[Note: an updated version of these tutorials is being developed for the 2025 SRF conference. New URL will be added here when ready]

Salmonid Restoration Federation 2023 The Future Is Now: Geospatial Workshop: Tools, Techniques and Tricks

Eli Asarian, Emily Fairfax, Adam Cummings, David Dralle

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Introduction

This electronic handout covers 14 tutorials for remote sensing techniques relevant to restoration projects. These tutorials were created for use in the afternoon session of the Salmonid Restoration Federation's April 26, 2023 Remote Sensing workshop where participants will have a hands-on opportunity to do these tutorials as guided or self-paced learning. The tutorials teach methods ranging from basic to advanced, catering to different levels of expertise. Whether new to remote sensing or with prior experience, participants can use this handout to advance their remote sensing abilities and gain new insights to further their salmonid restoration work.

Techniques include:
- Accessing and georeferencing historical imagery and topographic maps
- Accessing satellite-based imagery and derived products
- Calculating a hydrologic budget for a watershed
- Tricks to visualize elevation data

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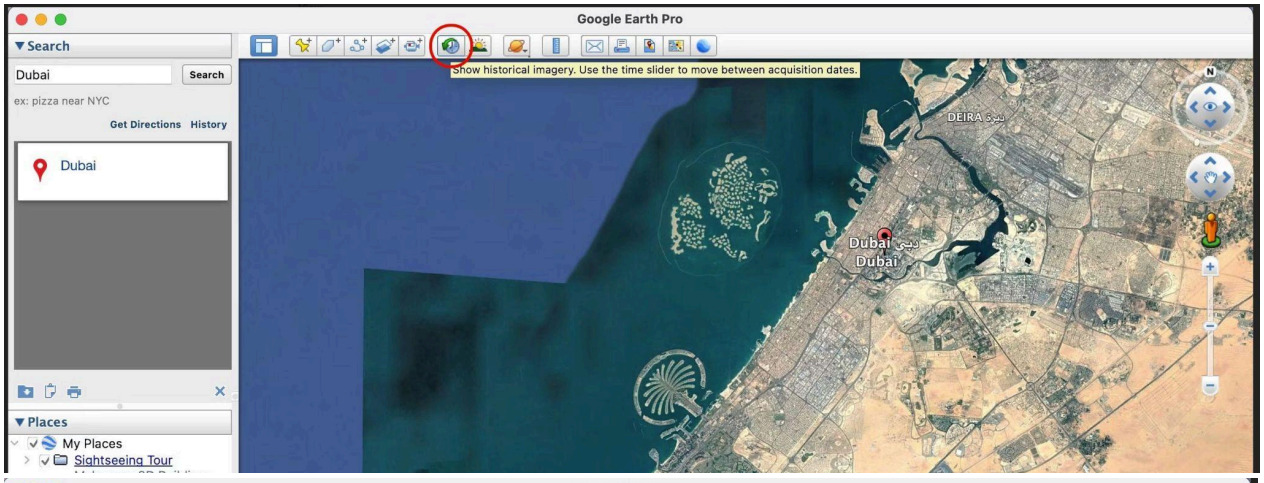
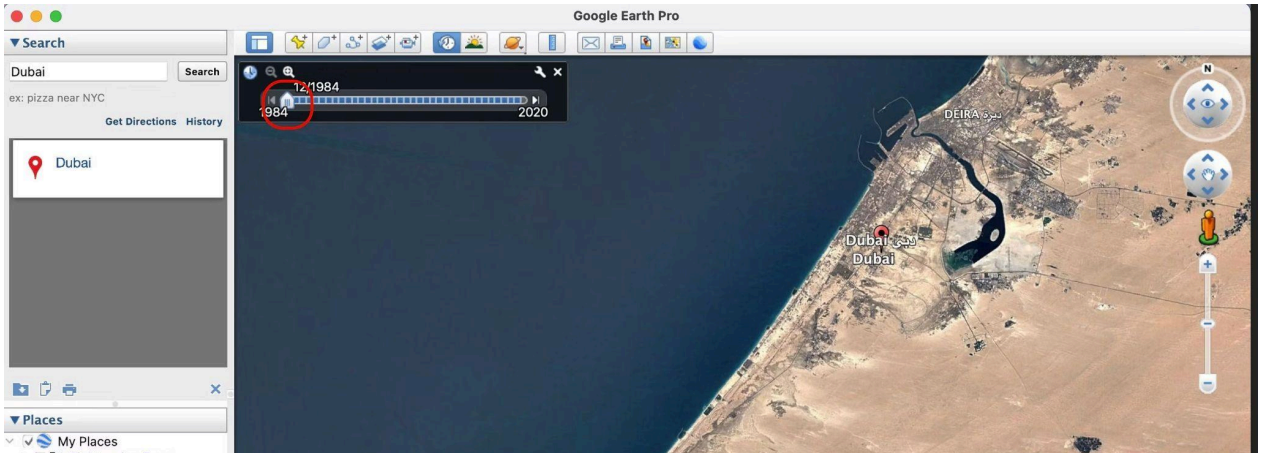
Imagery and historical maps

