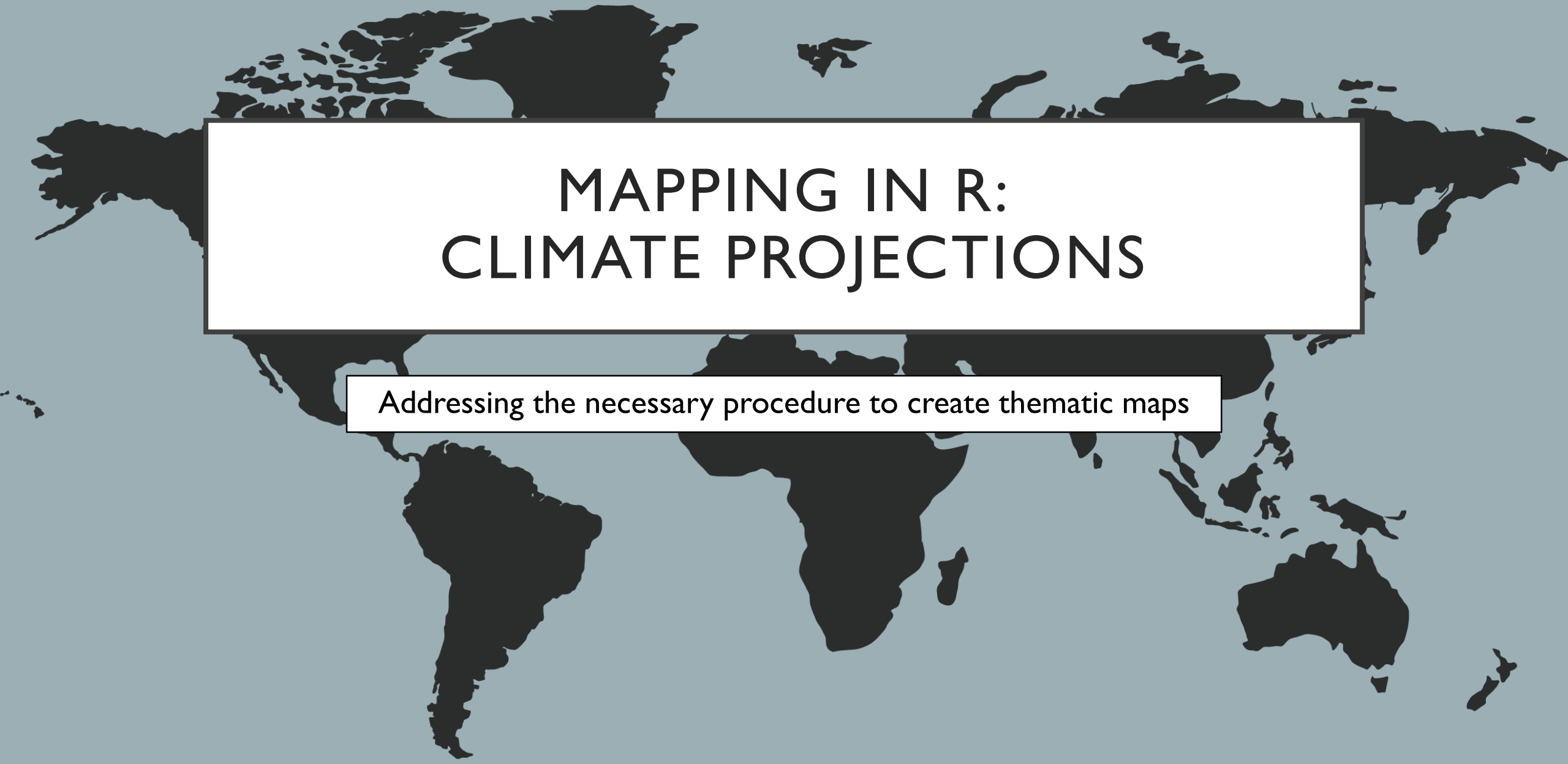
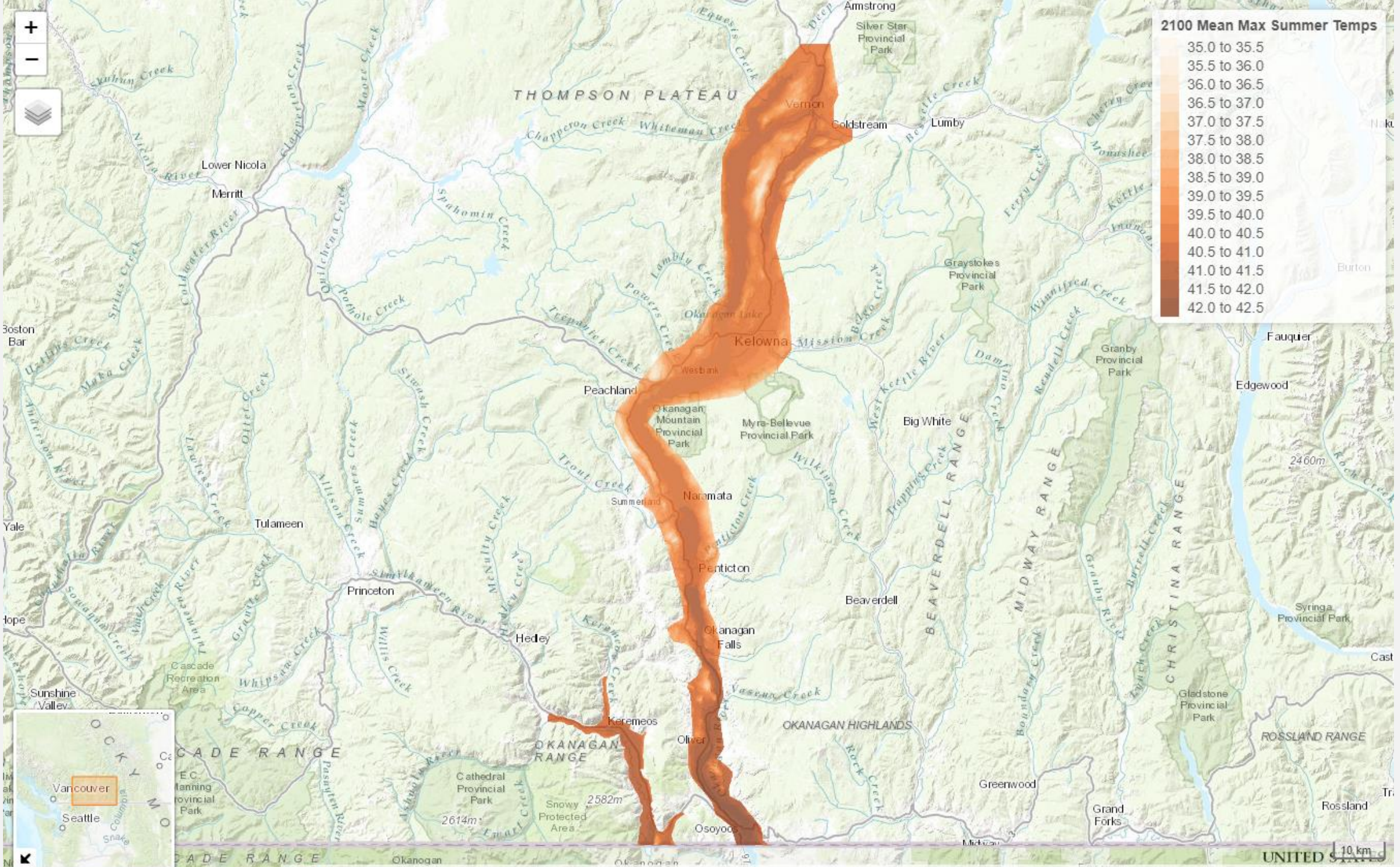


