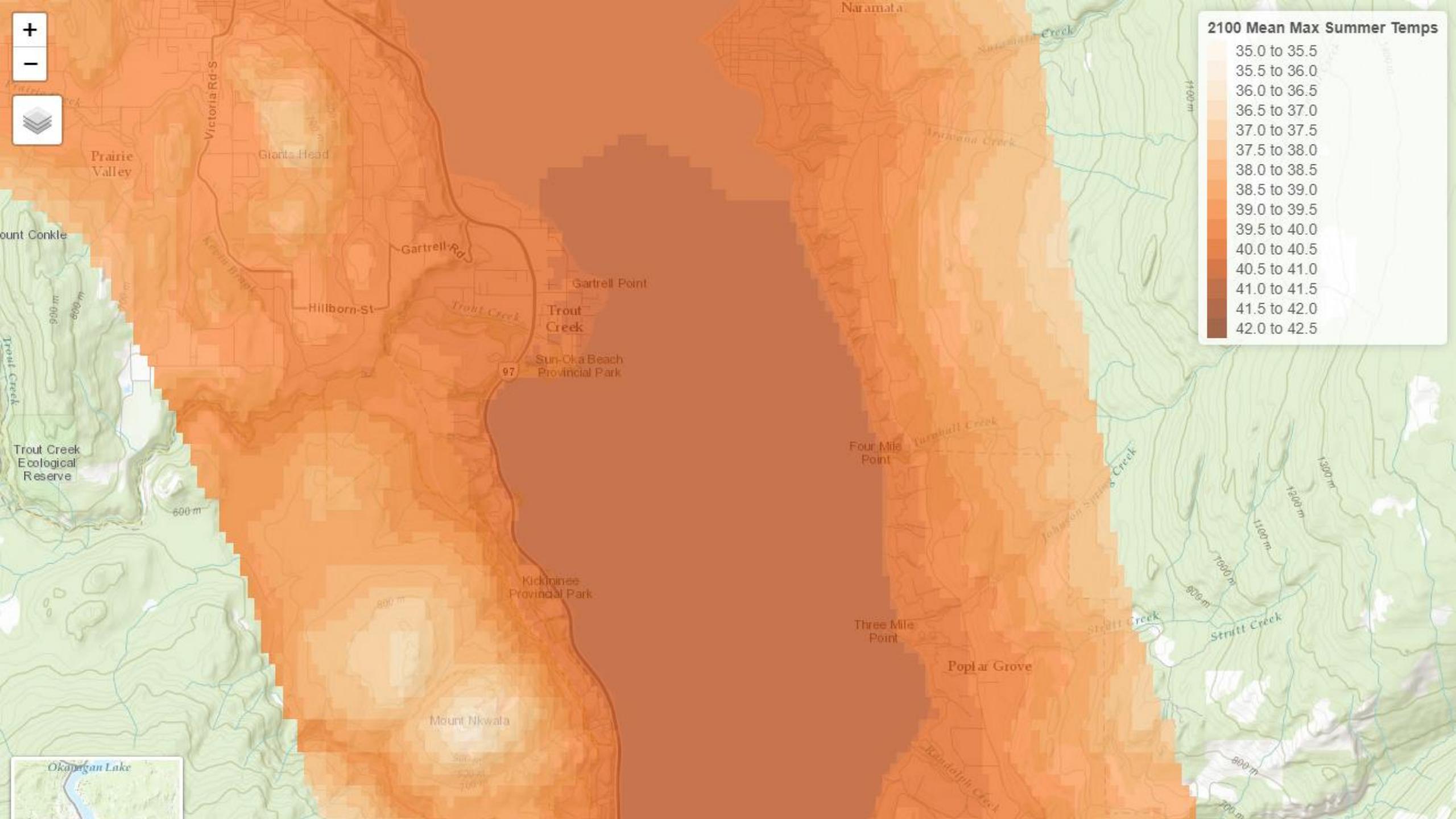


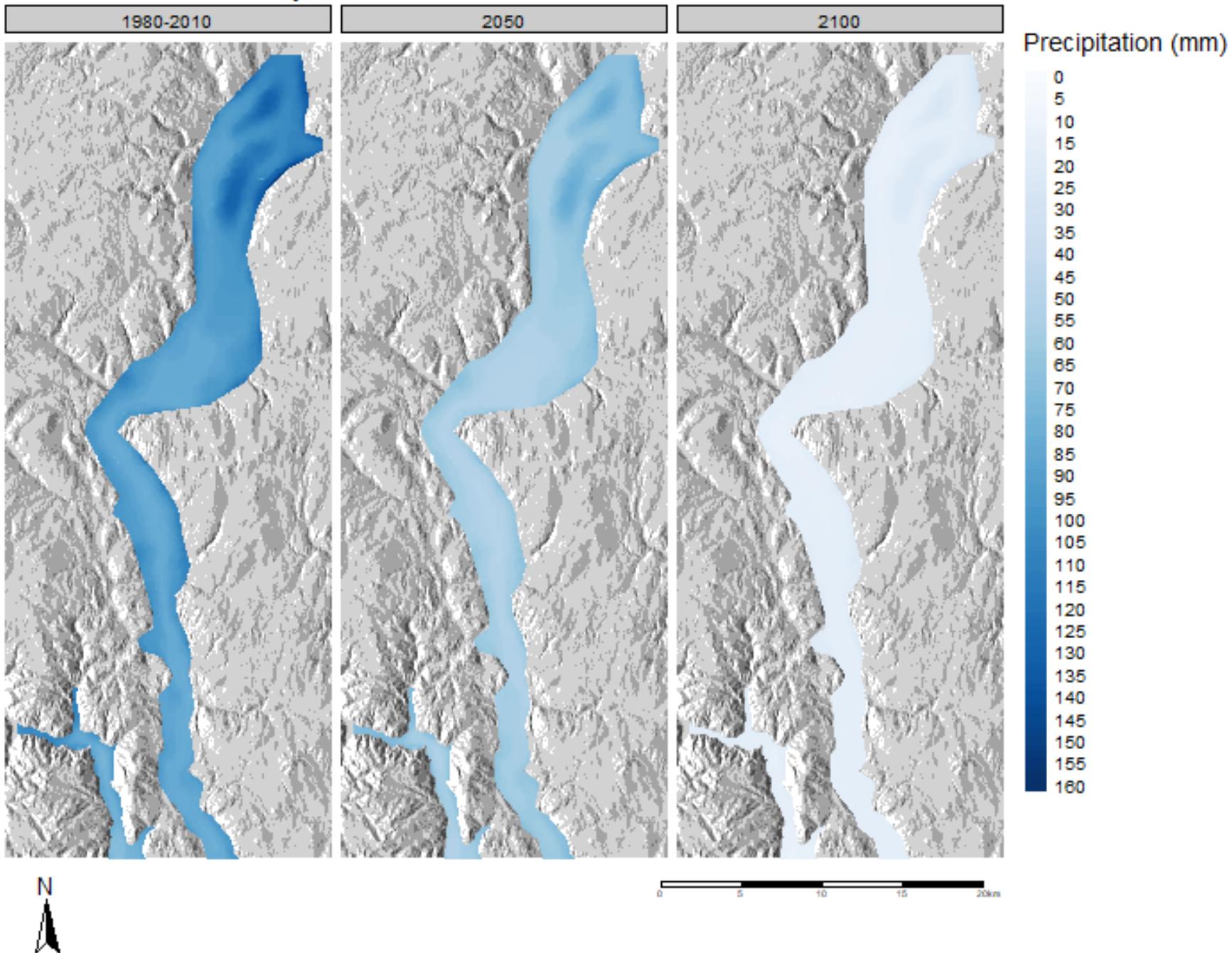
MAPPING IN R: CLIMATE PROJECTIONS

Addressing the necessary procedure to create thematic maps



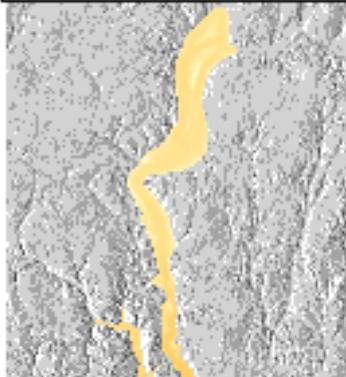


Summer Precipitation RCP 8.5



Mean Maximum Summer Temperature (RCP 8.5)

Average 1980-2010

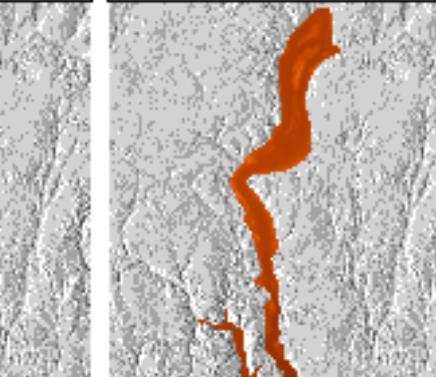
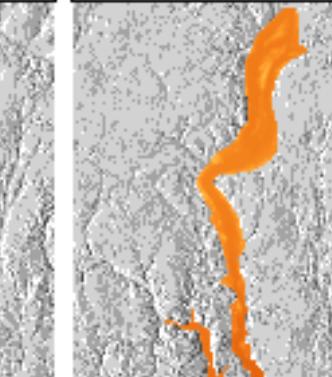
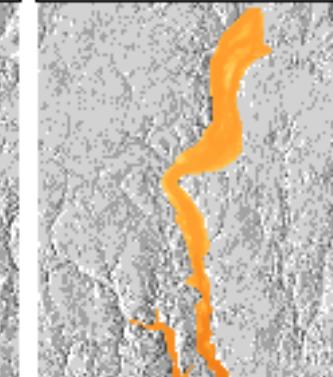
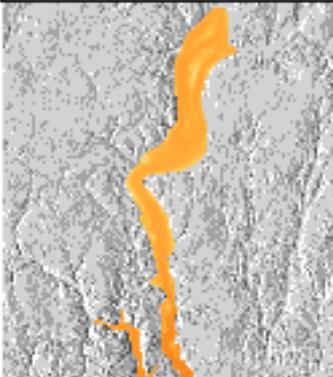