Use Google Earth's time slider to compare historical images 1990s–present (Tutorial 1)

Software: Google Earth Pro desktop
Difficulty: Easy
Time: 5–15 minutes
Data needs: none
Lead: Eli

Description: Google Earth Pro desktop software (https://www.google.com/earth/versions/#earth-pro) allows browsing of historical aerial imagery from the 1990s through recent years. There will also likely be a coarse-resolution Landsat satellite image from 1984. Follow steps #1 through #10 in the illustrated tutorial https://www.androidpolice.com/go-back-in-time-google-earth/ to download and install Google Earth Pro, zoom to an area of interest, and browse a series of historical aerial photographs. The following images are screen shots from the tutorial:

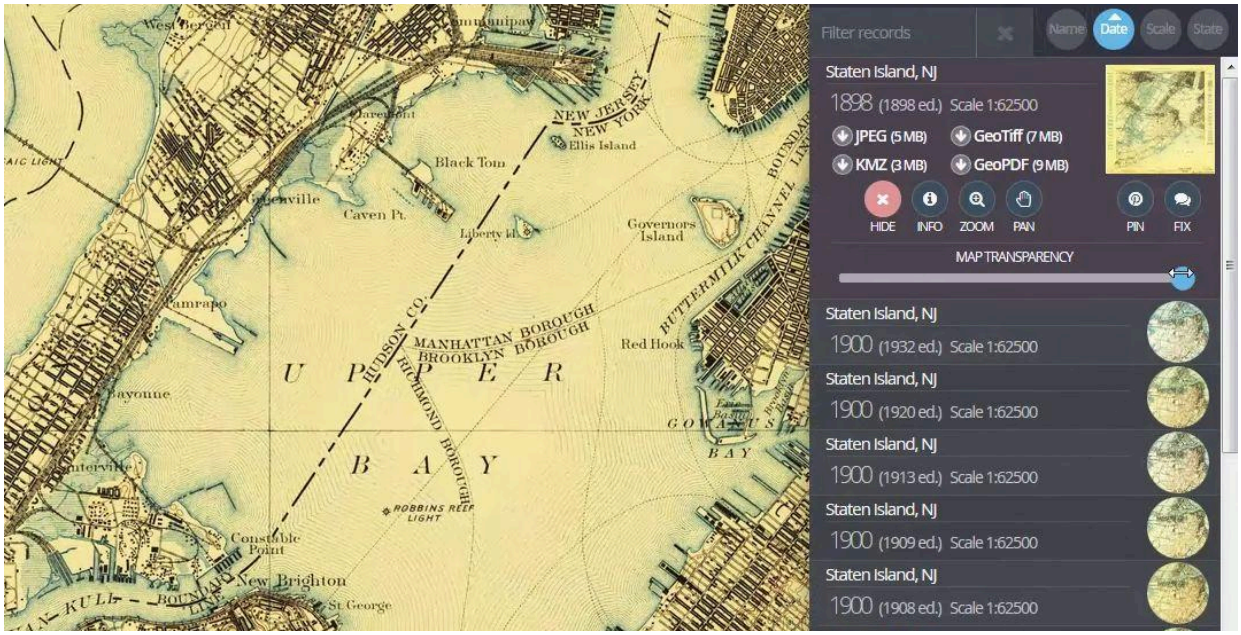




Download historical topographic maps from USGS TopoView website (Tutorial 2)

Software: Website
Difficulty: Easy
Time: 10–20 minutes
Data needs: none
Lead: Eli