MAPPING IN R: CLIMATE PROJECTIONS

Addressing the necessary procedure to create thematic maps


2100 Mean Max Summer Temps
35.0 to 35.5
35.5 to 36.0
36.0 to 36.5
36.5 to 37.0
37.0 to 37.5
37.5 to 38.0
38.0 to 38.5
38.5 to 39.0
39.0 to 39.5
39.5 to 40.0
40.0 to 40.5
40.5 to 41.0
41.0 to 41.5
41.5 to 42.0
42.0 to 42.5
THOMPSON PLATEAU
OKANAGAN RANGE
OKANAGAN HIGHLANDS
BEAVERDELL RANGE
MIDWAY RANGE
CHRISTINA RANGE
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Graystokes Provincial Park
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Westbank
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Okanagan Mountain Provincial Park
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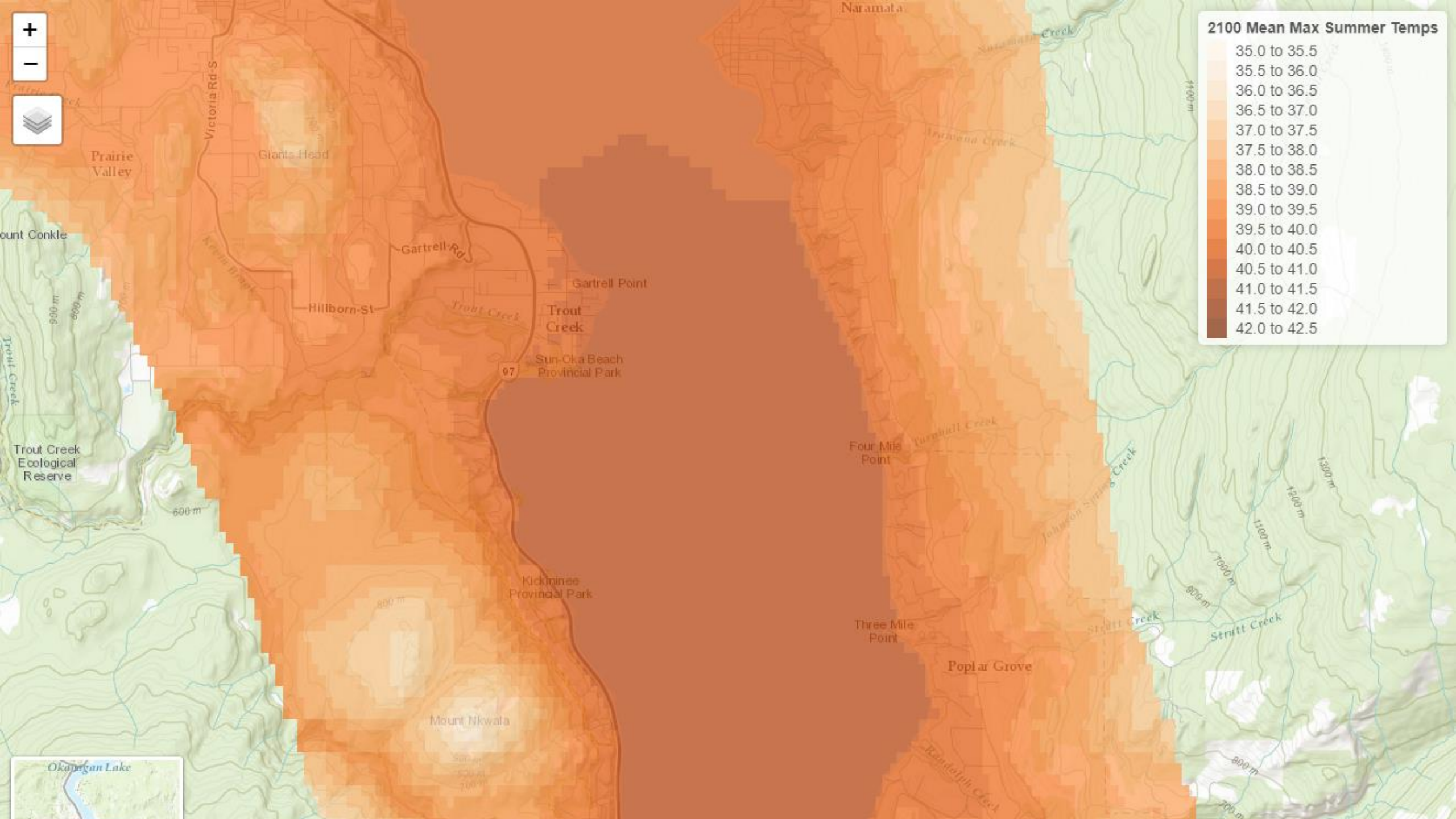
Big White
Granby Provincial Park
Fauquier
Edgewood
Naramata
Summerland
Penticton
Beaverdell
Okanagan Falls
Princeton
Hedley
Keremeos
Oliver
Osoyoos
Tulameen
Yale
Hope
Sunshine Valley
Cascade Recreation Area
Cathedral Provincial Park
Snowy Protected Area
2582m
2614m
2460m
Greenwood
Grand Forks
Rossland
Gladstone Provincial Park
Syringa Provincial Park
Vancouver
Seattle
10 km
UNITED STATES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35.5 to 36.0
36.0 to 36.5
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37.0 to 37.5
37.5 to 38.0
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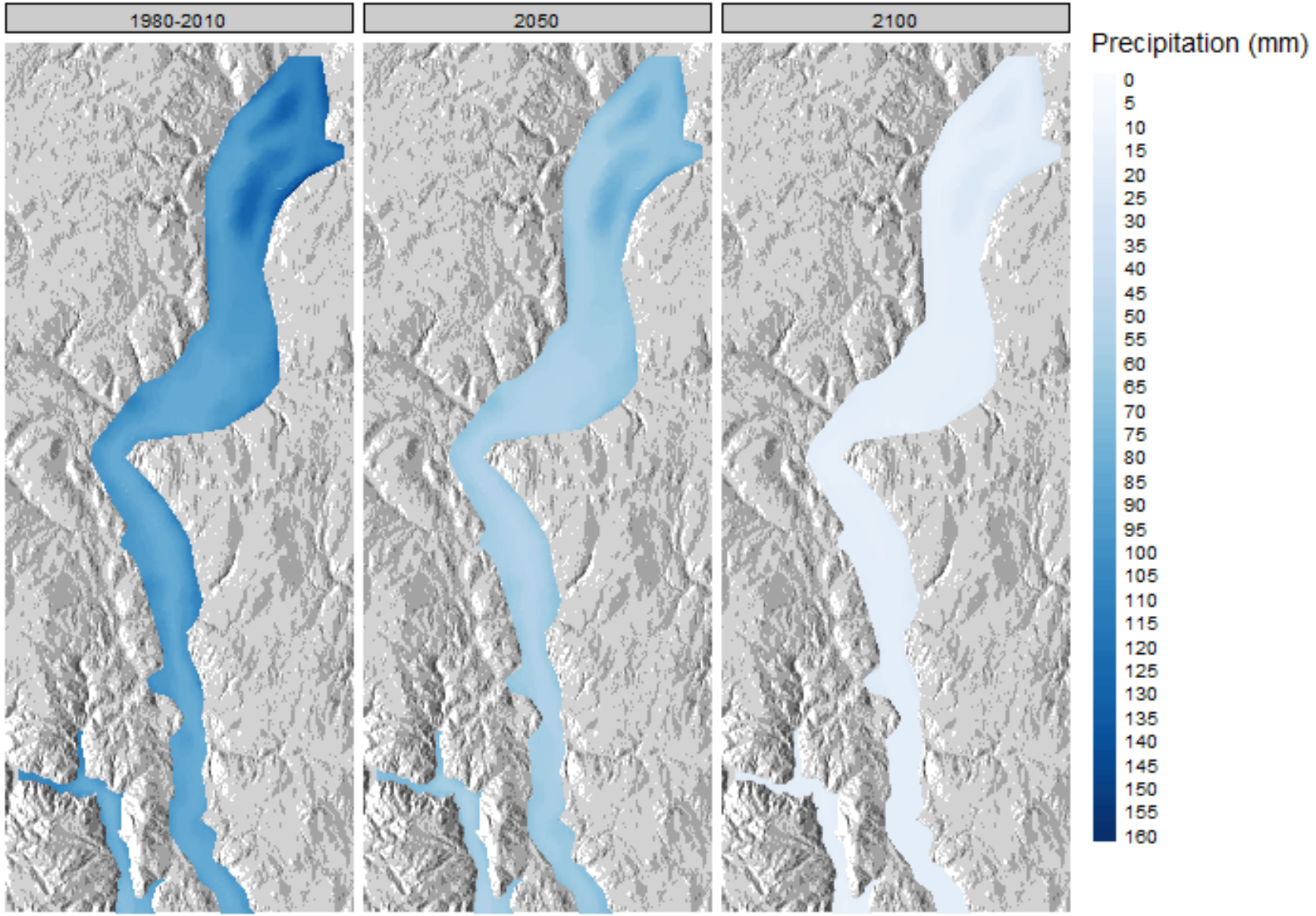
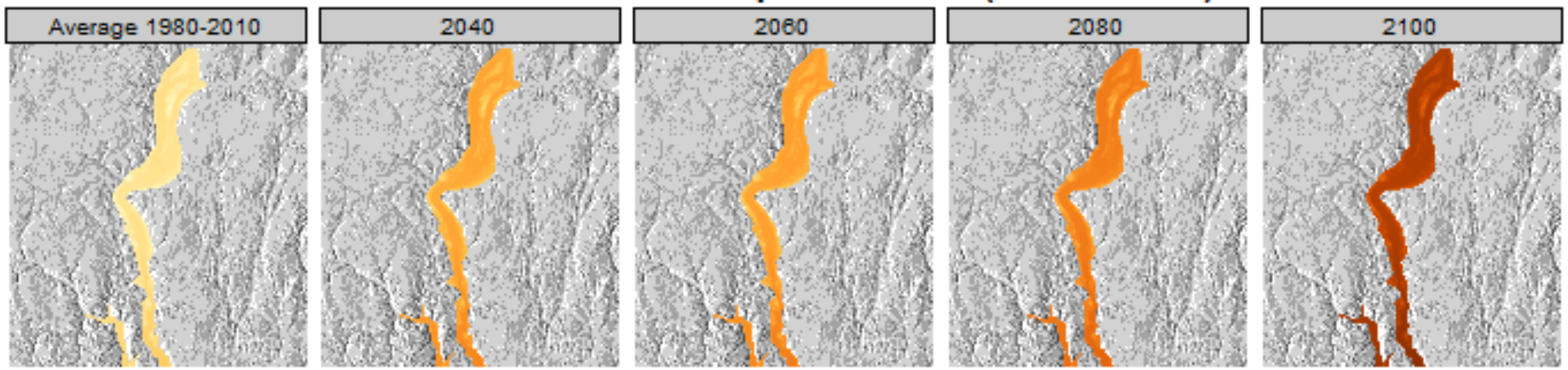
39.0 to 39.5
39.5 to 40.0
40.0 to 40.5
40.5 to 41.0
41.0 to 41.5
41.5 to 42.0
42.0 to 42.5
Naramata
Victoria Rd S
Prairie Valley
Giants Head
Gartrell Rd
Gartrell Point
Hillborn St
Trout Creek
Sun-Oka Beach Provincial Park
97
Trout Creek Ecological Reserve
Kickininee Provincial Park
Mount Nkwala
Four Mile Point
Three Mile Point
Poplar Grove
Strutt Creek
Okanagan Lake

Summer Precipitation RCP 8.5



Mean Maximum Summer Temperature (RCP 8.5)



Temperature (degrees C) [cont]