2040

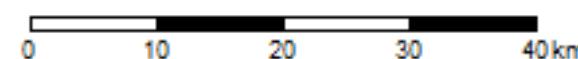
2060

2080

2100



Temperature (degrees C) [cont]



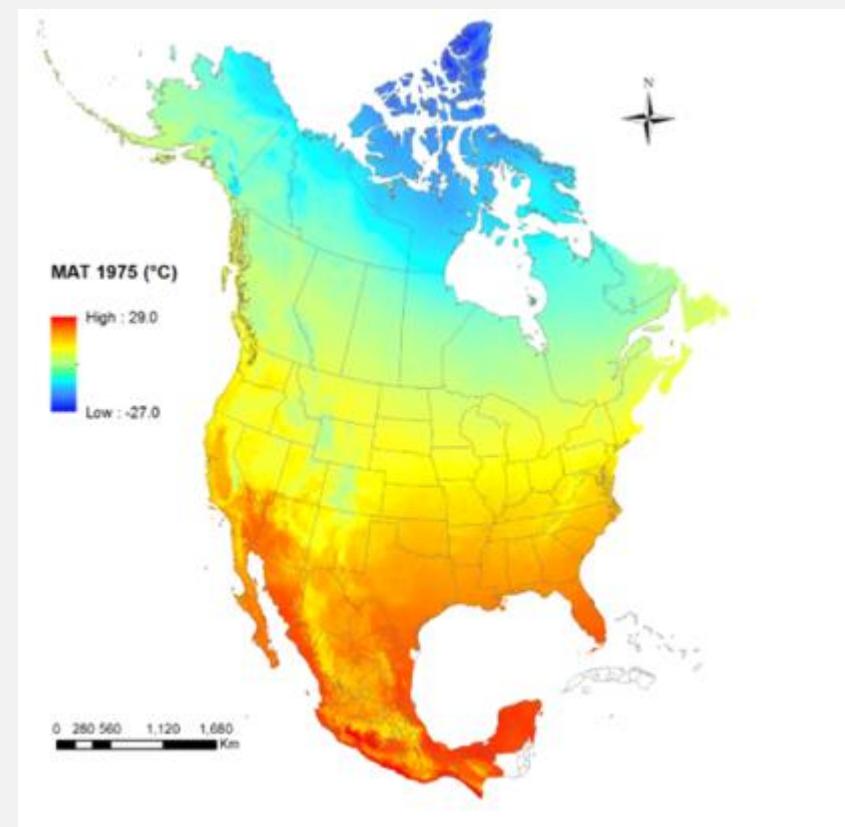
CLIMATE PROJECTIONS

Predicted climate variables according to a variety of different General Circulation Models (GCMs)

- Many temperature and precipitation projections for future years

Thanks to ClimateBC/ClimateNA

- UBC faculty, Dr. Tongli Wang's program
- Input: Digital Elevation Models (DEMs)
 - .asc, .csv
- Output: seasonal or annual projections



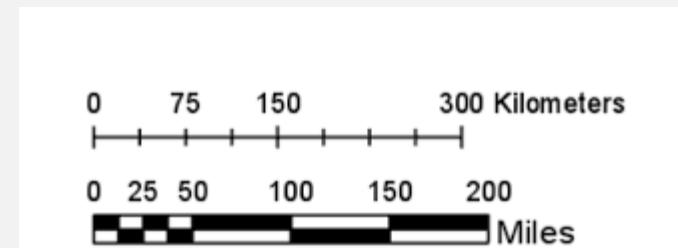
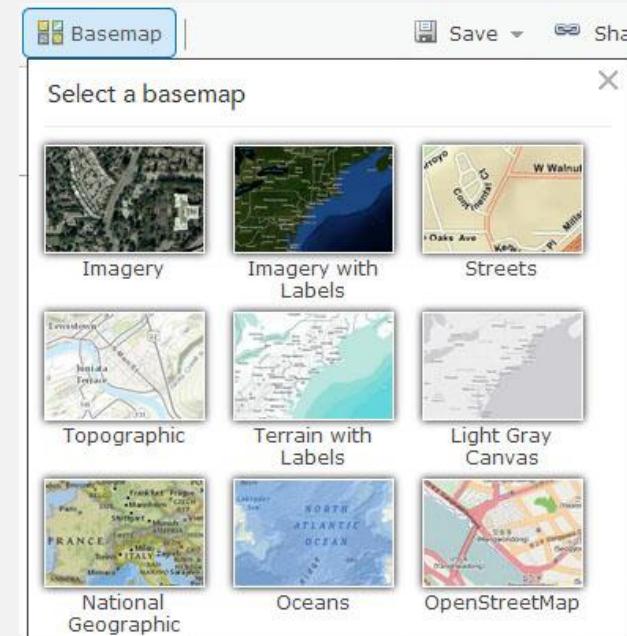
PACKAGES

- “tmap”
- “tmaptools”
- “raster”
- “rgdal”
- “rgeos”
- “sp”

MAP COMPONENTS



- Data
- Basemap (optional)
- Legend
- Scale bar/compass
- Map projection



VECTOR & RASTER DATA



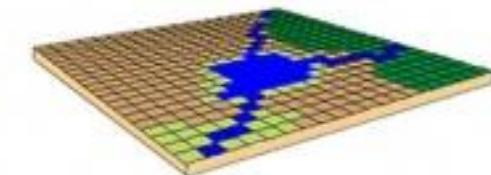
Vector

- Points, lines, polygons
- Discrete
- Can contain useful 2D data: distance and area
- File Type: KML, KMZ, shp

Raster

- Grid of uniform cells
- Continuous
- Resolution (size of each cell) determines precision
- Can display temperature, elevation, and RGB images
- File Type: asc, tiff, png