Description: The USGS TopoView website https://ngmdb.usgs.gov/topoview provides free browsing and download of historical USGS topographic maps from the years 1884–2006. This USGS 4-minute video tutorial will show you how to find, browse, and download historical maps for your area of interest: https://www.youtube.com/watch?v=UCTIvQqVr4E, but since bandwidth is limited please try using the TopoView website first without watching the video. If you want to load the map into a desktop GIS software such as Google Earth or QGIS, download the map in a georeferenced format (e.g. KMZ or GeoTiff). The following image is a screen shot from the video tutorial:



Georeferencing Photographs (Tutorial 3)

Software: QGIS, Google Earth
Difficulty: Medium
Time: 30 minutes
Data needs: Historical imagery or similar
Lead: Adam

Description: A georeferenced image or raster can be loaded into GIS software for mapping or analysis. We occasionally come upon maps that have lost their georeferencing or never had them, for example:

- A photo of a map or a pdf that someone sent you.
- Or a historical photograph that was never georeferenced.
- A hand drawn field map from 75 years ago.

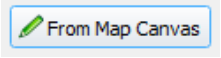
The approach to georeferencing such data sources would vary depending on the intended use of the data. If the purpose is just to visualize the data briefly, georeferencing with Google Earth Pro would suffice. However, if the image is to be incorporated into mapping, analysis, or visualization, georeferencing with QGIS or ArcMap Pro would be necessary. These options will stretch and skew the image to more accurately georeference it.

Georeferencing using Google Earth:

1. Click Tools > Add Image Overlay.
2. Shift the green overlay corners so that it covers the approximate area of the image you're georeferencing. The diamond lets you rotate and the cross in the center lets you move the center.
3. In the dialogue box, under "Link:" add the image you're georeferencing
4. Use the Transparency slider to make the image partially clear and refine the placement. Select OK to finish.

Georefencing using QGIS:

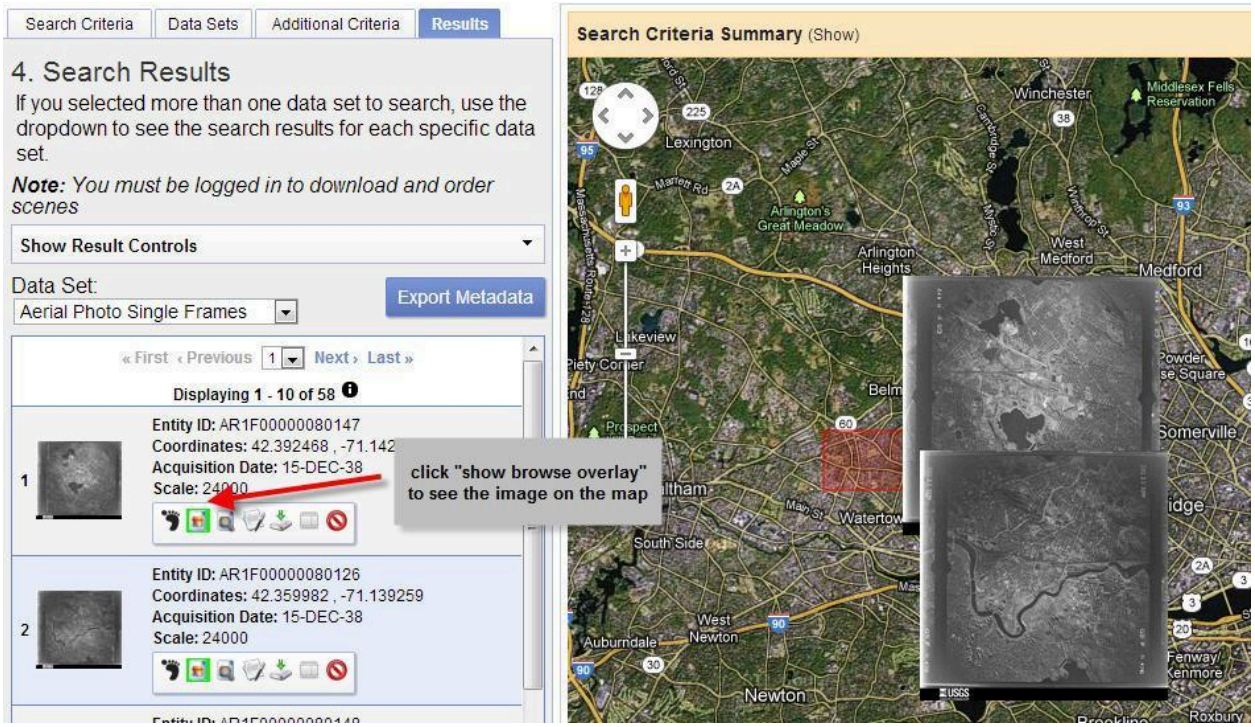
(From: https://docs.qgis.org/2.18/en/docs/training_manual/forestry/map_georeferencing.html)