20
25
30
35
40
45

N

0 10 20 30 40 km

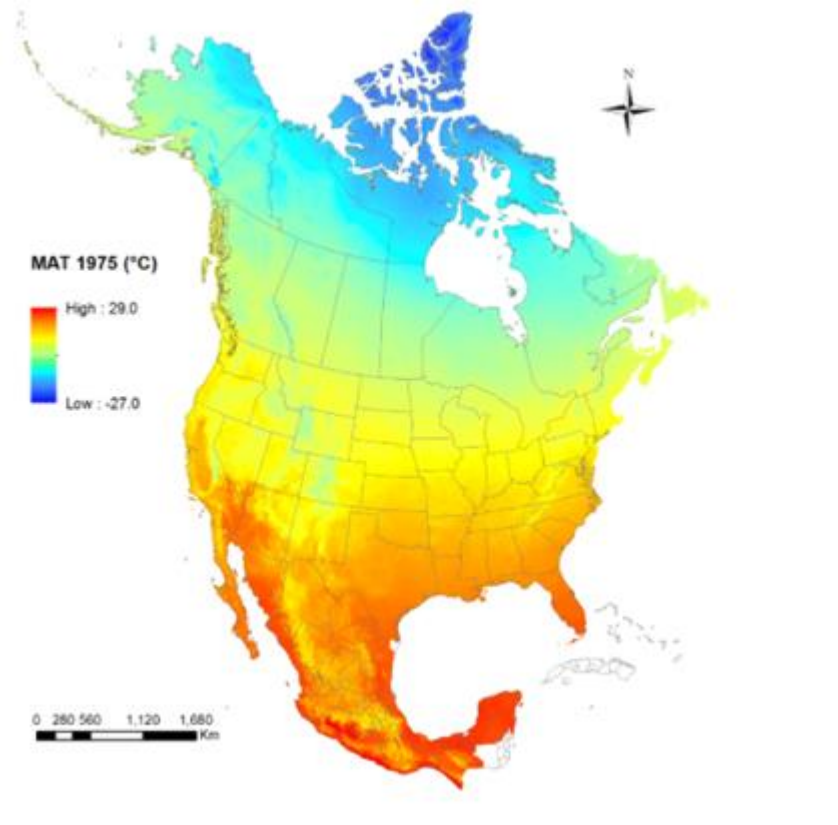
CLIMATE PROJECTIONS

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

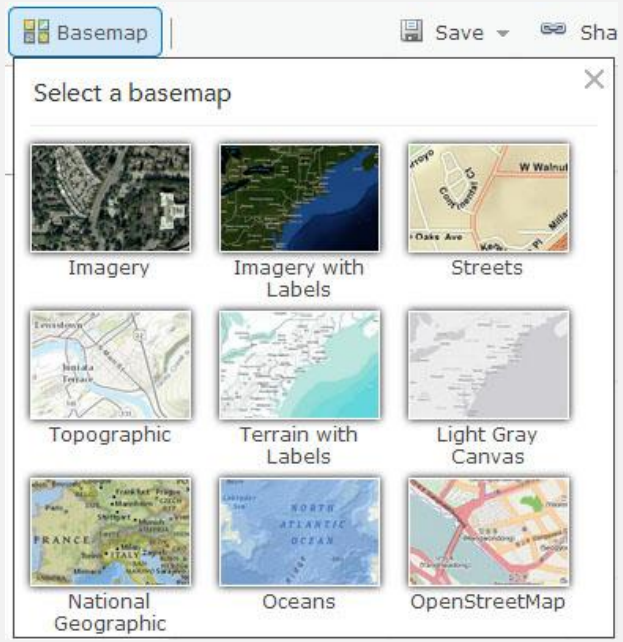


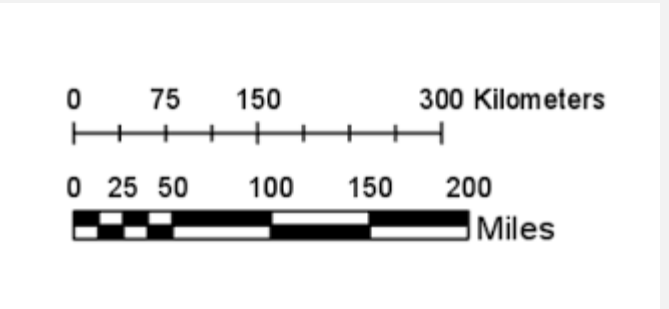
PACKAGES

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

MAP COMPONENTS

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

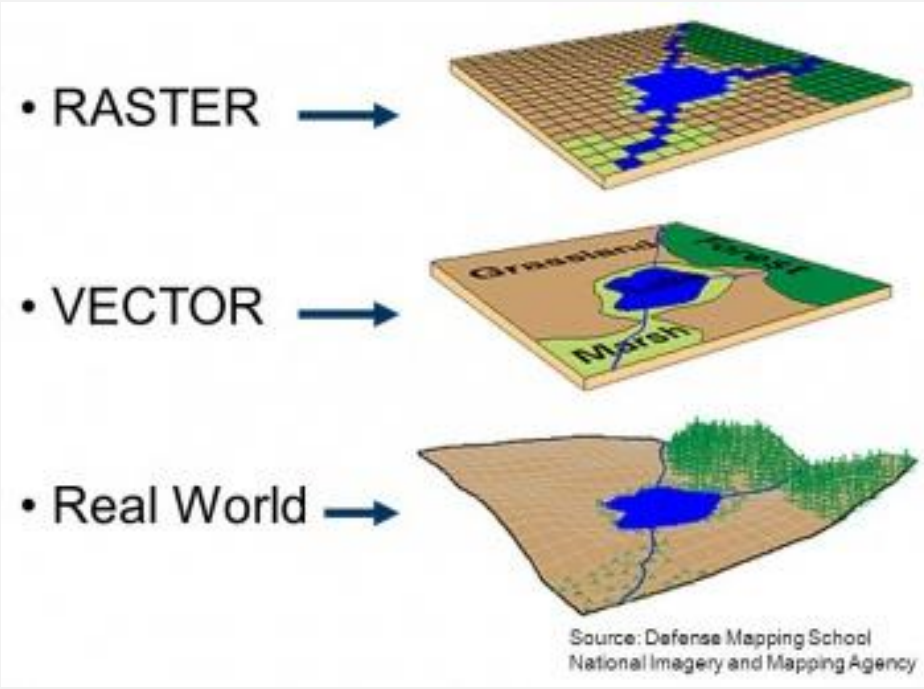




VECTOR & RASTER DATA

Vector

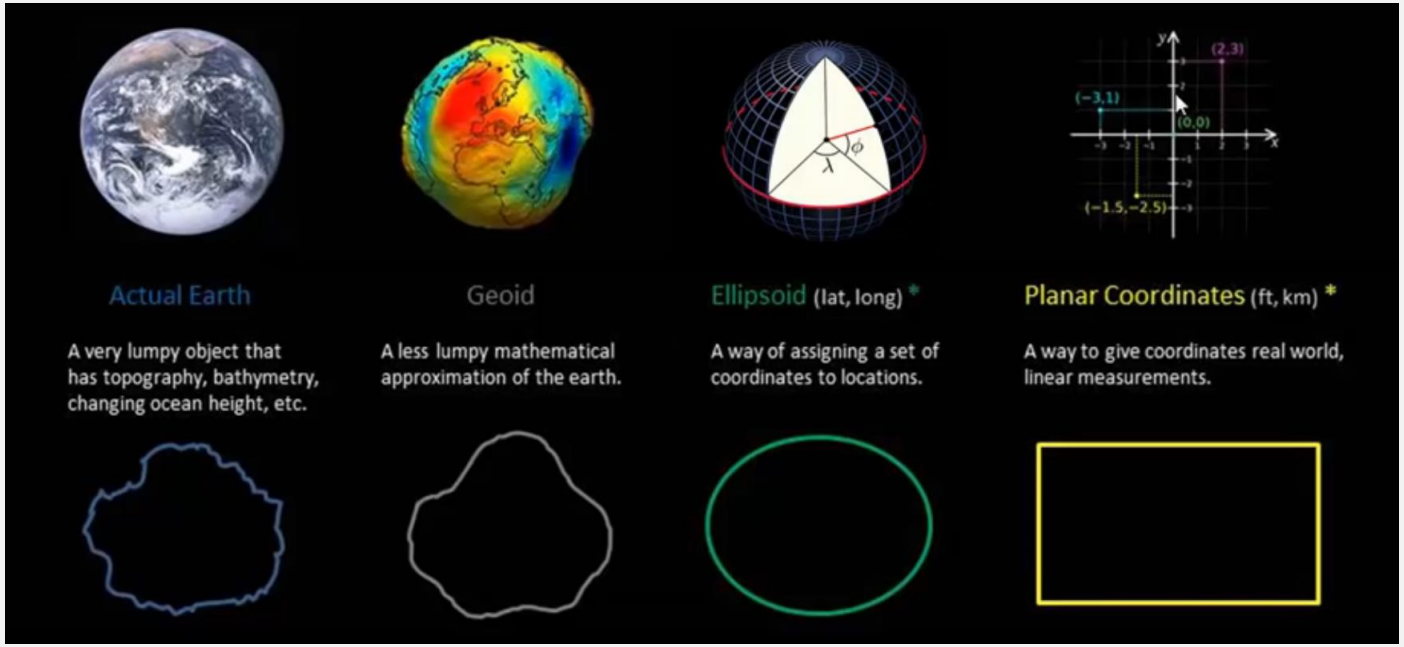
- Points, lines, polygons
- Discrete
- Can contain useful 2D data: distance and area
- File Type: KML, KMZ, shp



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

REFERENCE/COORDINATE SYSTEMS

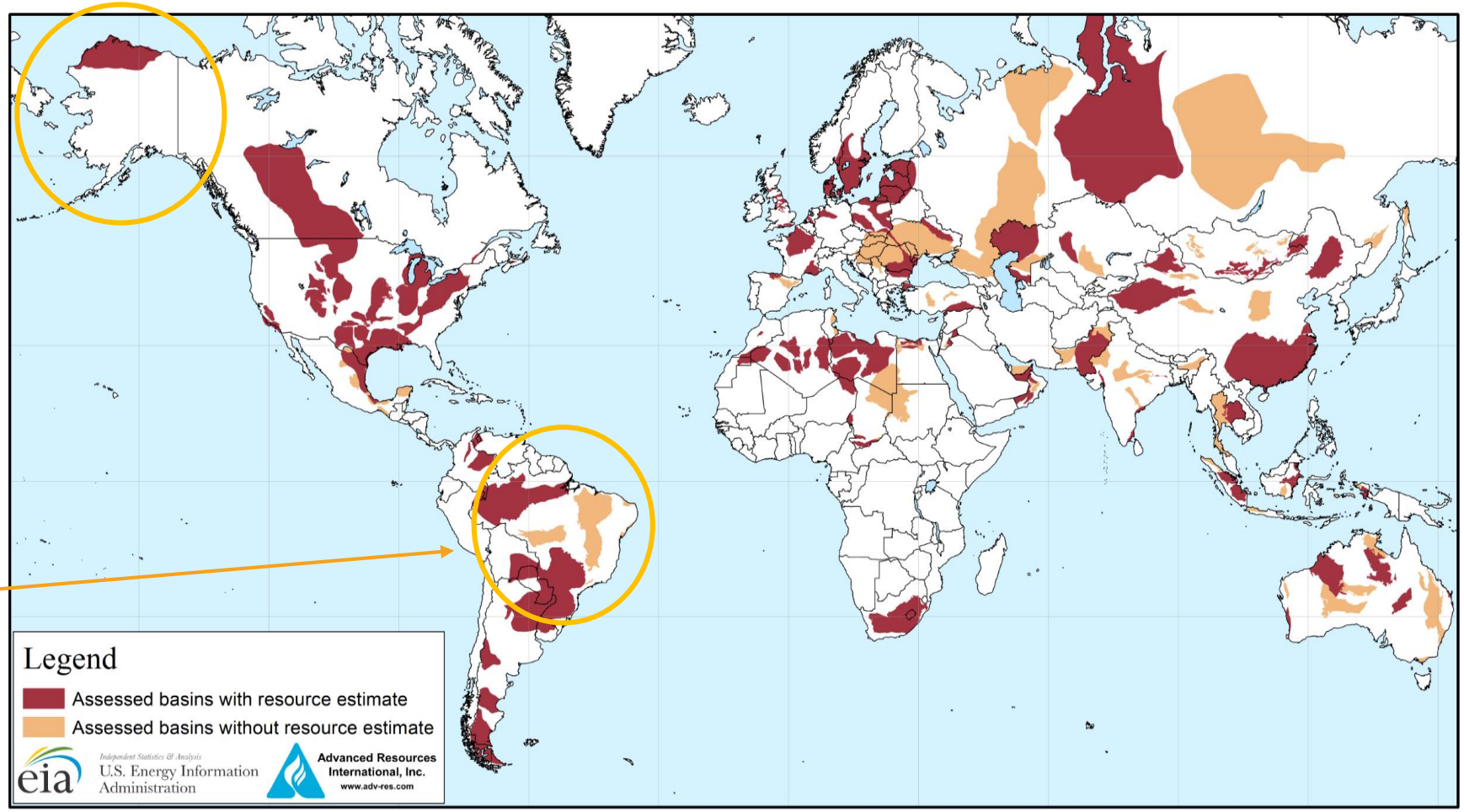


- data is related to each other spatially with reference systems
- Many types of Geographic and Projected Coordinate Systems
- For simplicity, stick to WGS 84 and plot in latitude & longitude
- Data must be in the same coordinate system to plot correctly