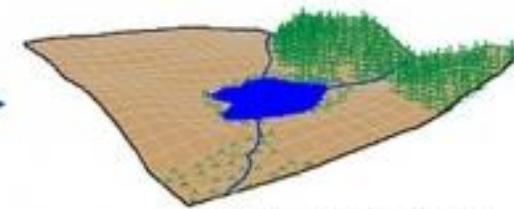
• RASTER →



• VECTOR →

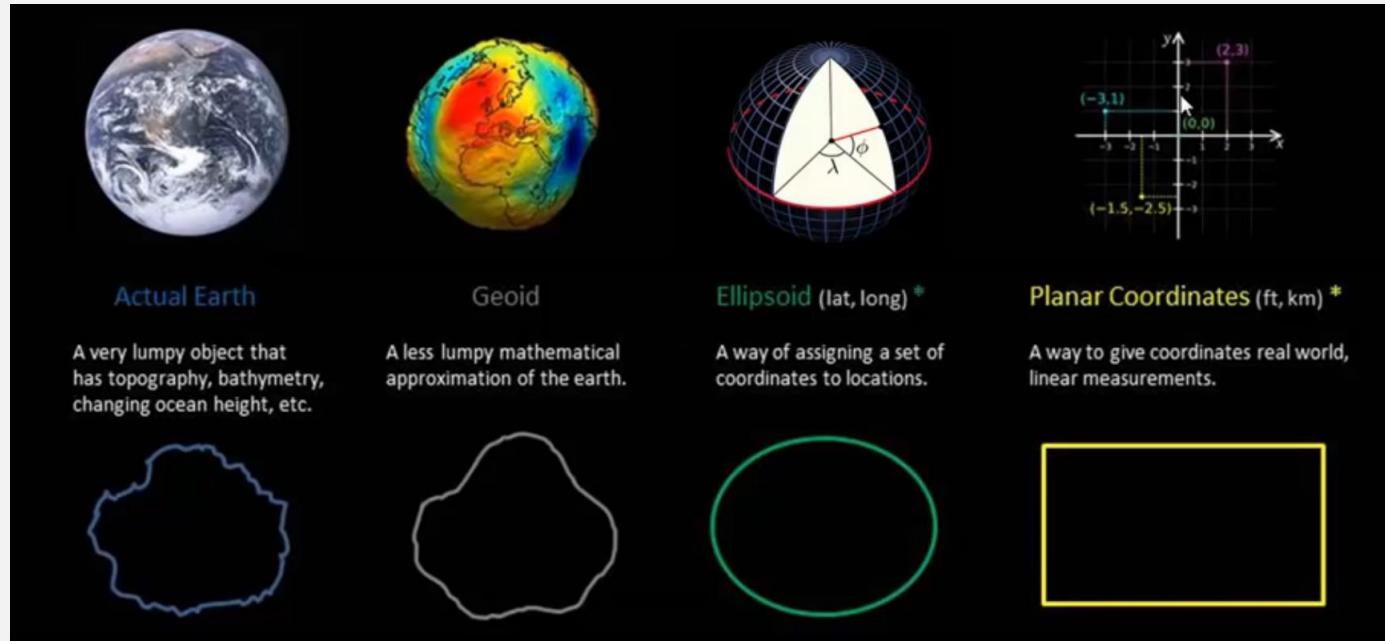


• Real World →



Source: Defense Mapping School
National Imagery and Mapping Agency

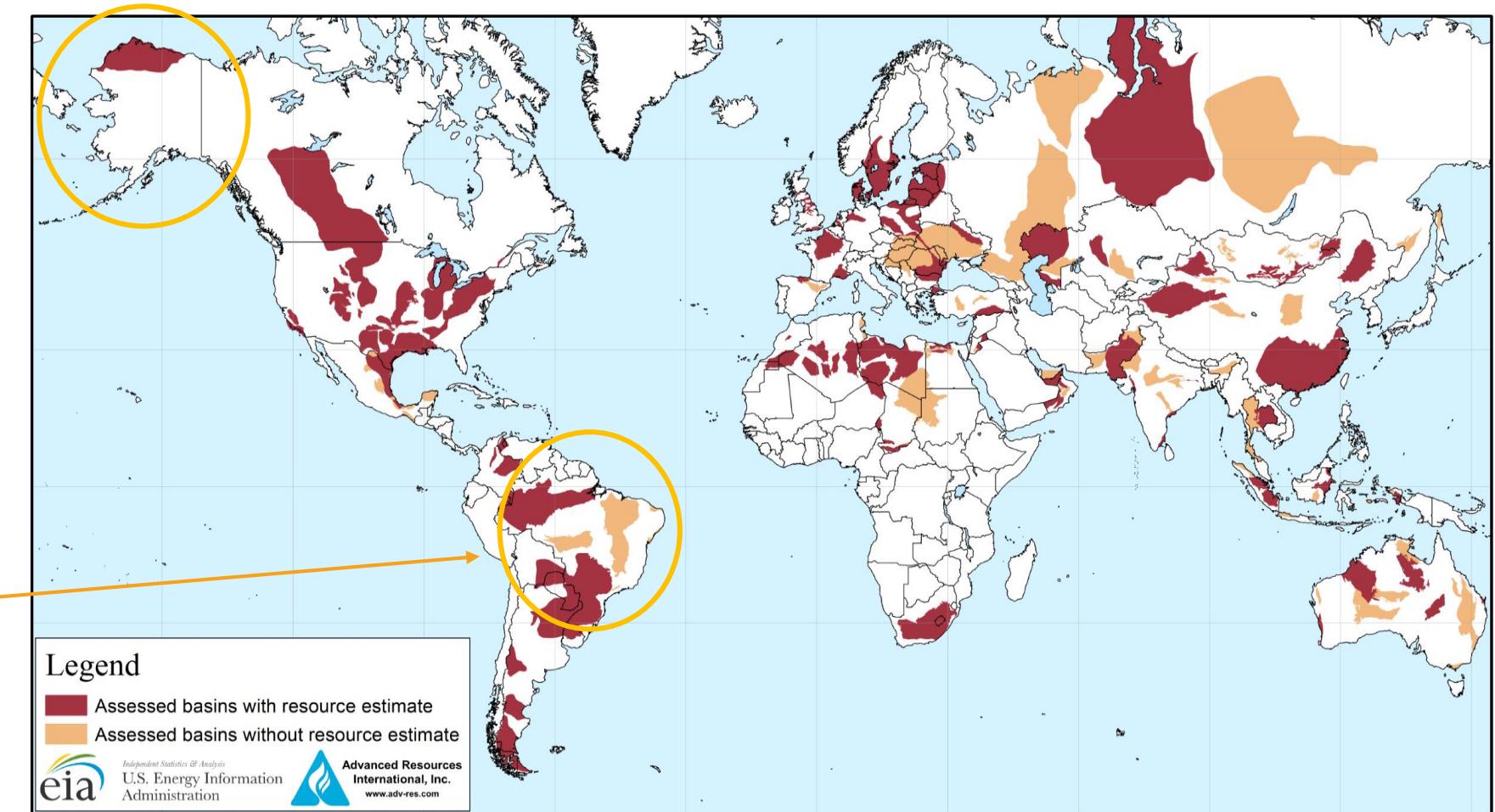
REFERENCE/COORDINATE SYSTEMS



- data is related to each other spatially with reference systems
- Many types of Geographic and Projected Coordinate Systems
- For simplicity, stick to WGS 84 and plot in latitude & longitude
- Data must be in the same coordinate system to plot correctly

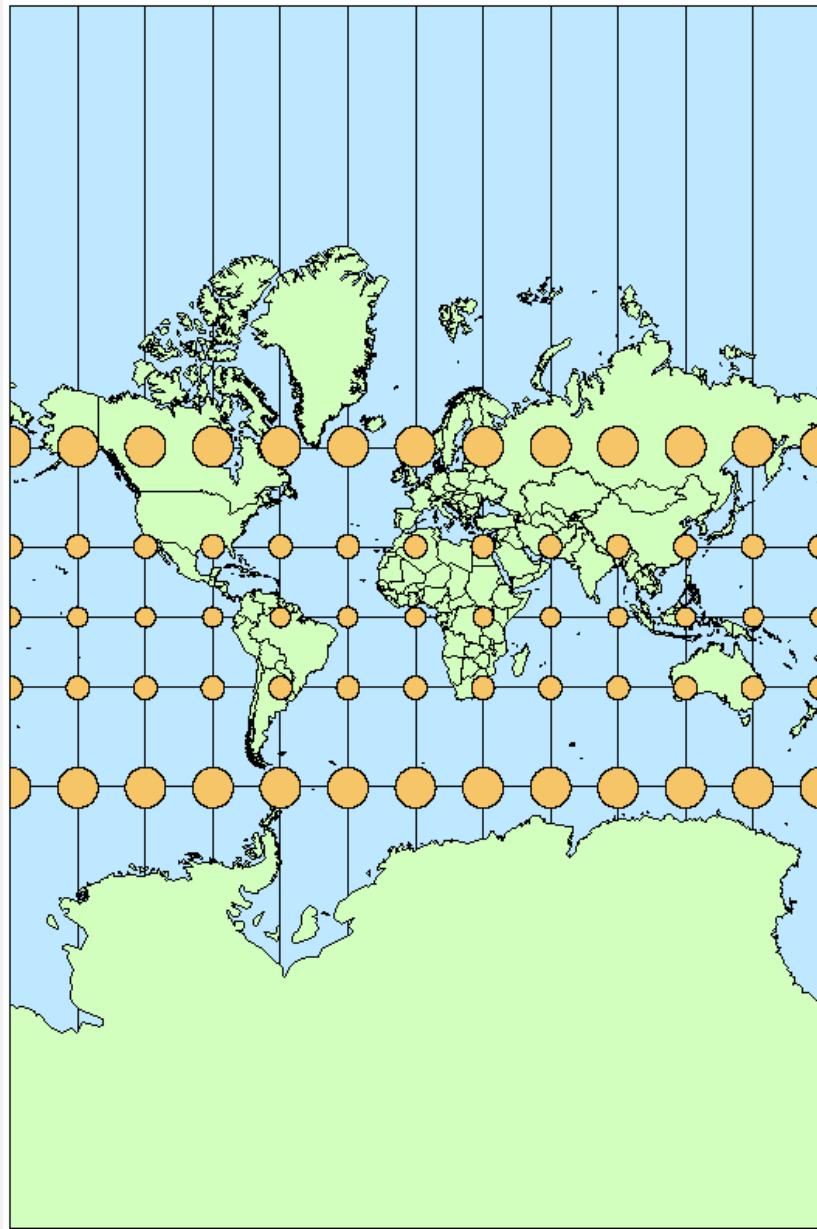
- https://www.youtube.com/watch?v=Z4IDt7_R180