1. Add a basemap with landmarks such as road intersections or landscape features
2. Open the georeference tool, Raster ‣ Georeferencer ‣ Georeferencer. Under Transformation Settings () select "Load in QGIS when done."
3. Add the image to georeference ()
4. Click a landmark on the image to georeference, in the popup select the From Map Canvas button () and click the corresponding point on the map canvas.
5. Repeat this 4-5 more times. More points the better and the more spread out the better.
6. Click "Start Georeferencing" ().
7. If the final output doesn't look quite right, keep iterating, adding points and removing points that aren't helpful (i.e. points that show a high Residual in the table).

Download historical aerial photographs from USGS EarthExplorer website (Tutorial 4)

Software: Website
Difficulty: Easy (if you follow tutorial, otherwise there are too many confusing options)
Time: 15–30 minutes
Data needs: none
Lead: Eli

Description: The USGS EarthExplorer website https://earthexplorer.usgs.gov/ provides free browsing and download of historical aerial imagery. The oldest images are “single frame records” which in most of California date back as far as the 1940s and are available approximately every 10 years. The Massachusetts Institute of Technology (MIT) Library produced a PDF tutorial that shows you how to find, browse, and download single frame records for your area of interest: https://libraries.mit.edu/files/gis/earthexplorer.pdf. While you can search by location and see a thumbnail preview of an image on the EarthExplorer map, the images that you will download will not be georectified (i.e., stretched to match a particular coordinate system) and may even be sideways or upside-down. Therefore, if you want to load an image into a desktop GIS software like Google Earth or QGIS, after downloading the image you will then need to follow the steps in the Georeferencing Photographs tutorial below. If you have not used EarthExplorer before, you should register (free) because while you can search for images without registering, you cannot download images without registering. The following image is a screen shot from the tutorial:



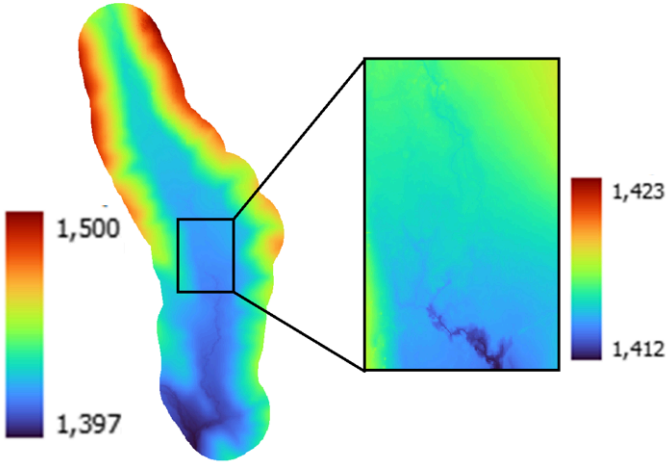
Topography visualization to inform restoration design

Dynamic Range Adjustment (Tutorial 5)

Software: ArcMap Pro, QGIS
Difficulty: Easy
Time: 5 minutes
Data needs: Elevation Raster
Lead: Adam

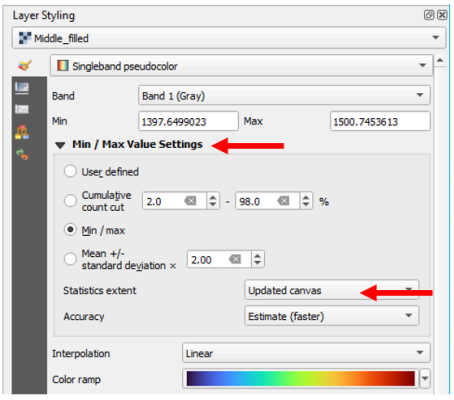
Description. Dynamic Range Adjustment simplifies the visualization of raster data with a wide range of values, eliminating the need to repeatedly modify color palettes while viewing different areas. This is particularly useful when examining elevation data where significant variations are present. To illustrate this point, consider an image depicting elevations in a meadow featuring a prominent headcut and incised channel at its midpoint. Despite zooming in on these features, they may be difficult to discern without modifying the visualization palette or activating Dynamic Range Adjustment.