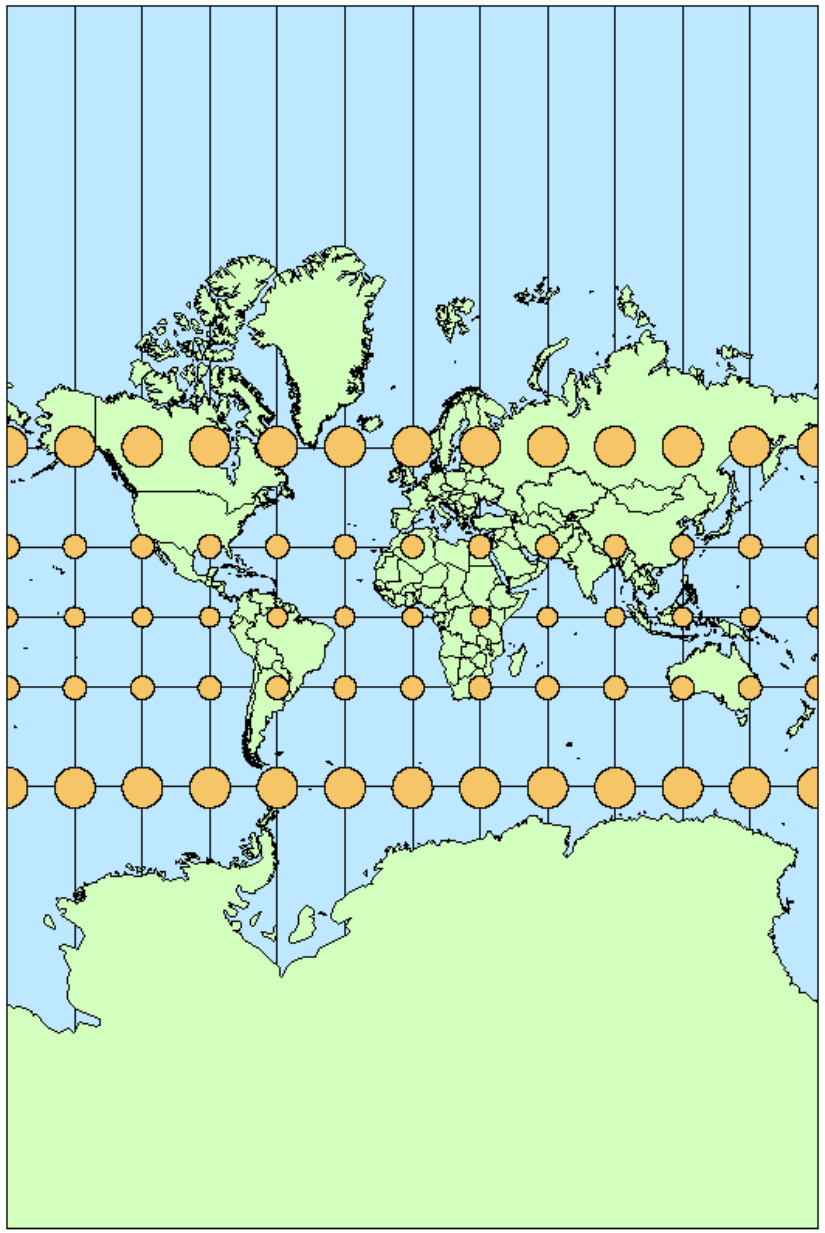
- https://www.youtube.com/watch?v=Z41Dt7_R180

Alaska is 1.718 million square km

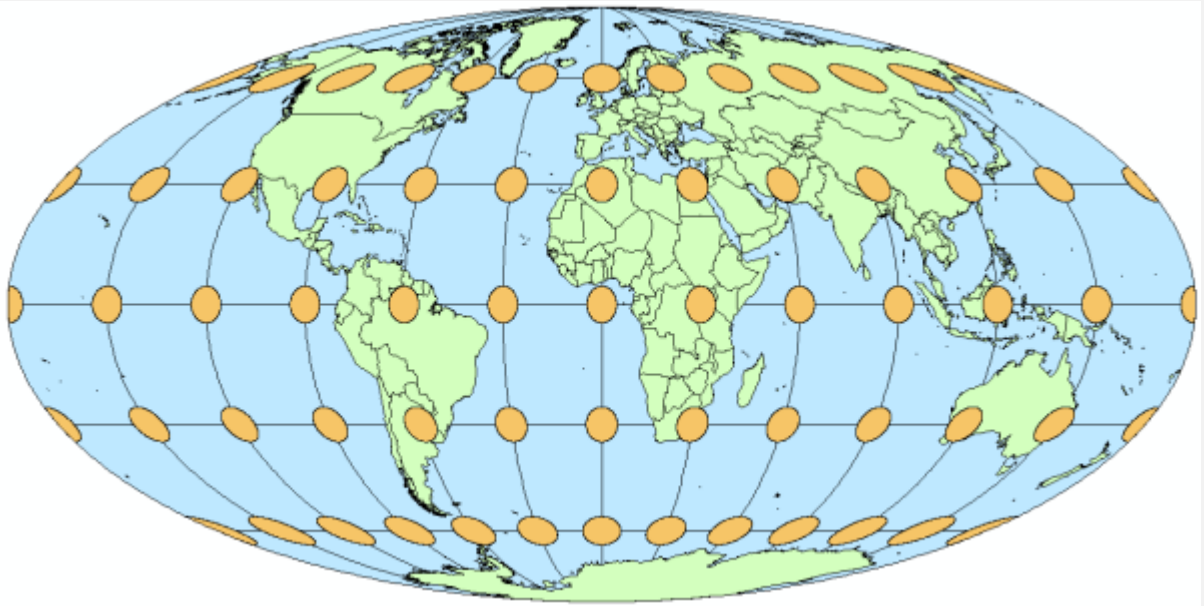
Brazil is 8.511 million square km



MERCATOR: WGS84

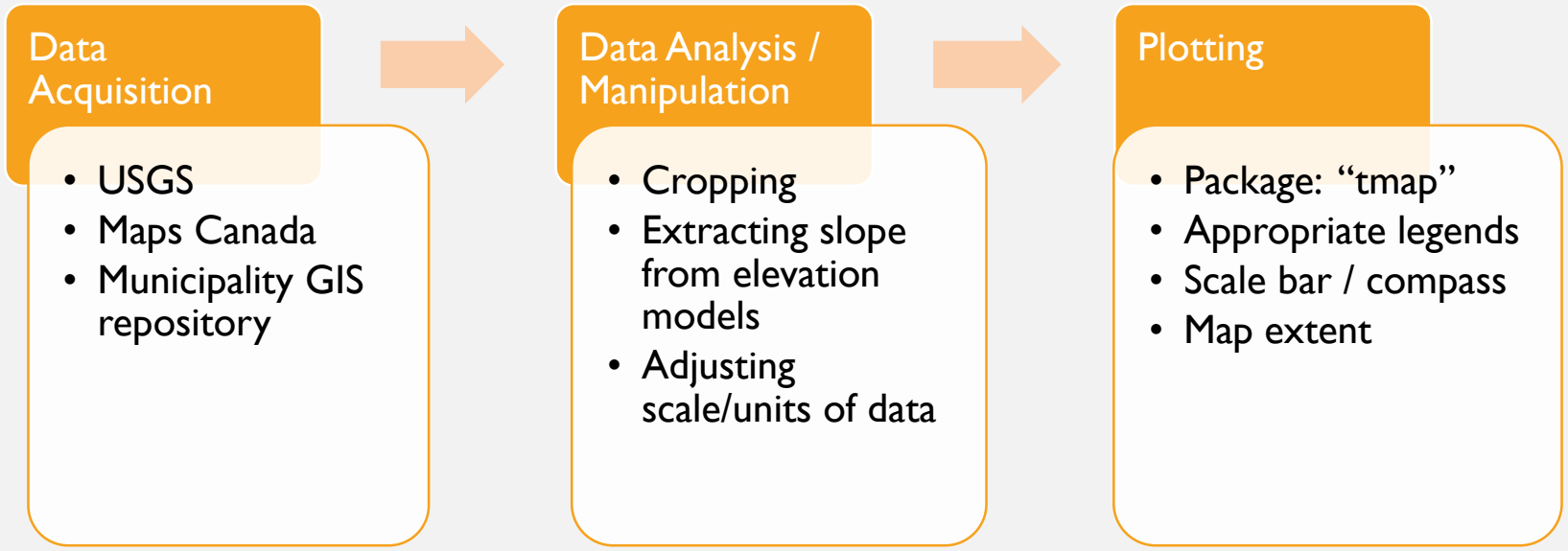


EQUAL AREA: MOLLWEIDE



Source: ESRI.com

MAP MAKING STEPS



DATA ACQUISITION: USEFUL WEBSITES

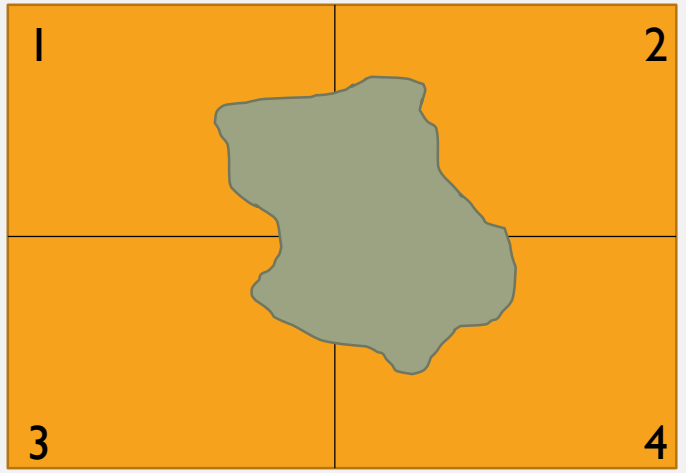
Canada:

- 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

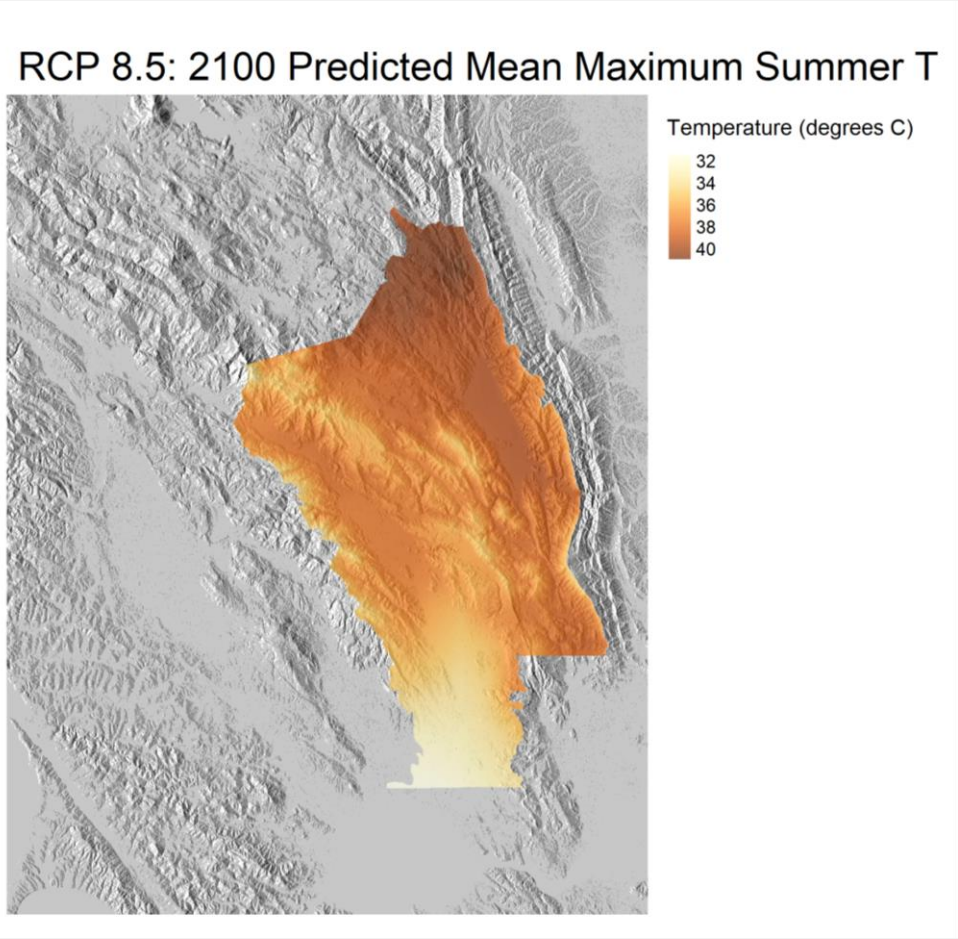
Outside of Canada:

- 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

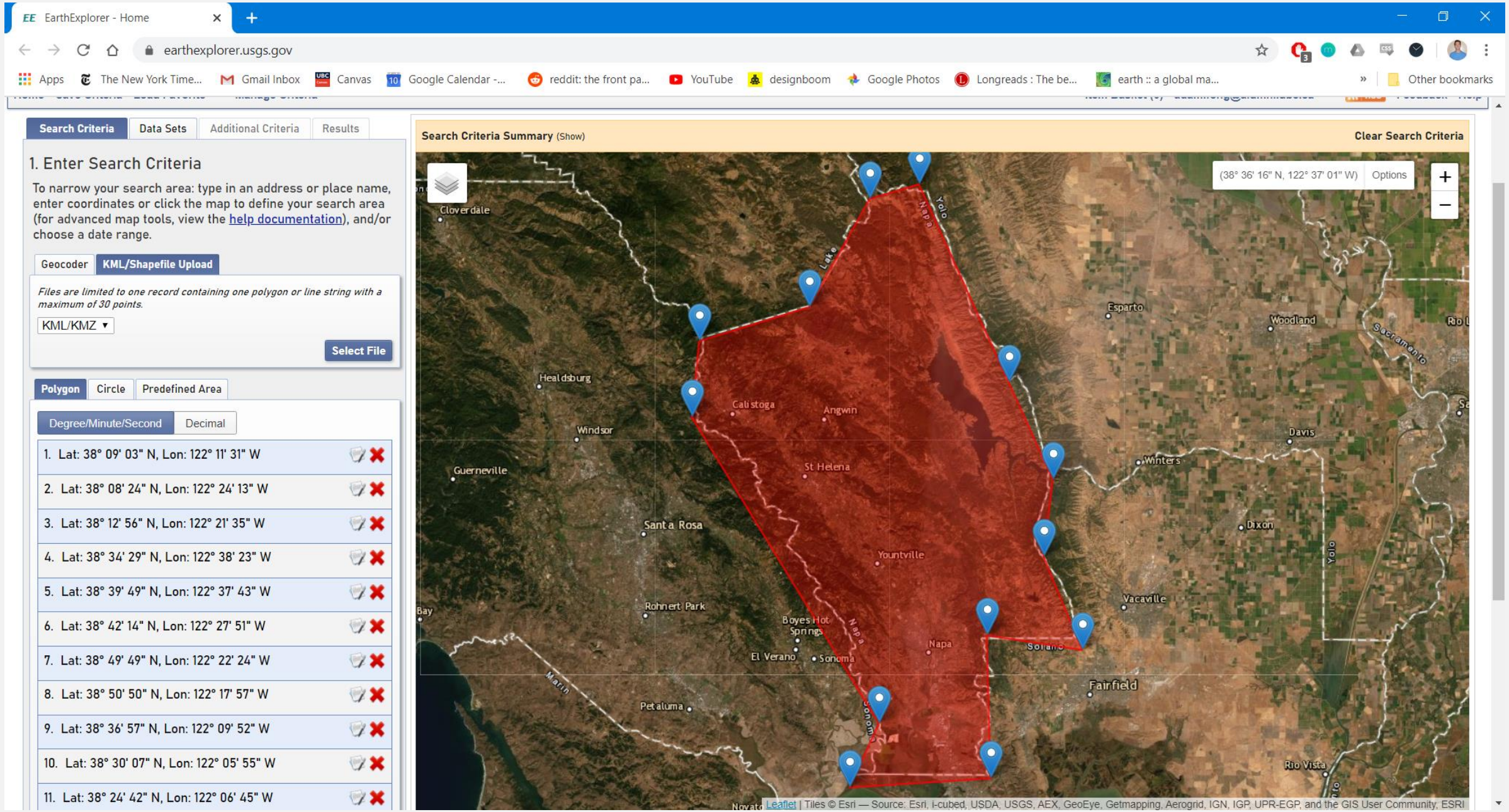


I) Data Acquisition: DEM & RCP 8.5 Climate Projections

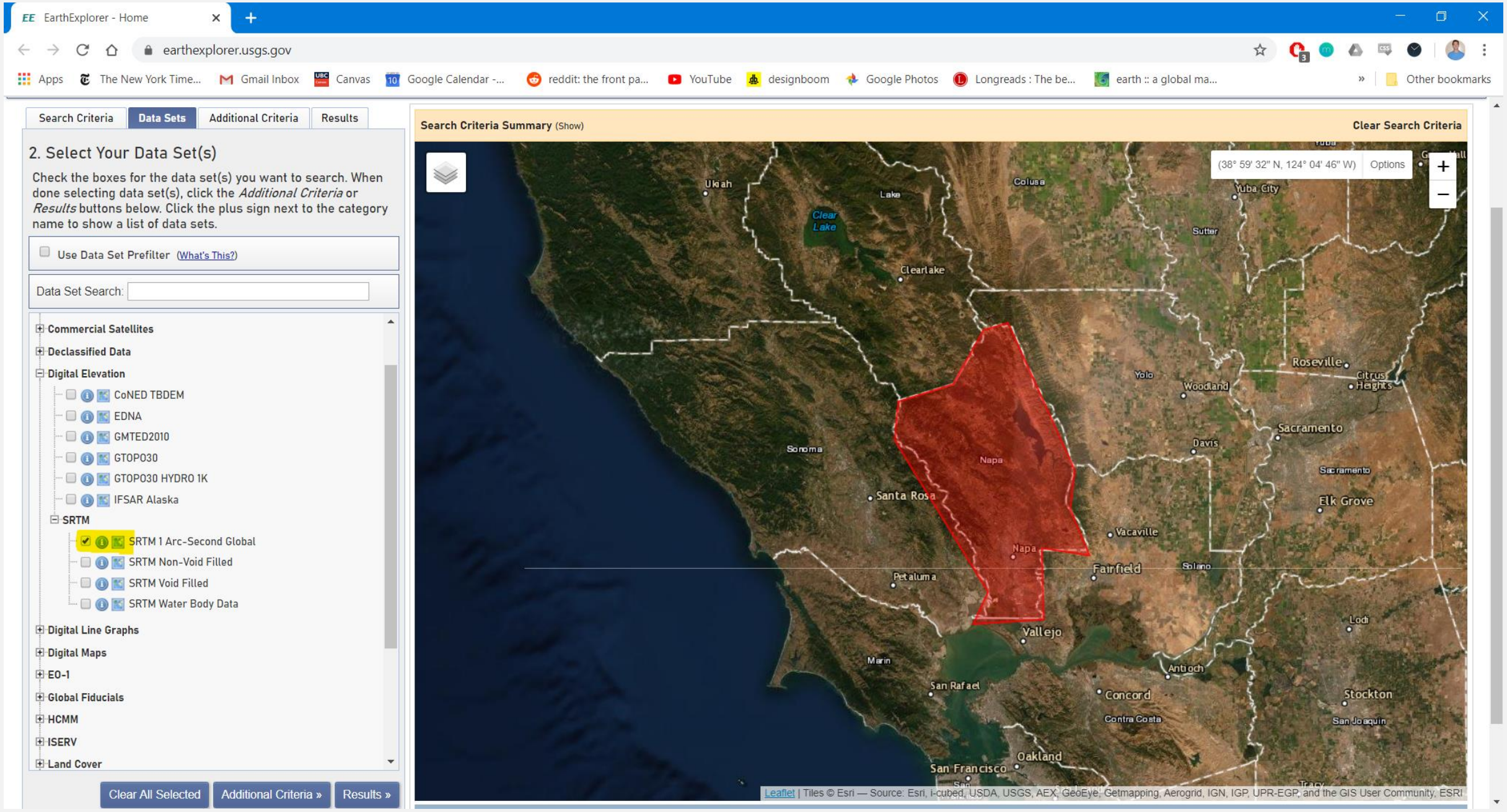
II) Data Manipulation: cropping, rescaling, creating hillshade

III) Plotting: using the functionality of "tmap" to plot informative and aesthetic maps