Alaska is 1.718 million square km

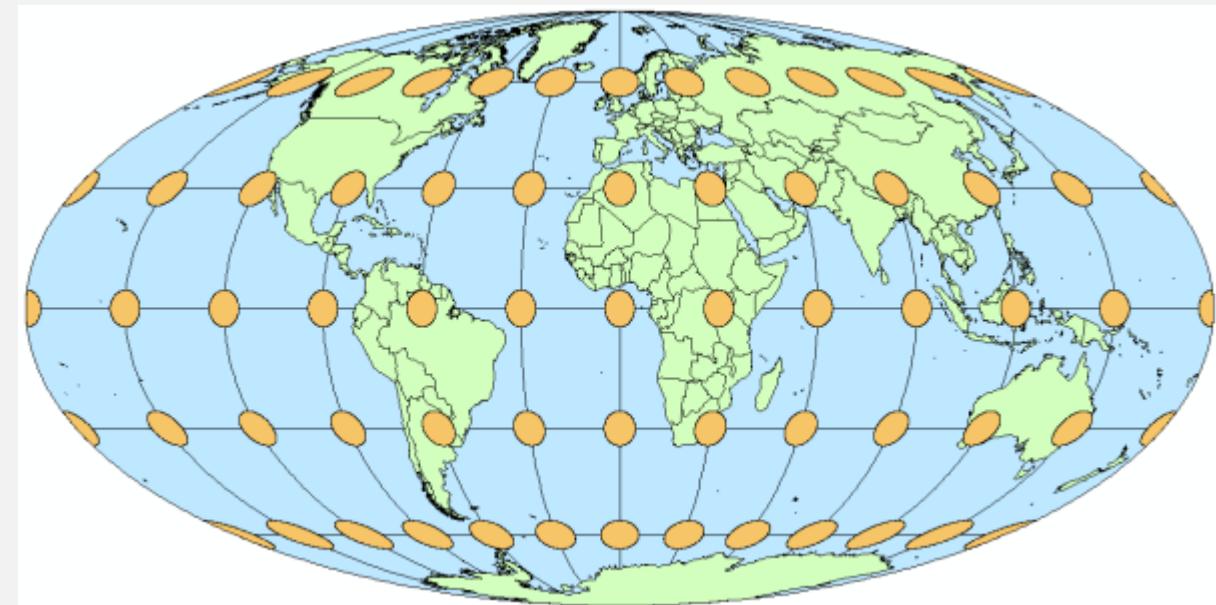


Brazil is 8.511 million square km

MERCATOR:
WGS84

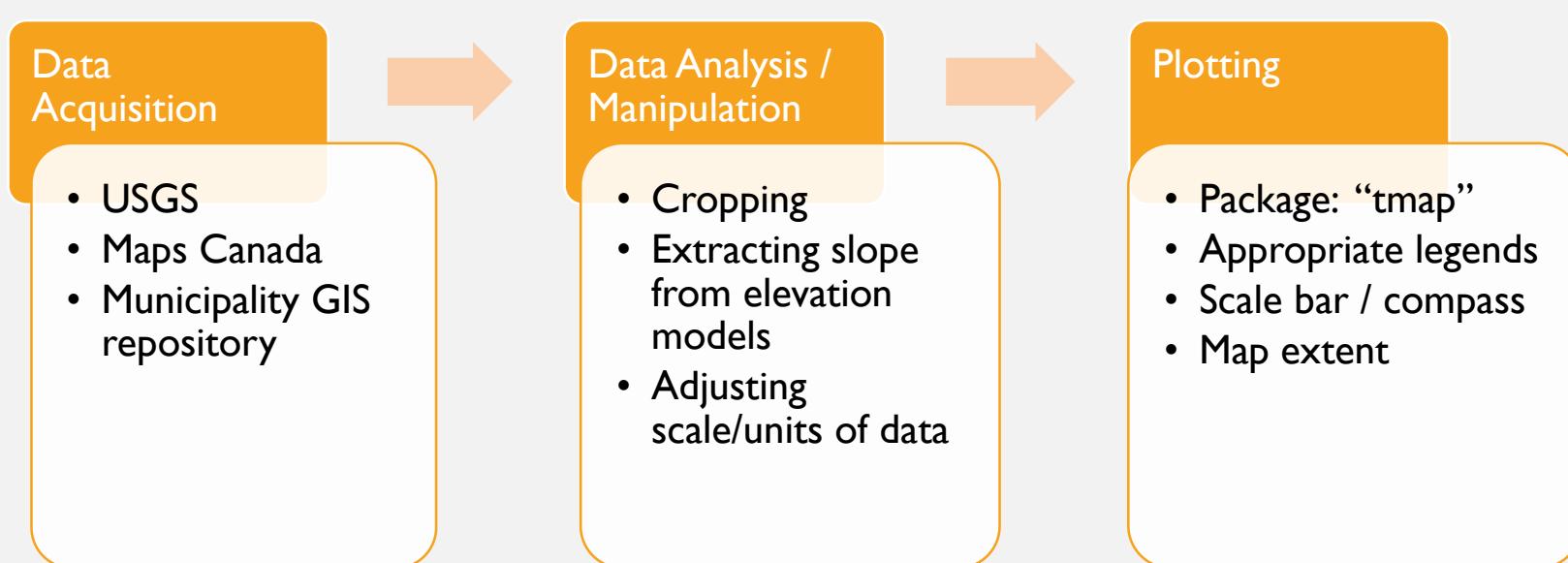


EQUAL AREA:
MOLLWEIDE



Source: ESRI.com

MAP MAKING STEPS



DATA ACQUISITION: USEFUL WEBSITES

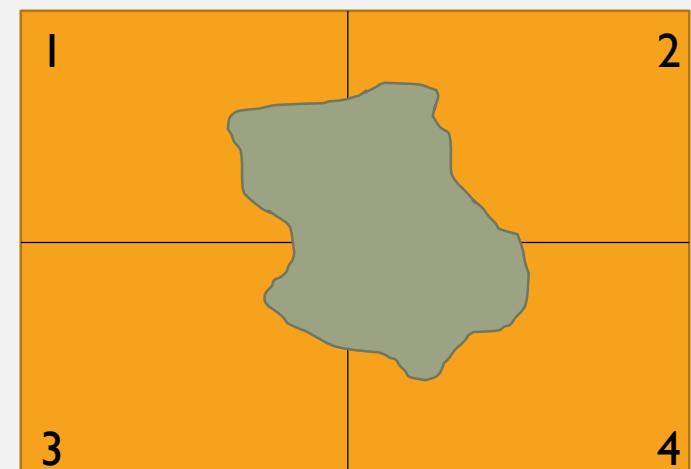
Canada:

- DEMs can be retrieved from <https://maps.canada.ca/czs/index-en.html>
- They have a very intuitive website and have the option to import .shp files to get DEMs
- Can download as .asc

Outside of Canada:

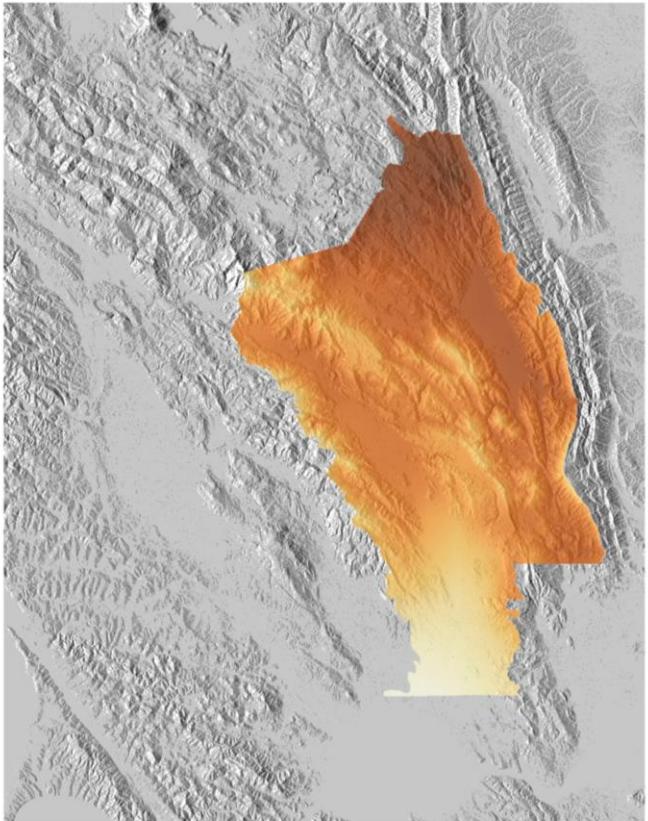
- USGS (<https://earthexplorer.usgs.gov/>)
 - Less intuitive due to the mass amounts of datasets
 - Worldwide (although climate data is restricted to North America from ClimateBC/NA)
 - Only useful file type for DEM for our purpose is .tif
 - Must convert to .asc in R
 - Some datasets are only accessible as multiple files
 - Would have to download all 4 orange squares to get the green shape

 .shp of
interest



MAP WALKTHROUGH: NAPA, CA

RCP 8.5: 2100 Predicted Mean Maximum Summer T



- I) Data Acquisition: DEM & RCP 8.5 Climate Projections
- II) Data Manipulation: cropping, rescaling, creating hillshade
- III) Plotting: using the functionality of “tmap” to plot informative and aesthetic maps

DATA ACQUISITION: DEM FROM USGS

EE EarthExplorer - Home x + - □ X

earthexplorer.usgs.gov

Apps The New York Times Gmail Inbox UBC Canvas Google Calendar ... reddit: the front page YouTube designboom Google Photos Longreads : The best of the web earth :: a global map Other bookmarks

Search Criteria Data Sets Additional Criteria Results

1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the [help documentation](#)), and/or choose a date range.

Geocoder KML/Shapefile Upload

Files are limited to one record containing one polygon or line string with a maximum of 30 points.

KML/KMZ Select File

Polygon Circle Predefined Area

Degree/Minute/Second Decimal

1. Lat: 38° 09' 03" N, Lon: 122° 11' 31" W ✖

2. Lat: 38° 08' 24" N, Lon: 122° 24' 13" W ✖

3. Lat: 38° 12' 56" N, Lon: 122° 21' 35" W ✖

4. Lat: 38° 34' 29" N, Lon: 122° 38' 23" W ✖

5. Lat: 38° 39' 49" N, Lon: 122° 37' 43" W ✖

6. Lat: 38° 42' 14" N, Lon: 122° 27' 51" W ✖

7. Lat: 38° 49' 49" N, Lon: 122° 22' 24" W ✖

8. Lat: 38° 50' 50" N, Lon: 122° 17' 57" W ✖

9. Lat: 38° 36' 57" N, Lon: 122° 09' 52" W ✖

10. Lat: 38° 30' 07" N, Lon: 122° 05' 55" W ✖

11. Lat: 38° 24' 42" N, Lon: 122° 06' 45" W ✖

Search Criteria Summary (Show) Clear Search Criteria

(38° 36' 16" N, 122° 37' 01" W) Options

Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, ESRI

DATA ACQUISITION: DEM FROM USGS

EE EarthExplorer - Home x +

earthexplorer.usgs.gov

Apps The New York Times... Gmail Inbox Canvas Google Calendar ... reddit: the front pa... YouTube designboom Google Photos Longreads : The be... earth :: a global ma... Other bookmarks

Search Criteria Data Sets Additional Criteria Results

2. Select Your Data Set(s)

Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the *Additional Criteria* or *Results* buttons below. Click the plus sign next to the category name to show a list of data sets.

Use Data Set Prefilter ([What's This?](#))

Data Set Search:

Commercial Satellites

Declassified Data

Digital Elevation

- CoNED TBDEM
- EDNA
- GMTED2010
- GTOPO30
- GTOPO30 HYDRO 1K
- IFSAR Alaska

SRTM

- SRTM 1 Arc-Second Global
- SRTM Non-Void Filled
- SRTM Void Filled
- SRTM Water Body Data

Digital Line Graphs

Digital Maps

EO-1

Global Fiducials

HCMM

ISERV

Land Cover

Clear All Selected Additional Criteria » Results »

Search Criteria Summary (Show)

(38° 59' 32" N, 124° 04' 46" W) Options

Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community. ESRI

DATA ACQUISITION: DEM FROM USGS

EE EarthExplorer - Home x +

earthexplorer.usgs.gov

Apps The New York Times... Gmail Inbox Canvas Google Calendar ... reddit: the front pa... YouTube designboom Google Photos Longreads : The be... earth :: a global ma... Other bookmarks

Search Criteria Data Sets Additional Criteria Results

4. Search Results

If you selected more than one data set to search, use the dropdown to see the search results for each specific data set.