When dynamic range is enabled, the location appears different depending on the level of zoom. Initially, at a high-level view, there are no significant changes observed in terms of value ranges for visualization, which still includes all values present in the raster image. However, as we zoom in further, the entire color palette becomes visible, and details such as headcut and shallow upstream channels become more prominent .

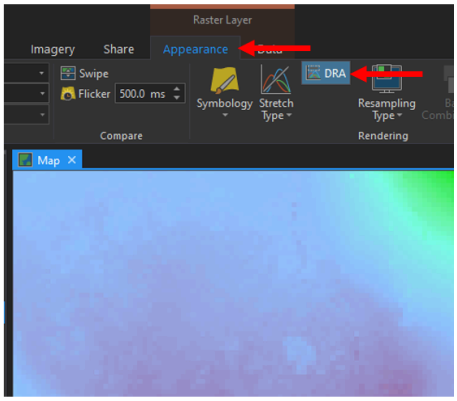


To turn on this visualization, it is just a button click away in both QGIS and ArcGIS Pro.

QGIS

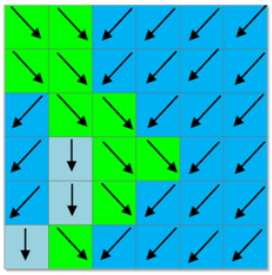


ARCGIS PRO



Colorization of Flow Accumulation Rasters (Tutorial 6)

Software: ArcMap Pro, QGIS
Difficulty: Easy
Time: 10 minutes
Data needs:
Lead: Adam



Flow Direction

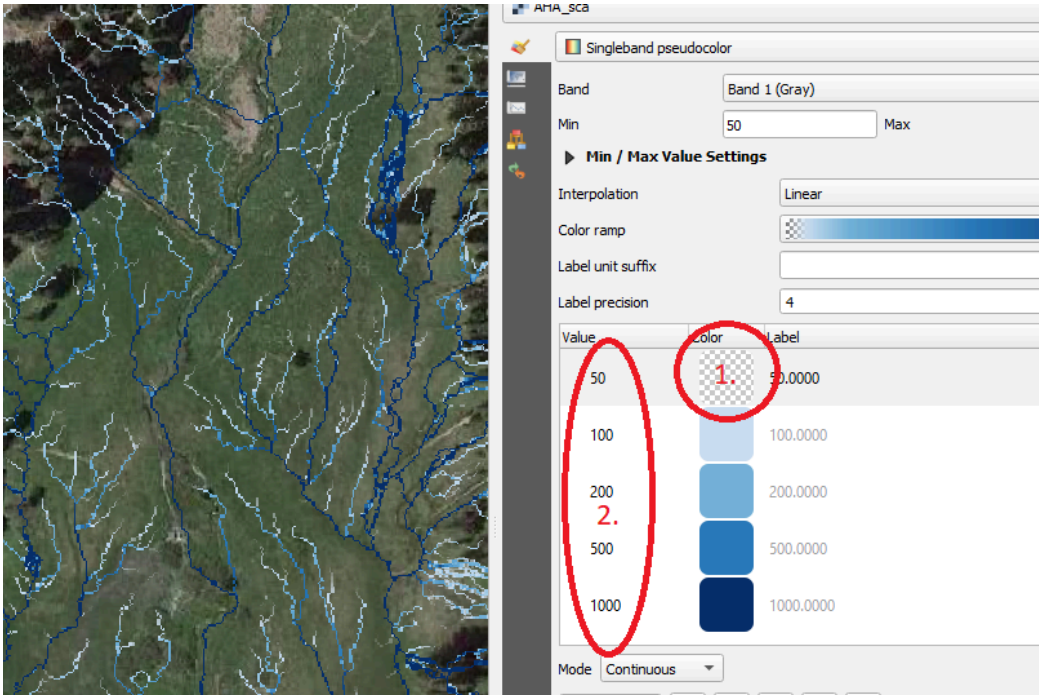
0	0	0	0	0	0
0	2	2	1	1	0
0	4	5	2	1	0
0	0	8	8	1	0
0	1	0	11	10	0
0	2	12	12	1	0

Flow Accumulation

Description. Flow Accumulation (also called contributing area) Rasters (FAR) are a common byproduct from creating flow lines using a Digital Elevation Model. Usually the steps involve creating a flow direction raster, a flow accumulation raster from that and then thresholding that raster to create a stream layer. Although flow accumulation rasters are useful in visualizing surface water flow, they require some visualization adjustments to be easily usable.