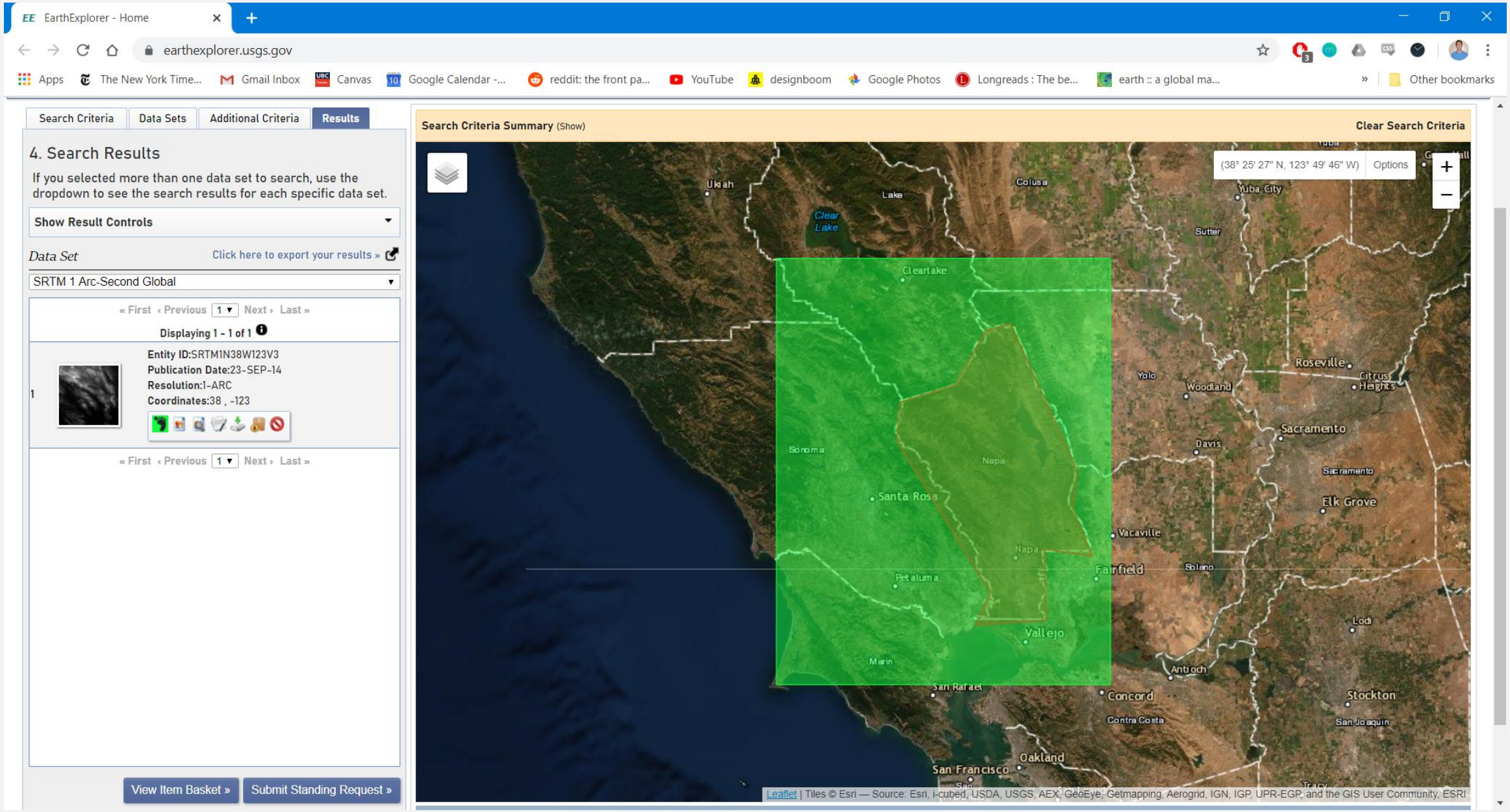
DATA ACQUISITION: DEM FROM USGS



DATA ACQUISITION: DEM FROM USGS



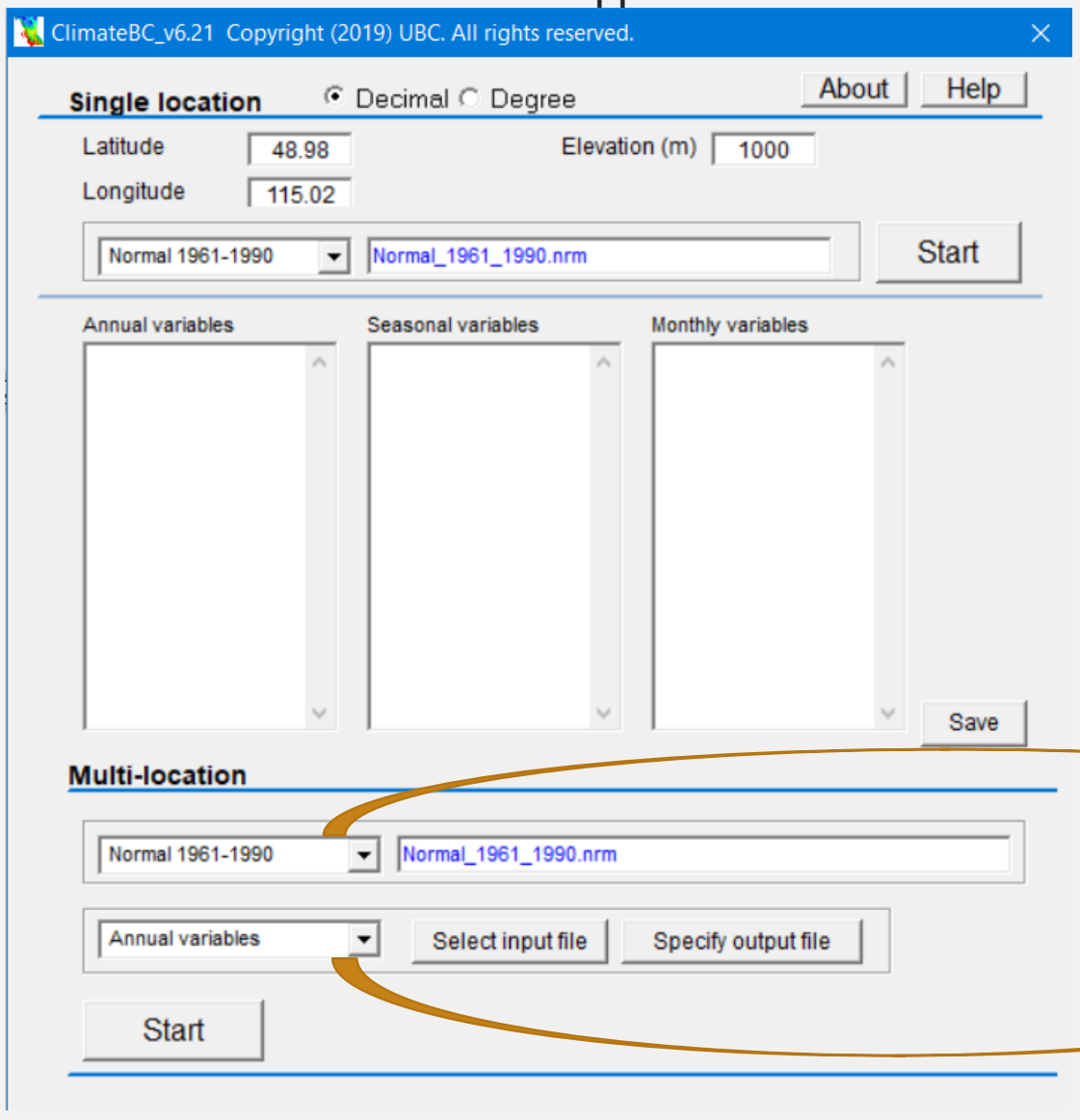
DATA ACQUISITION: DEM FROM USGS

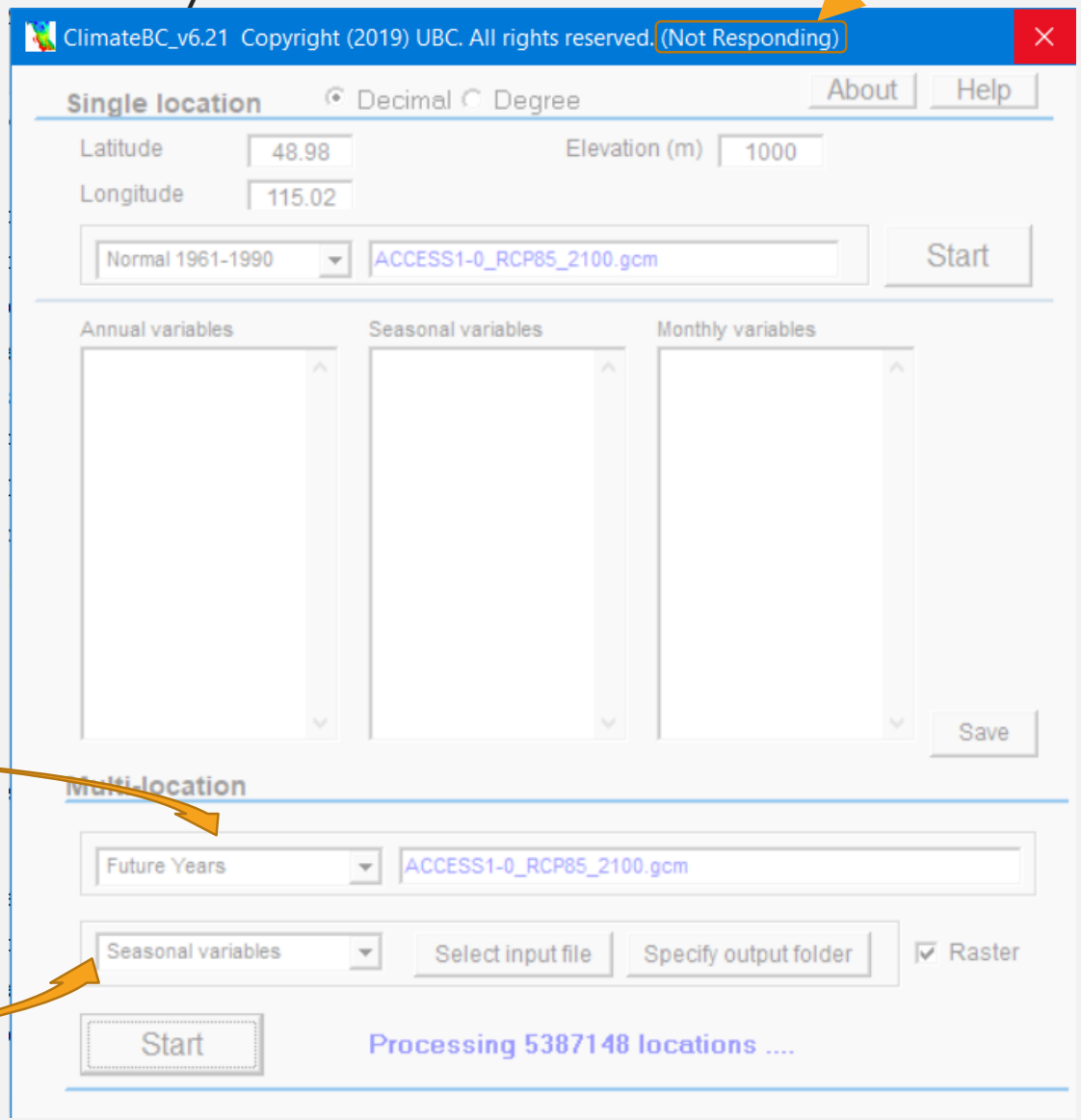


Napa DEM 1 arcsecond resolution: napa_1arc.tif aka NapaDEM.tif

DATA ACQUISITION: CLIMATE PROJECTIONS

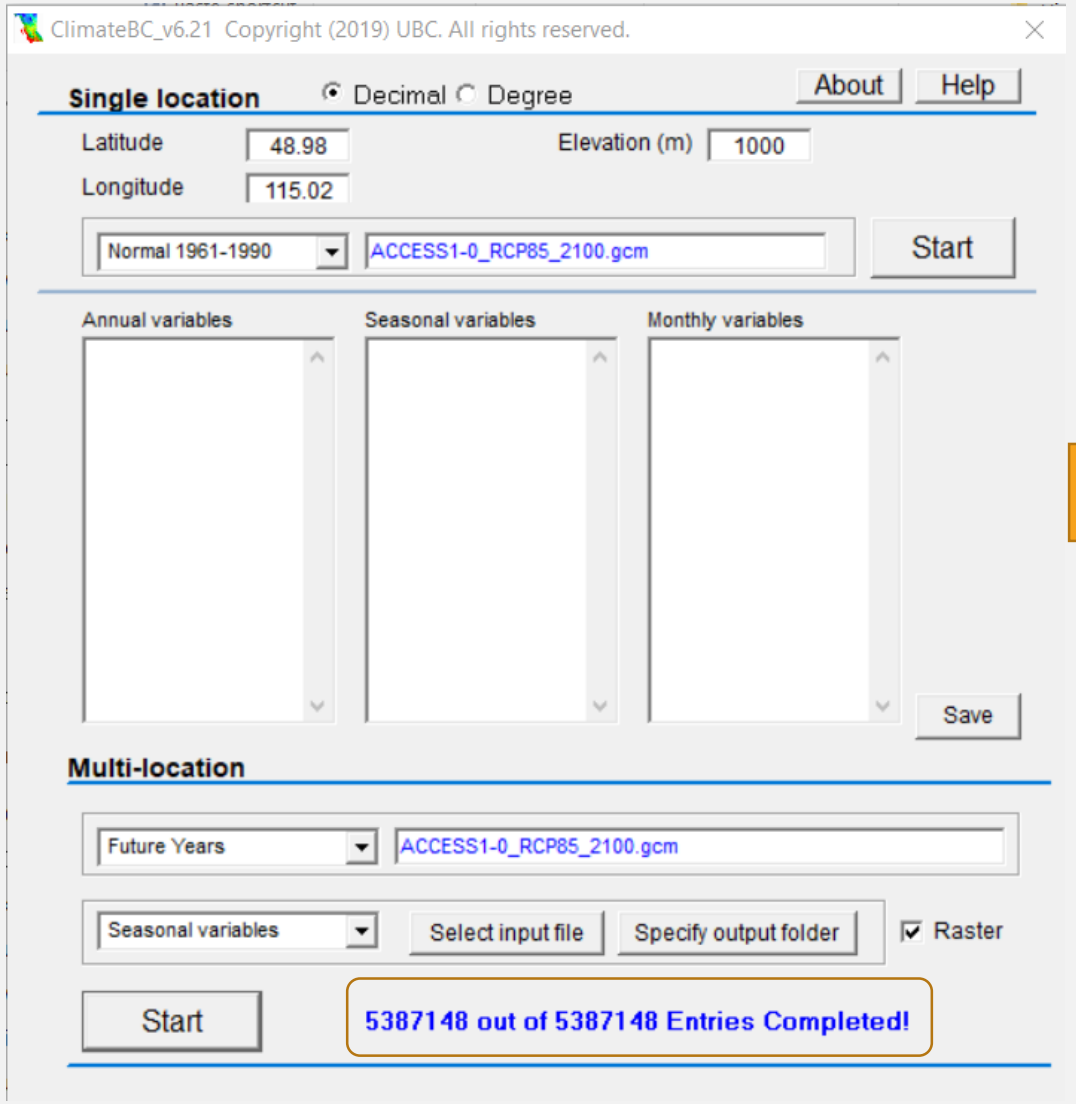
- I then downloaded a .shp file of Napa Country through a Berkeley data archive
- I cropped the DEM.tif file with the border of the county and converted the file to .asc