Show Result Controls

Data Set Click here to export your results »

SRTM 1 Arc-Second Global

« First < Previous 1 Next > Last »

Displaying 1 - 1 of 1 1

Entity ID: SRTM1N38W123V3
Publication Date: 23-SEP-14
Resolution: 1-ARC
Coordinates: 38°, -123°

1 

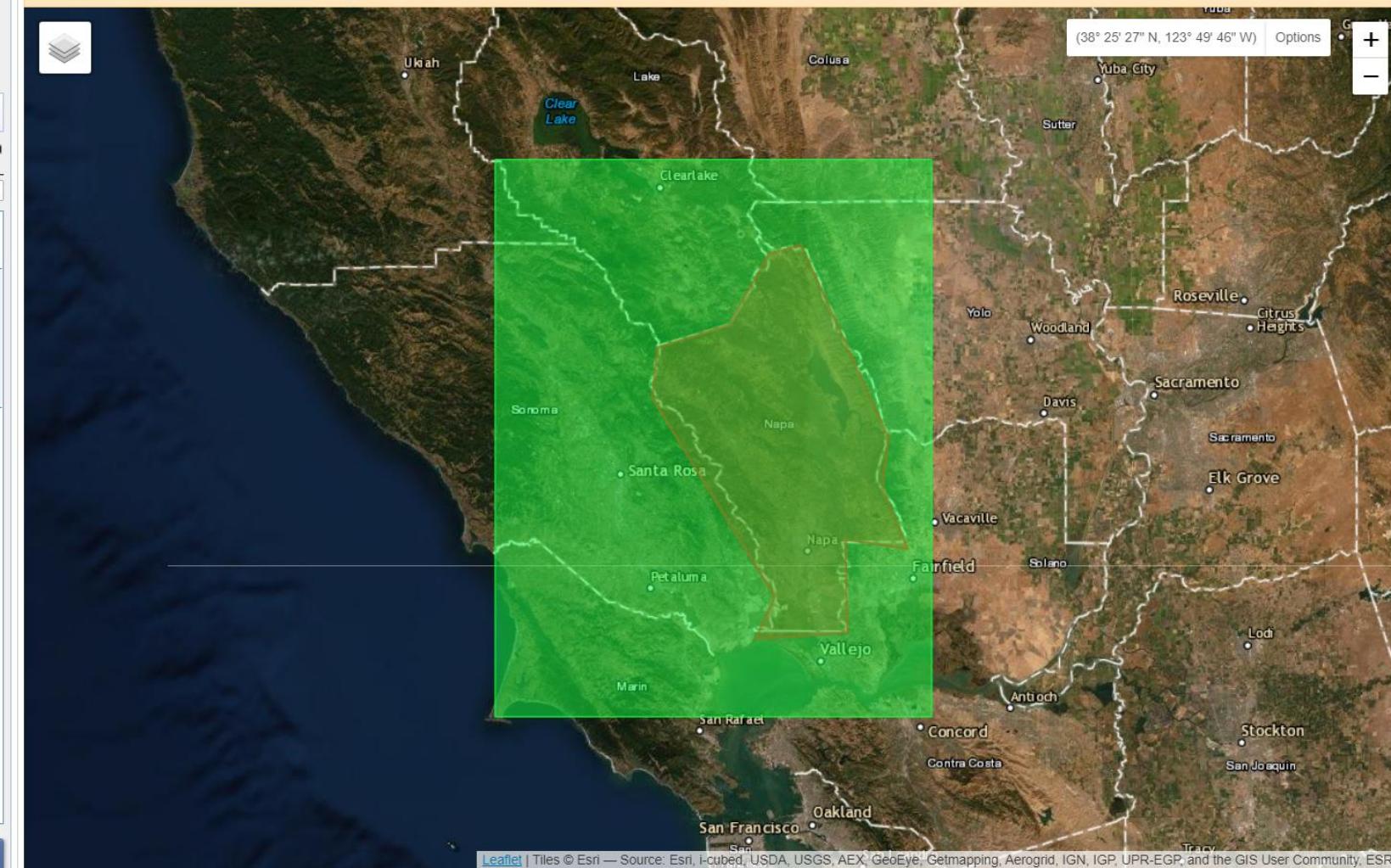
« First < Previous 1 Next > Last »

Search Criteria Summary (Show)

(38° 25' 27" N, 123° 49' 46" W) Options

Yuba Lake Clear Lake Colusa Yuba City Sutter Roseville Citrus Heights Woodland Sacramento Davis Elk Grove Vacaville Fairfield Solano Lodi Antioch Concord Contra Costa Stockton San Joaquin Tracy

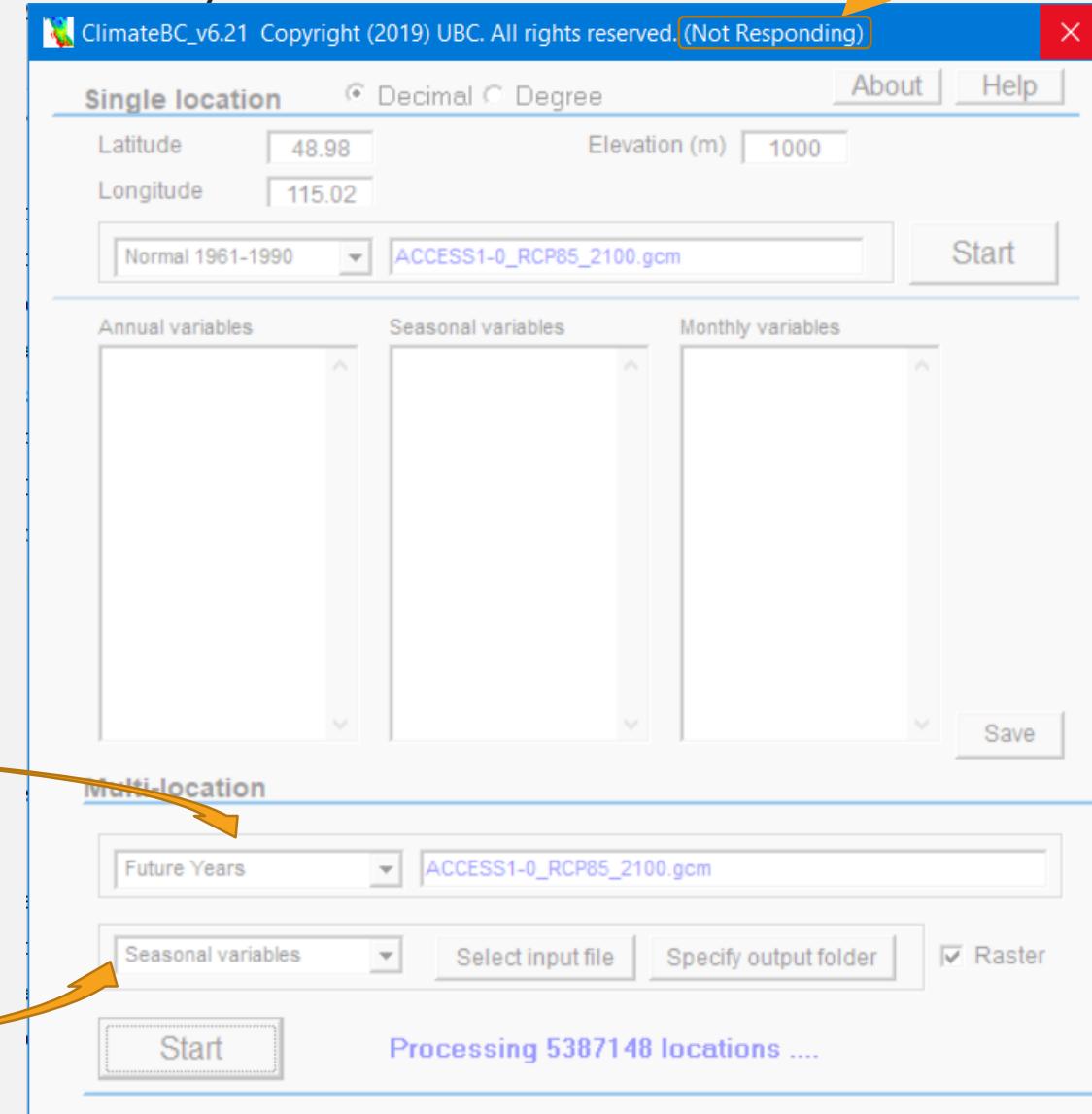
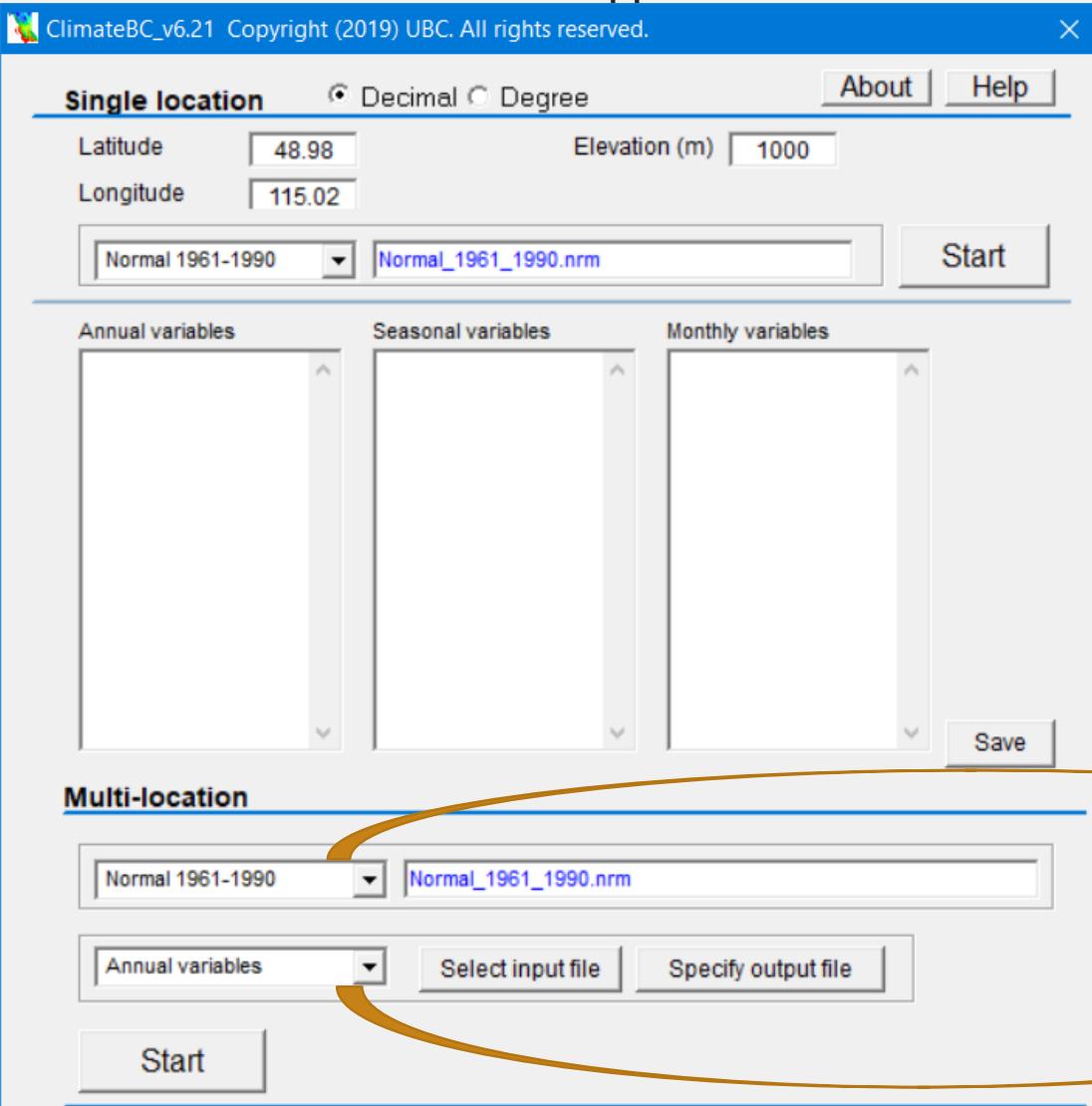
Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, ESRI