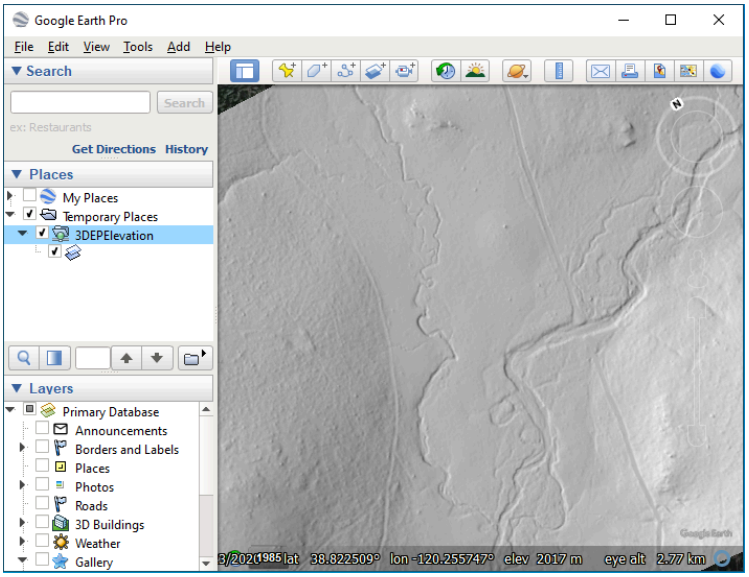
The easiest way to use a FAR is to add it directly into Google Earth Pro. GE Pro will generate a visualization of the FAR, and you can adjust the transparency of the layer to see how water may flow through your project area.

If you want more control, you can use QGIS or Arc. Simply set the raster to display distinct classes and follow these two steps: 1. Set the lowest class to transparent and 2. Set the values for all classes to be relatively low. This particular FAR has a maximum value of over 10 million, but the variation of interest is usually at values less than 1000, so that's how I set the class values.



LiDAR Hillshade Visualization in Google Earth (Tutorial 7)

Software: Google Earth
Difficulty: Easy
Time: 5 minutes
Data needs: None
Lead: Adam



Description. Google Earth Pro is an amazing platform that provides a simple interface for flying around and viewing projects from an aerial perspective. However, it can be challenging to visualize smaller terrain features such as incised channels and headcuts, particularly if they are under a canopy, with just imagery. Thankfully, GE Pro can display more streaming data sources than the built-in imagery. You can easily visualize LiDAR data, other imagery sources, vector data like stream flowlines, current snow conditions, and many other applications. This is done by adding WMS (Web Map Service) links or WFS (Web Feature Service) links to Google Earth. Or it can more easily be accomplished by finding a pre-made KML file that has the links built in. The following steps will guide you through the process of adding 3DEP hillshade data to Google Earth, and there are links to other resources below that can significantly enhance your Google Earth experience.

1. Google “3DEP elevation ImageServer” or go to this link: https://elevation.nationalmap.gov/arcgis/rest/services/3DEPElevation/ImageServer
2. Near the top, click “ArcGIS Earth”. This should download a file called “3DEPElevation.kmz”. Opening this file in GE should add elevation hillshades.
3. 3DEP Elevation data varies in resolution from 10m to 1m depending on if the program has incorporated LiDAR in that region or not.