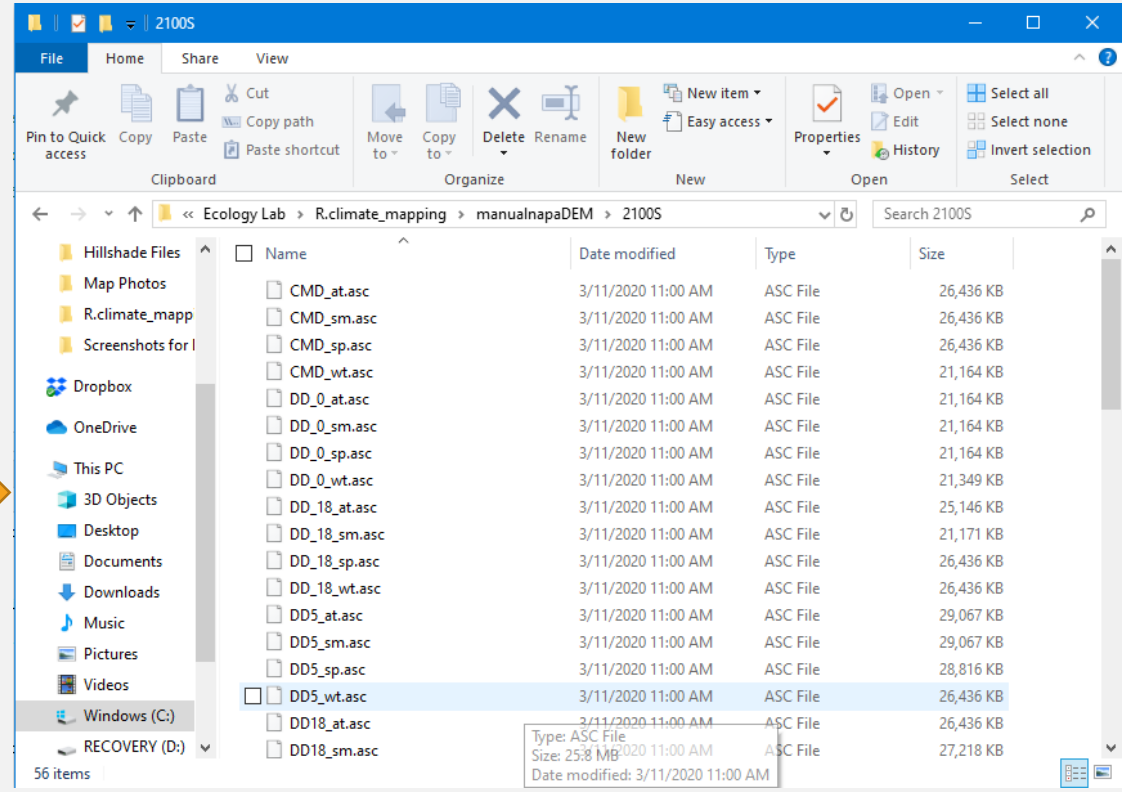




DATA ACQUISITION: CLIMATE PROJECTIONS

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





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)
```

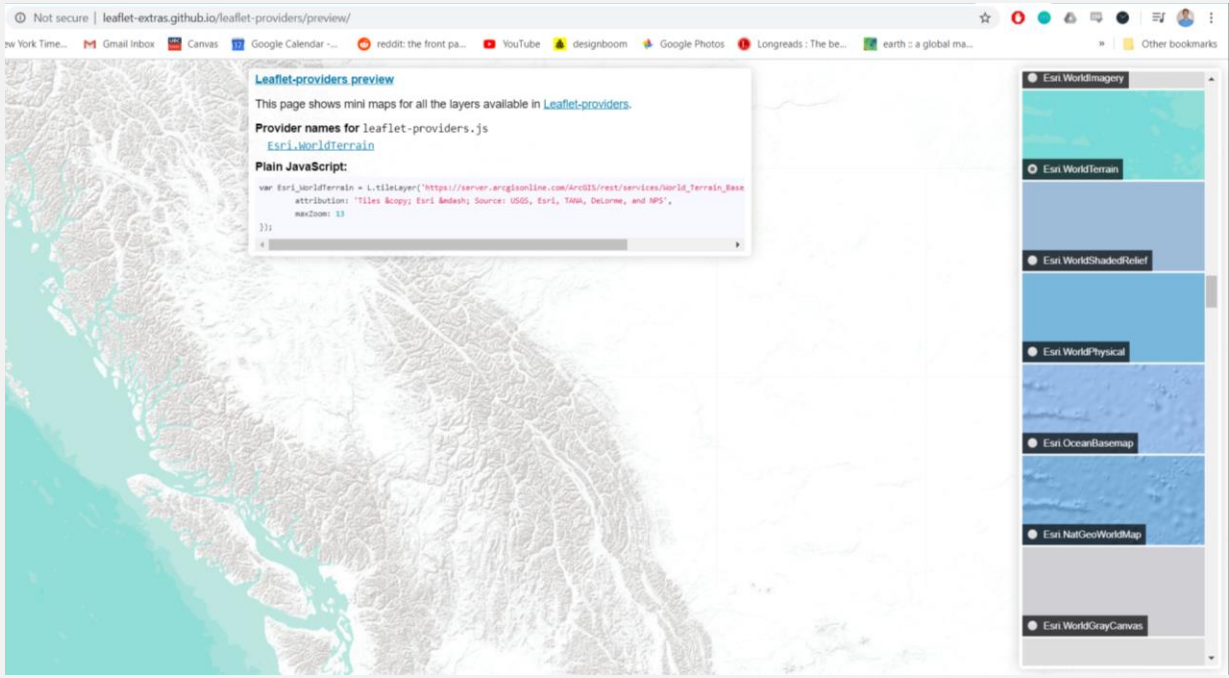
"raster"

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

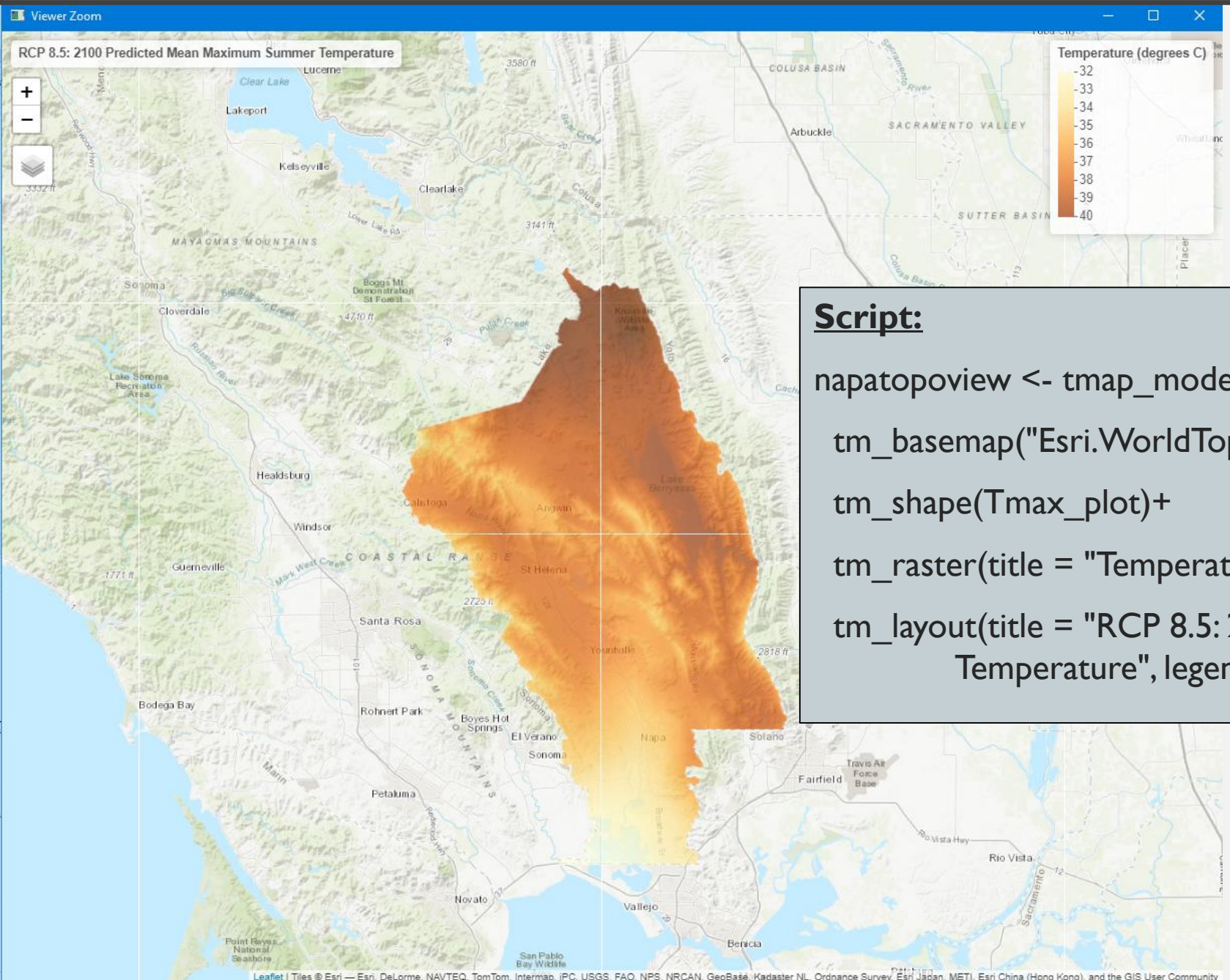
Confirm the hillshade looks correct by plotting

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")



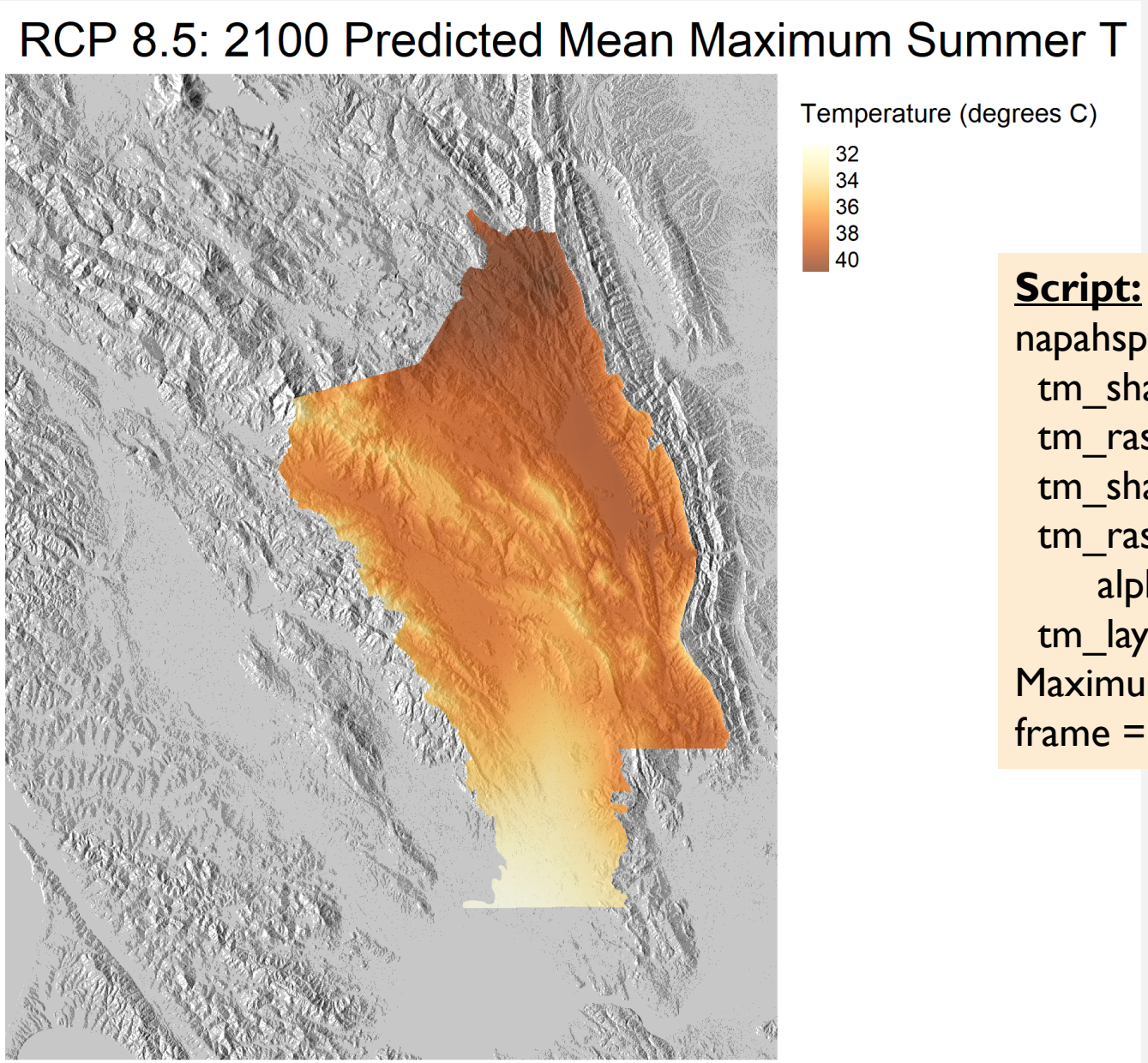
Interactive file:

napa_topo_view.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")



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