Napa DEM 1 arcsecond resolution: napa_1arc.tif aka NapaDEM.tif

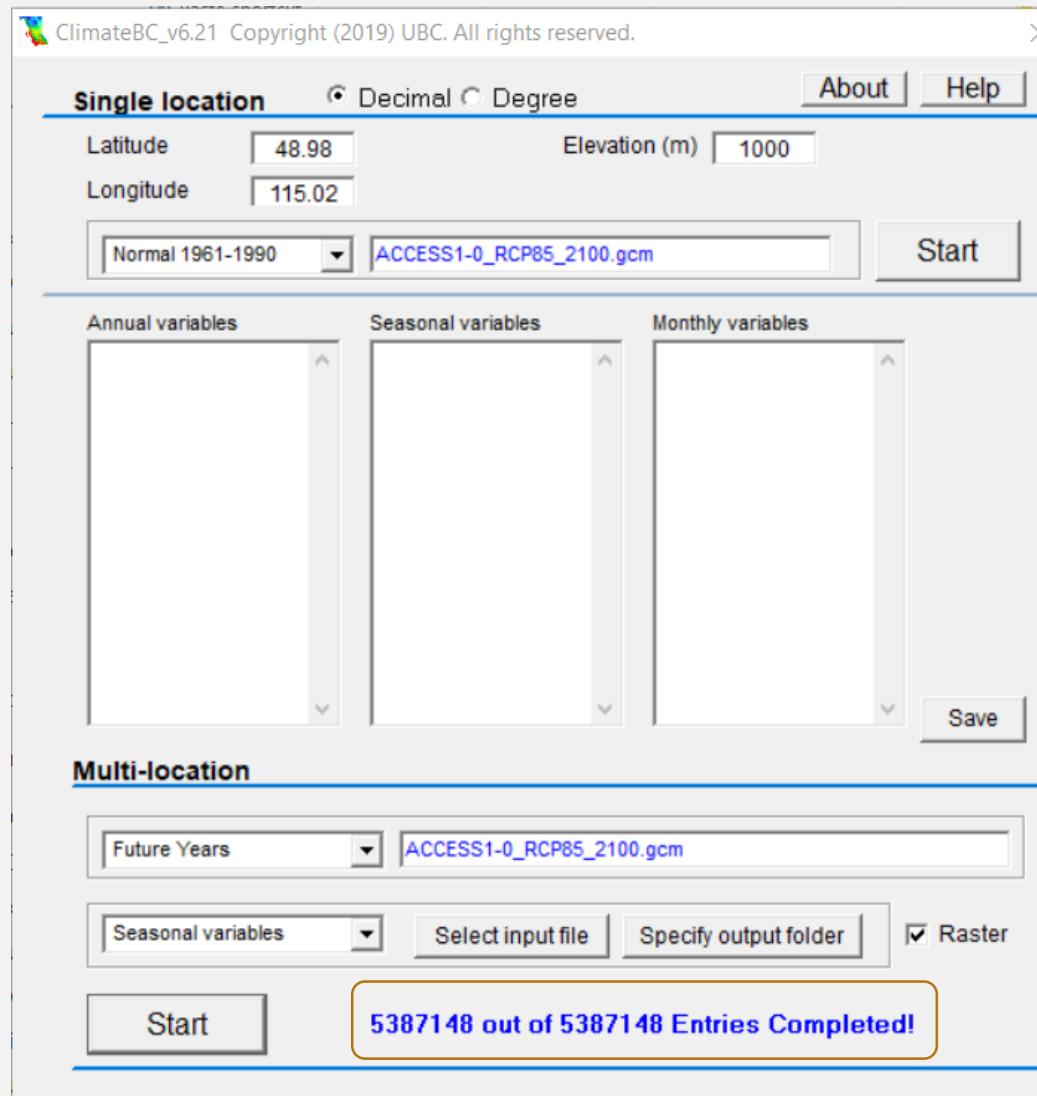
DATA ACQUISITION: CLIMATE PROJECTIONS

- I then downloaded a .shp file of Napa Country through a Berkeley data archive
- I cropped the DEM.tif file with the border of the county and converted the file to .asc



DATA ACQUISITION: CLIMATE PROJECTIONS

- Fine resolution DEMs make this lengthy
- This 1 arc second file took about 1.5 hours to process (in ClimateNA)



A screenshot of a Windows File Explorer window titled "2100S". The left pane shows a navigation tree with "Ecology Lab", "R.climate_mapping", "manualnapaDEM", and "2100S". The right pane displays a list of files in the "2100S" folder. The files are ASC files, mostly named "DD_X_sm.asc" or "DD_X_sp.asc" where X is a digit. The list includes several files for "Hillshade Files" and "Screenshots for I". The table below provides a detailed view of the file list:

Name	Date modified	Type	Size
CMD_at.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
CMD_sm.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
CMD_sp.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
CMD_wt.asc	3/11/2020 11:00 AM	ASC File	21,164 KB
DD_0_at.asc	3/11/2020 11:00 AM	ASC File	21,164 KB
DD_0_sm.asc	3/11/2020 11:00 AM	ASC File	21,164 KB
DD_0_sp.asc	3/11/2020 11:00 AM	ASC File	21,164 KB
DD_0_wt.asc	3/11/2020 11:00 AM	ASC File	21,349 KB
DD_18_at.asc	3/11/2020 11:00 AM	ASC File	25,146 KB
DD_18_sm.asc	3/11/2020 11:00 AM	ASC File	21,171 KB
DD_18_sp.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
DD_18_wt.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
DD5_at.asc	3/11/2020 11:00 AM	ASC File	29,067 KB
DD5_sm.asc	3/11/2020 11:00 AM	ASC File	29,067 KB
DD5_sp.asc	3/11/2020 11:00 AM	ASC File	28,816 KB
DD5_wt.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
DD18_at.asc	3/11/2020 11:00 AM	ASC File	26,436 KB
DD18_sm.asc	3/11/2020 11:00 AM	ASC File	27,218 KB

Current Dataset:

- Tmax_sm.asc
- NapaDEM.tif

DATA MANIPULATION: RESCALING TEMPERATURES

- Tongli's program scales temperature data by a factor of 10
- The temperatures must be rescaled to plot

```
Tmaxnapa2100 <- raster("manualnapaDEM/2100S/Tmax_sm.asc")
Tmax_plot <- overlay(Tmaxnapa, fun = function(r1){r1/10})
```

} Temperatures are ready to plot

DATA MANIPULATION: HILLSHADE BASEMAP

- Use the NapaDEM.tif file to extract two files: slope & aspect
- Combine these two files into a hillshade using the function hillShade()

```
crs(napaDEM)  
  
slope <- terrain(napaDEM, opt="slope")  
  
aspect <- terrain(napaDEM, opt="aspect")  
  
hillshade <- hillShade(slope, aspect, 40, 270)
```