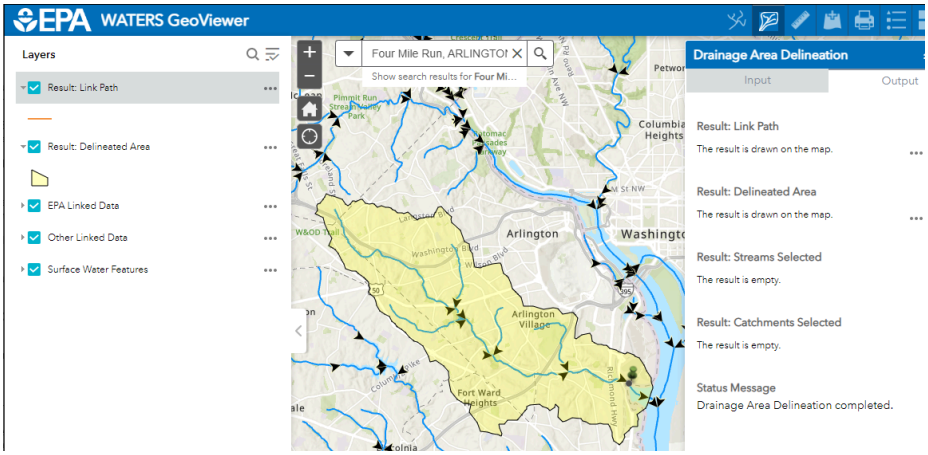
Here are several other data sources that can easily be added to GE:

Type of data	**Source**
Stream flowlines,watersheds, stream gages and much more from EPA	https://www.epa.gov/waterdata/viewing-waters-data-using-google-earth
California NAIP imagery (60cm) including NDVI and false color. Other data.	https://map.dfg.ca.gov/arcgis/rest/services/Base_Remote_Sensing
Current snow conditions	https://www.nohrsc.noaa.gov/earth/
USGS topographic maps	https://www.earthpoint.us/topomap.aspx

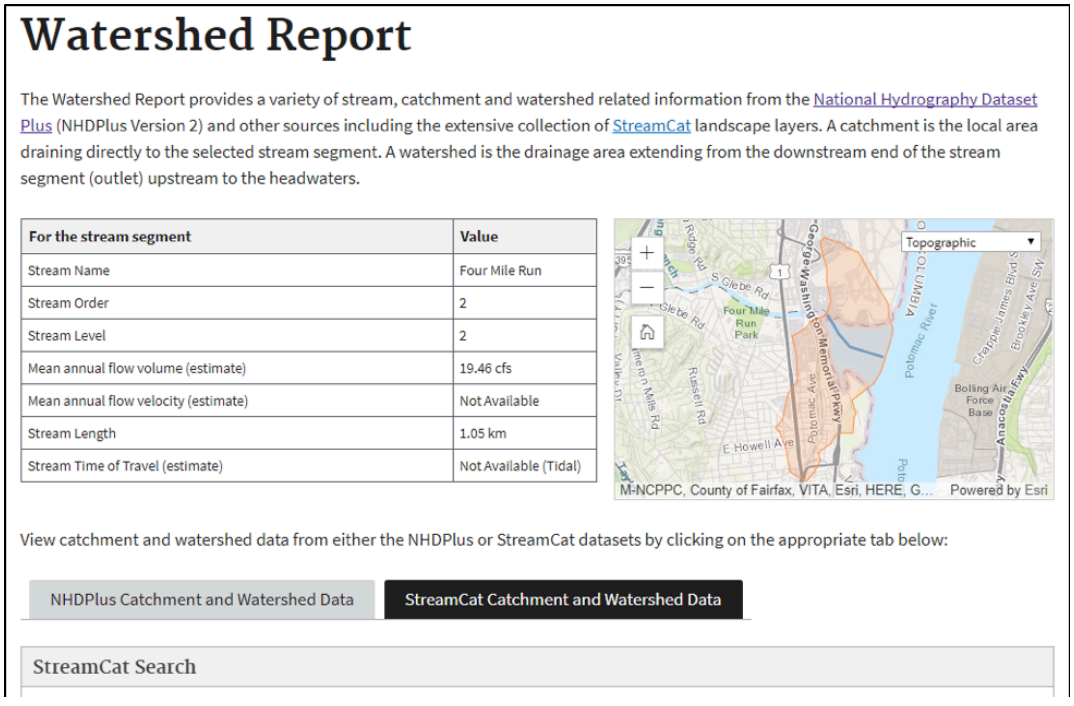
Watershed delineation

Use EPA WATERS GeoViewer to delineate the watershed upstream of a point and obtain a watershed report (Tutorial 8)

Software: Website or Google Earth
Difficulty: Easy
Time: 15–25 minutes
Data needs: none
Lead: Eli



Description: The EPA WATERS GeoViewer https://www.epa.gov/waterdata/waters-geoviewer is a web-based mapping application for generating watershed level reports with hundreds of pre-calculated attributes (drainage area, average precipitation, land cover, etc.) from NHDPlus and StreamCat. It also delineates watersheds (i.e., creates a GIS polygon of the upstream contributing area). We recommend reading/doing the following sections of EPA's tutorial https://www.epa.gov/waterdata/waters-geoviewer-tutorial: *Description*, *Watershed Delineation*, and *Watershed Report*. A Google Earth Pro alternative to the online GeoViewer is available: WATERSKMZ tool (https://www.epa.gov/waterdata/viewing-waters-data-using-google-earth).