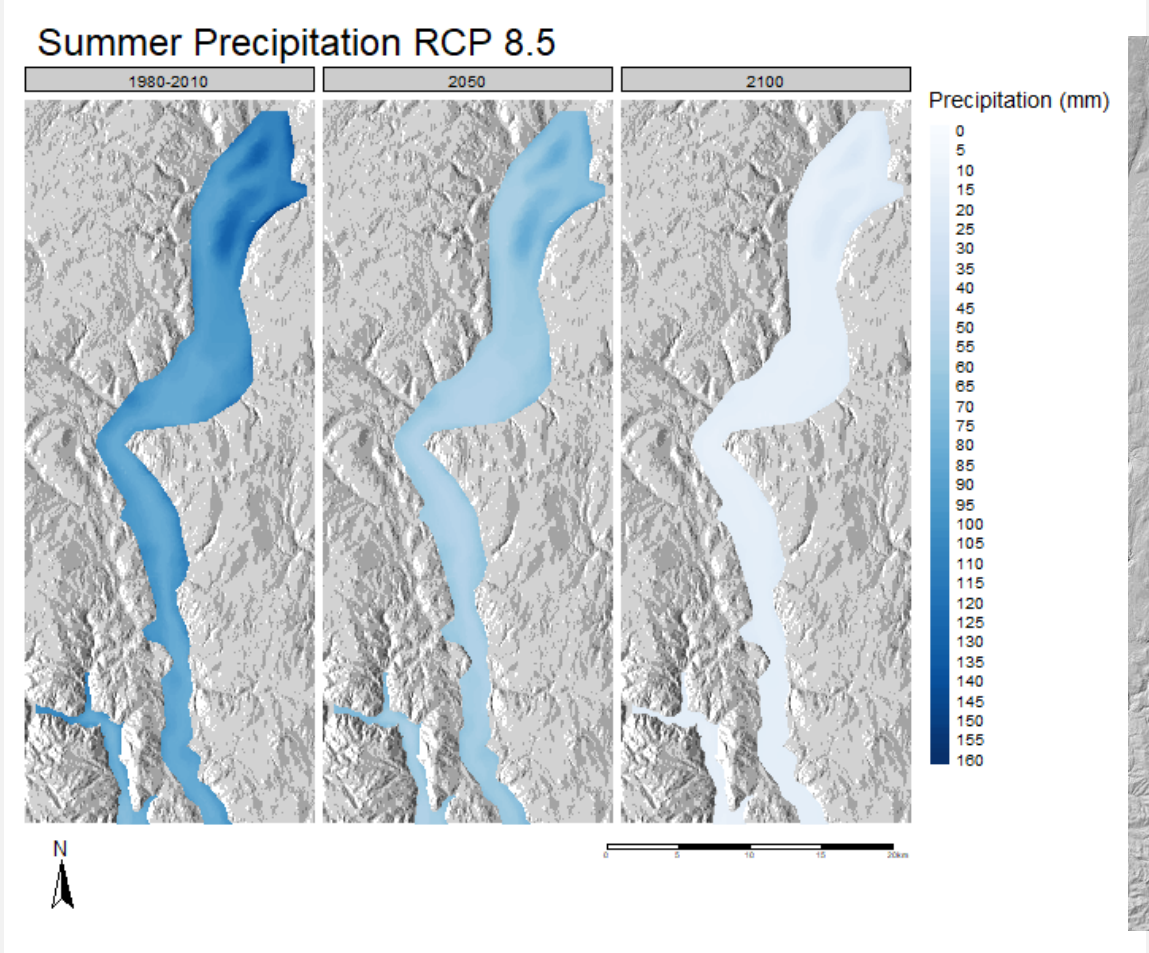
- Data categorization
- Only displaying selected data
- Data suppression

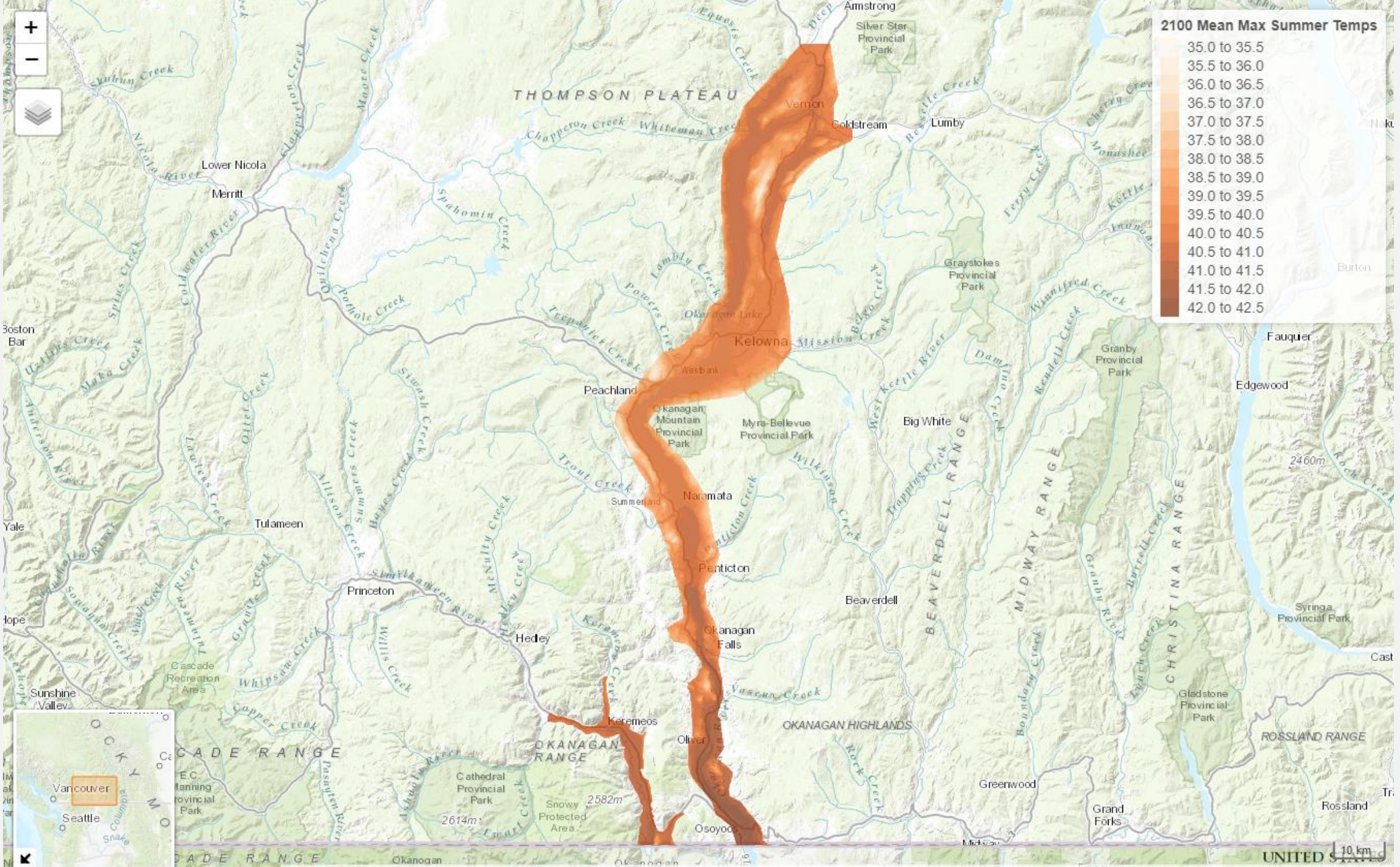
Raster Math

- Comparing different years
- Normalizing data

Max.Raster

- Default plot resolution is 1,000,000 cells

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Oliver
Osoyoos
Tulameen
Yale
Hope
Sunshine Valley
Cascade Recreation Area
Cathedral Provincial Park
Snowy Protected Area
2582m
2614m
2460m
Greenwood
Grand Forks
Rossland
Gladstone Provincial Park
Syringa Provincial Park
Vancouver
Seattle
10 km
UNITED STATES

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