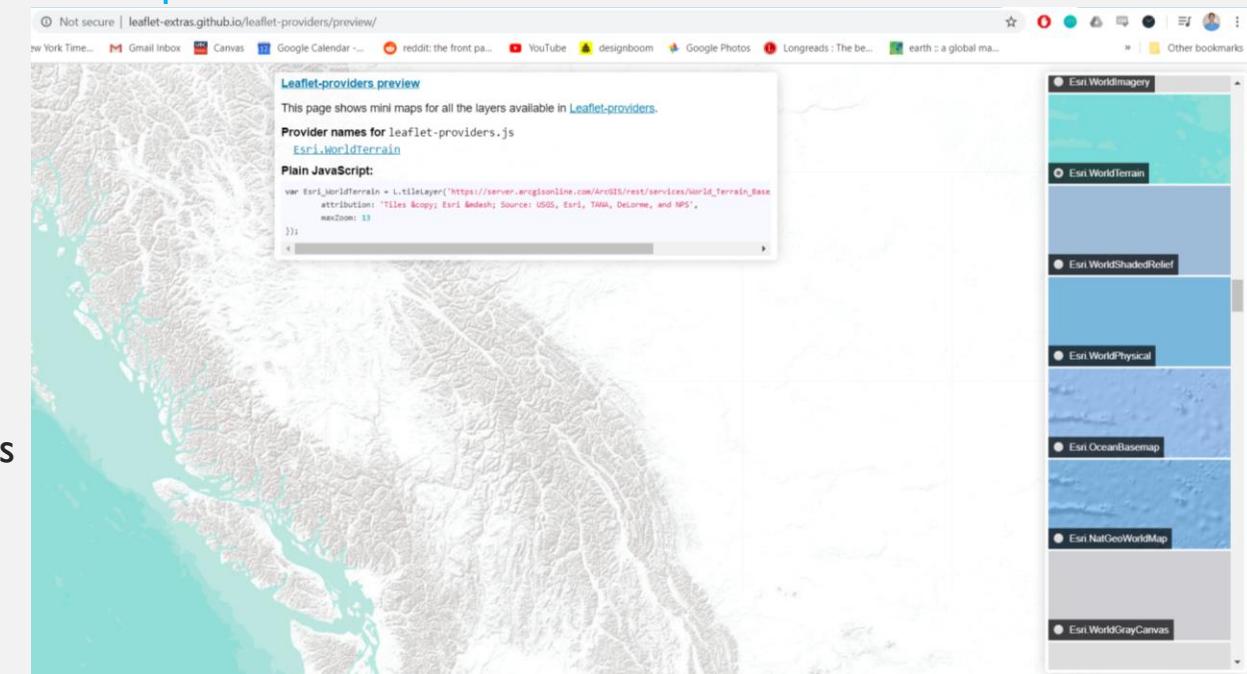
“raster”

```
tmap_mode("plot") +  
tm_shape(hillshade) +  
  tm_raster(palette = grey(0:100/100),  
            legend.show = FALSE)
```

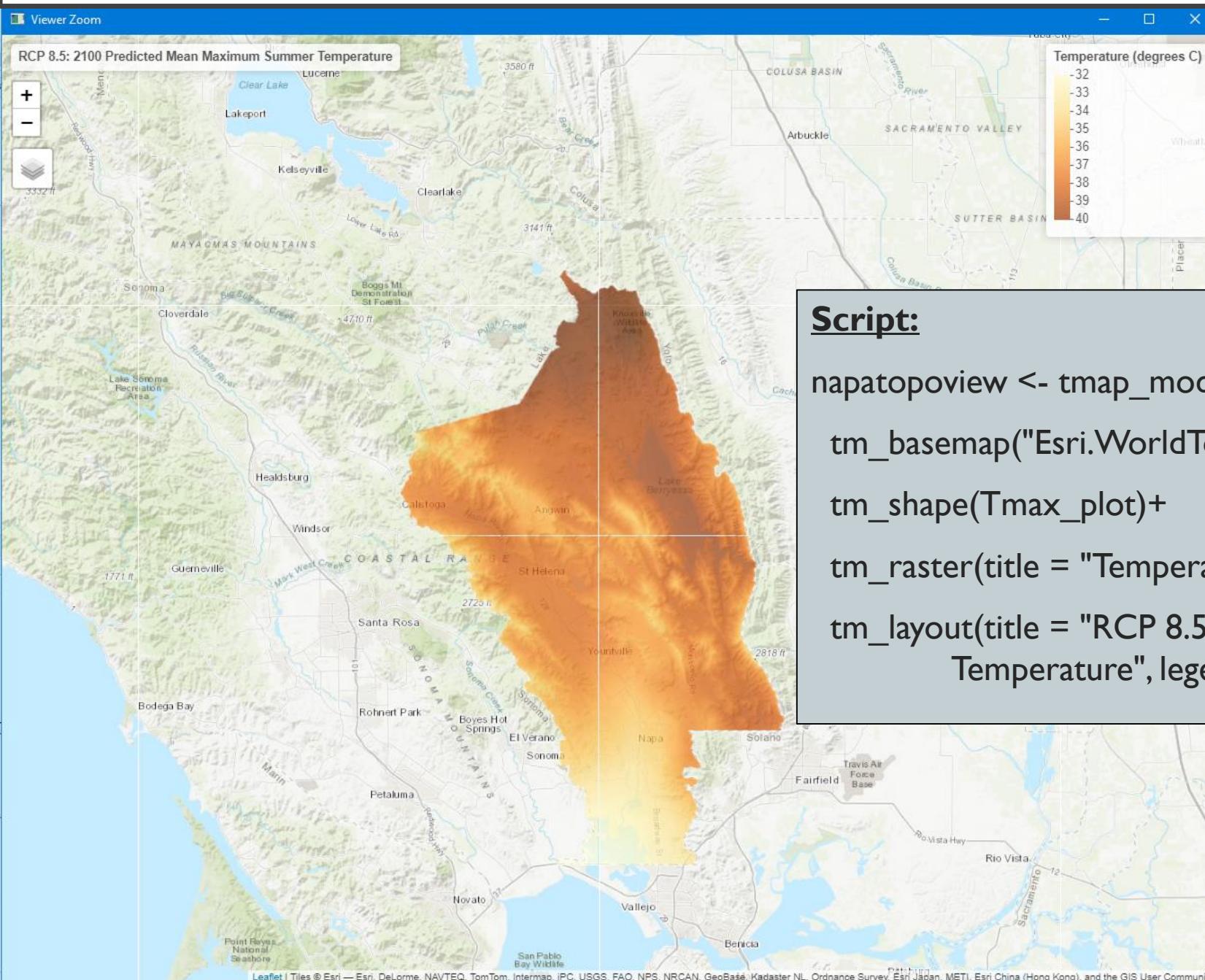
Confirm the
hillshade looks
correct by plotting

PLOTTING: “TMAP” MODES

- “tmap” has two modes of displaying data: “view” and “plot”
 - View is used to make interactive maps that can be panned, zoomed into, and toggle data on and off
 - Good for zooming in on locations
 - Can plot basemaps from <https://leaflet-extras.github.io/leaflet-providers/preview/>
 - ESRI maps included (surprisingly)
 - Only available in Mercator Map Projection
 - Mostly fixed aesthetic
 - Most effective showing one dataset
 - Plot creates static maps that are effectively photos
 - Difficult to find/plot fine resolution basemaps beyond hillshades
 - Great for creating faceted maps to compare time frames



PLOTTING: TMAP_MODE("VIEW")



Interactive file:



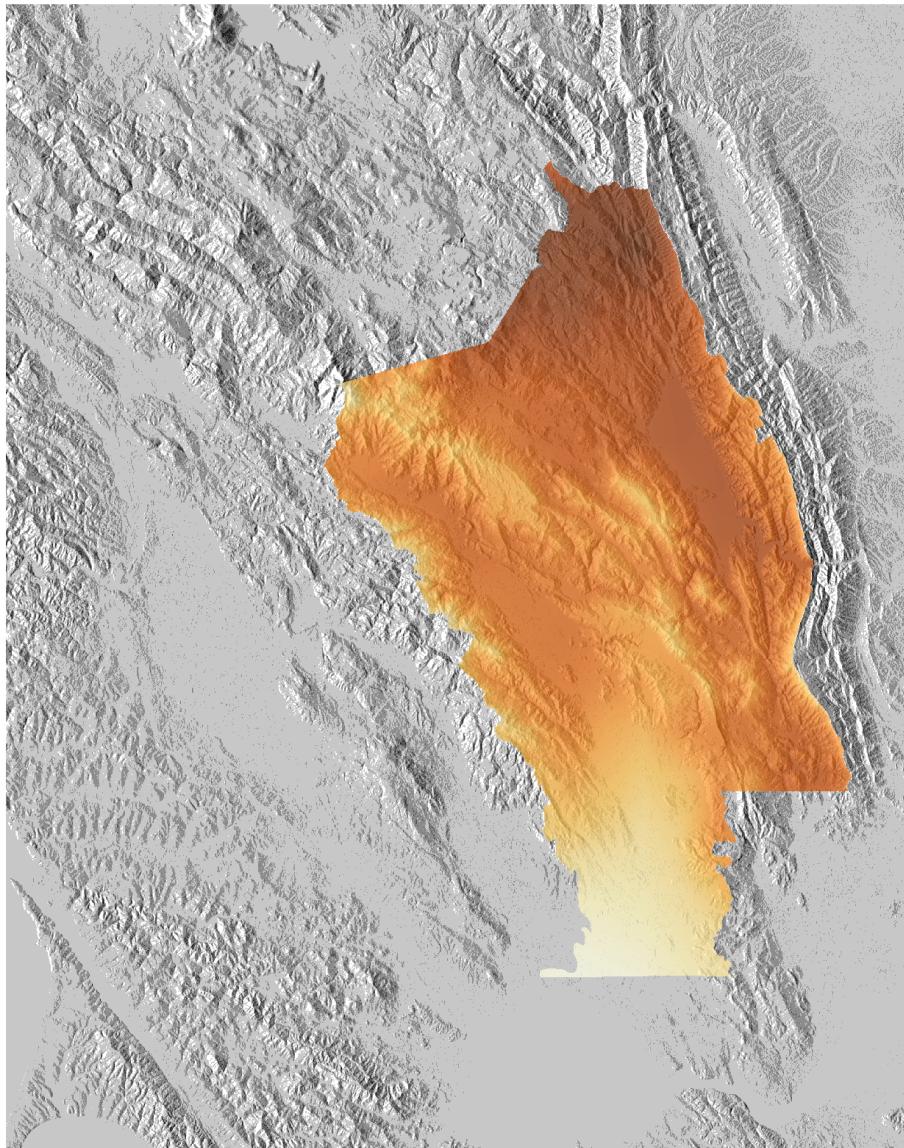
[napatopoview.html](#)

Script:

```
napatopoview <- tmap_mode("view")+
  tm_basemap("Esri.WorldTopoMap")+
  tm_shape(Tmax_plot)+
  tm_raster(title = "Temperature (degrees C)", style = 'cont', alpha = .7)+
  tm_layout(title = "RCP 8.5: 2100 Predicted Mean Maximum Summer Temperature", legend.outside = TRUE, frame = FALSE)
```

PLOTTING: TMAP_MODE("PLOT")

RCP 8.5: 2100 Predicted Mean Maximum Summer T



Temperature (degrees C)

32
34
36
38
40

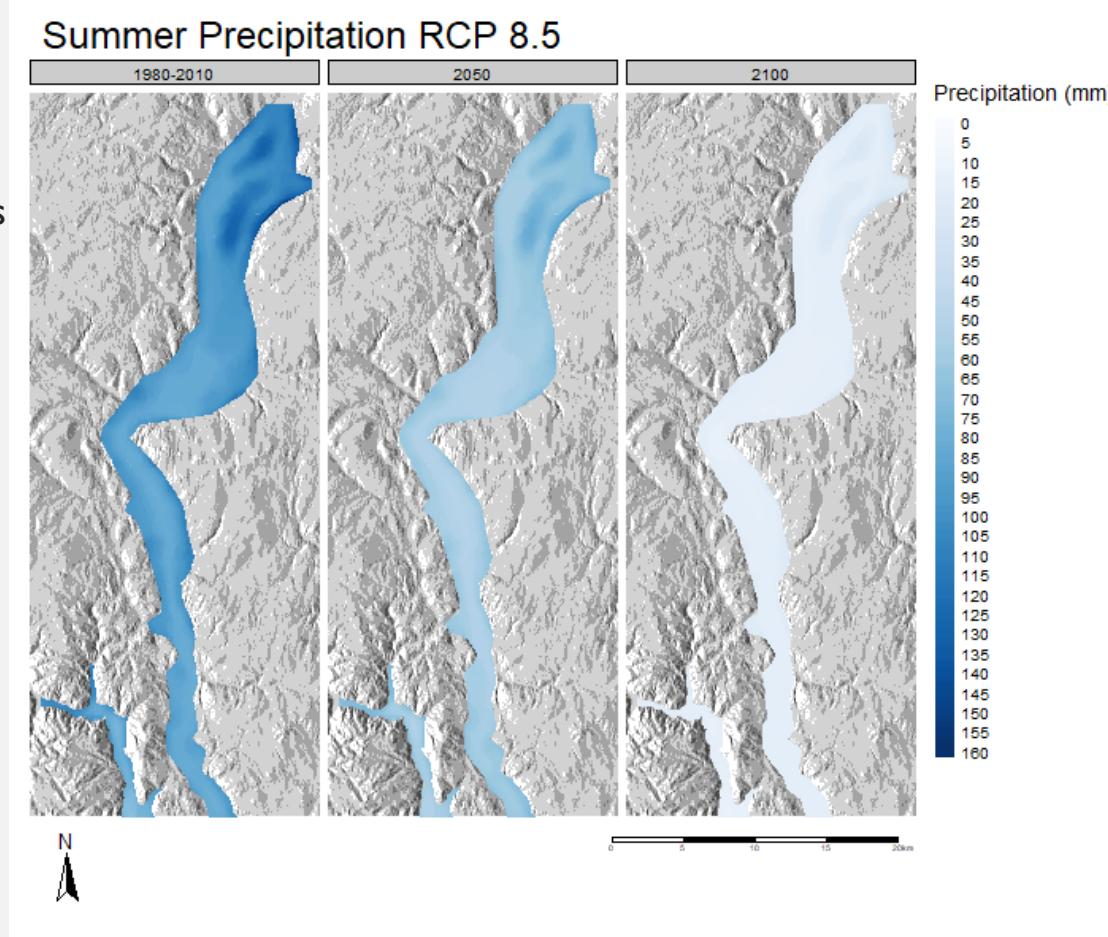
Script:

```
napahsplot <- tmap_mode("plot")+
  tm_shape(hillshade)+
  tm_raster(palette = grey(0:100/100), legend.show = FALSE)+
  tm_shape(Tmax_plot)+
  tm_raster(title = "Temperature (degrees C)", style = 'cont',
            alpha = .7)+
  tm_layout(main.title = "RCP 8.5: 2100 Predicted Mean
Maximum Summer Temperature", legend.outside = TRUE,
frame = FALSE)
```

FUNCTIONALITY BEYOND THE WALKTHROUGH

View mode

- Many different basemaps
- Scale bar
- Additional, toggleable, datasets
- Minimap
- Faceted maps



Plot mode

- Faceted maps
- North arrow

Legends

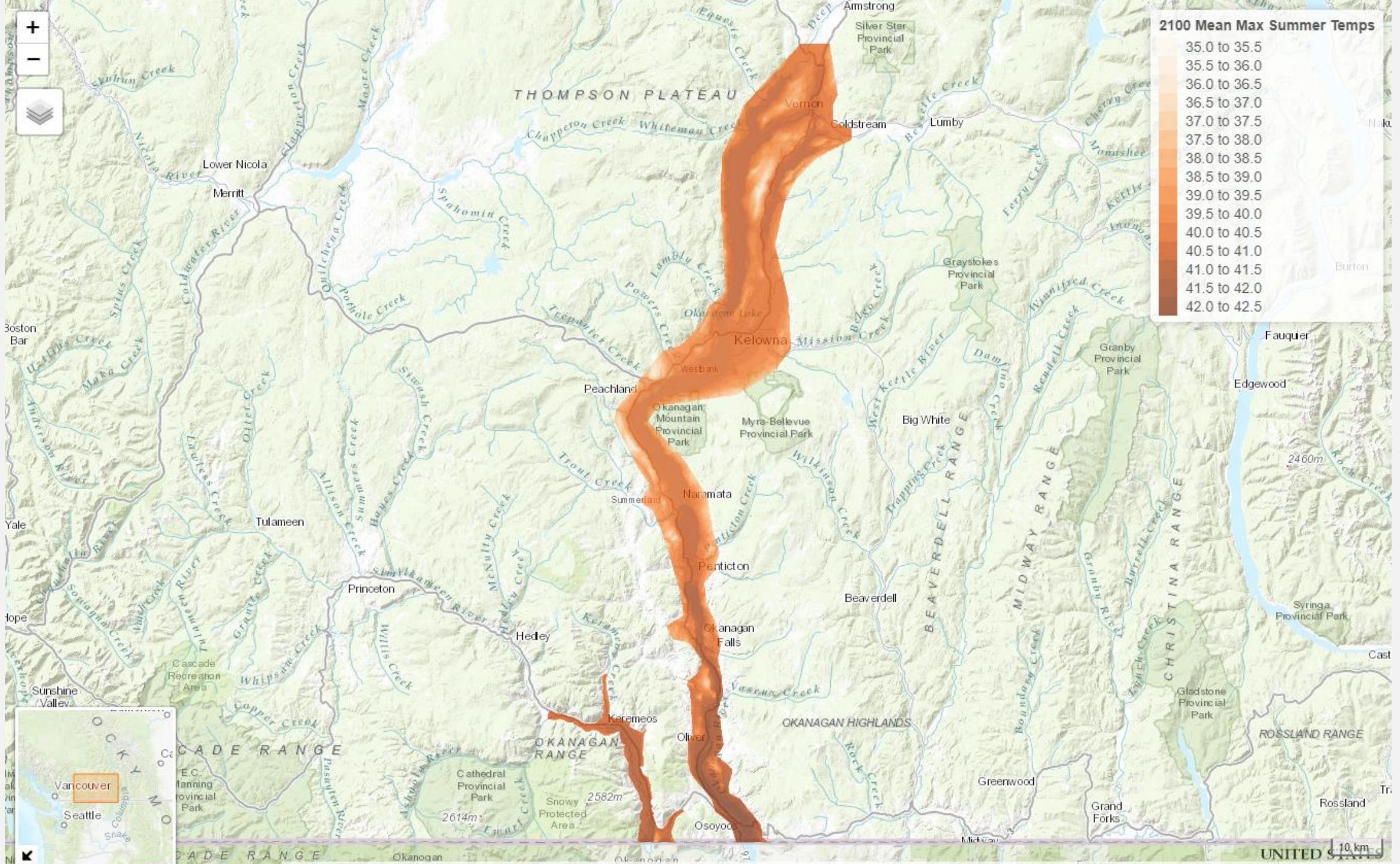
- Data categorization
- Only displaying selected data
- Data suppression

Raster Math

- Comparing different years
- Normalizing data

Max.Raster

- Default plot resolution is 1,000,000 cells



REFERENCES

- ClimateBC –
 - Wang T, Hamann A, Spittlehouse D, Carroll C (2016) Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America. PLoS ONE 11(6): e0156720. doi:10.1371/journal.pone.0156720
- “tmap” –
 - Martijn Tennekes et al (2020). <https://cran.r-project.org/web/packages/tmap/tmap.pdf>