Watershed Report

The Watershed Report provides a variety of stream, catchment and watershed related information from the National Hydrography Dataset Plus (NHDPlus Version 2) and other sources including the extensive collection of StreamCat landscape layers. A catchment is the local area draining directly to the selected stream segment. A watershed is the drainage area extending from the downstream end of the stream segment (outlet) upstream to the headwaters.

For the stream segment	Value
Stream Name	Four Mile Run
Stream Order	2
Stream Level	2
Mean annual flow volume (estimate)	19.46 cfs
Mean annual flow velocity (estimate)	Not Available
Stream Length	1.05 km
Stream Time of Travel (estimate)	Not Available (Tidal)

View catchment and watershed data from either the NHDPlus or StreamCat datasets by clicking on the appropriate tab below:

NHDPlus Catchment and Watershed Data | StreamCat Catchment and Watershed Data

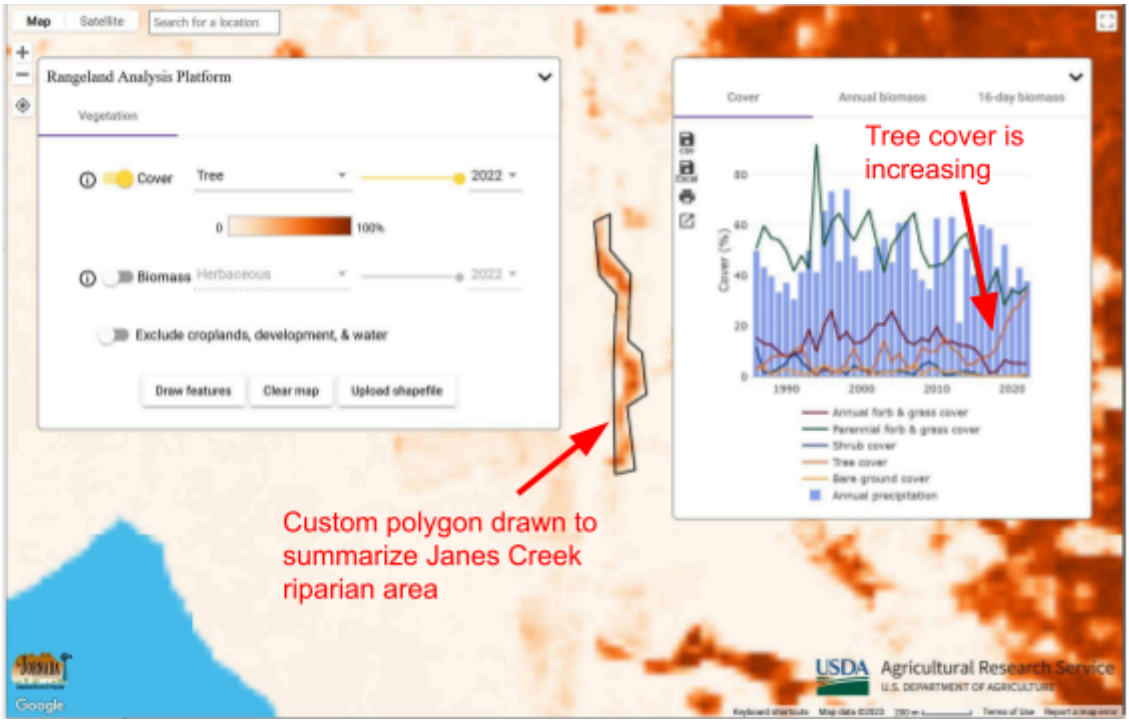
StreamCat Search

Vegetation, land cover, and watershed disturbance

Generate time series of tree canopy cover data using the Rangeland Analysis Platform website (Tutorial 9)

Software: Website
Difficulty: Easy
Time: 15–30 minutes
Data needs: none
Lead: Eli

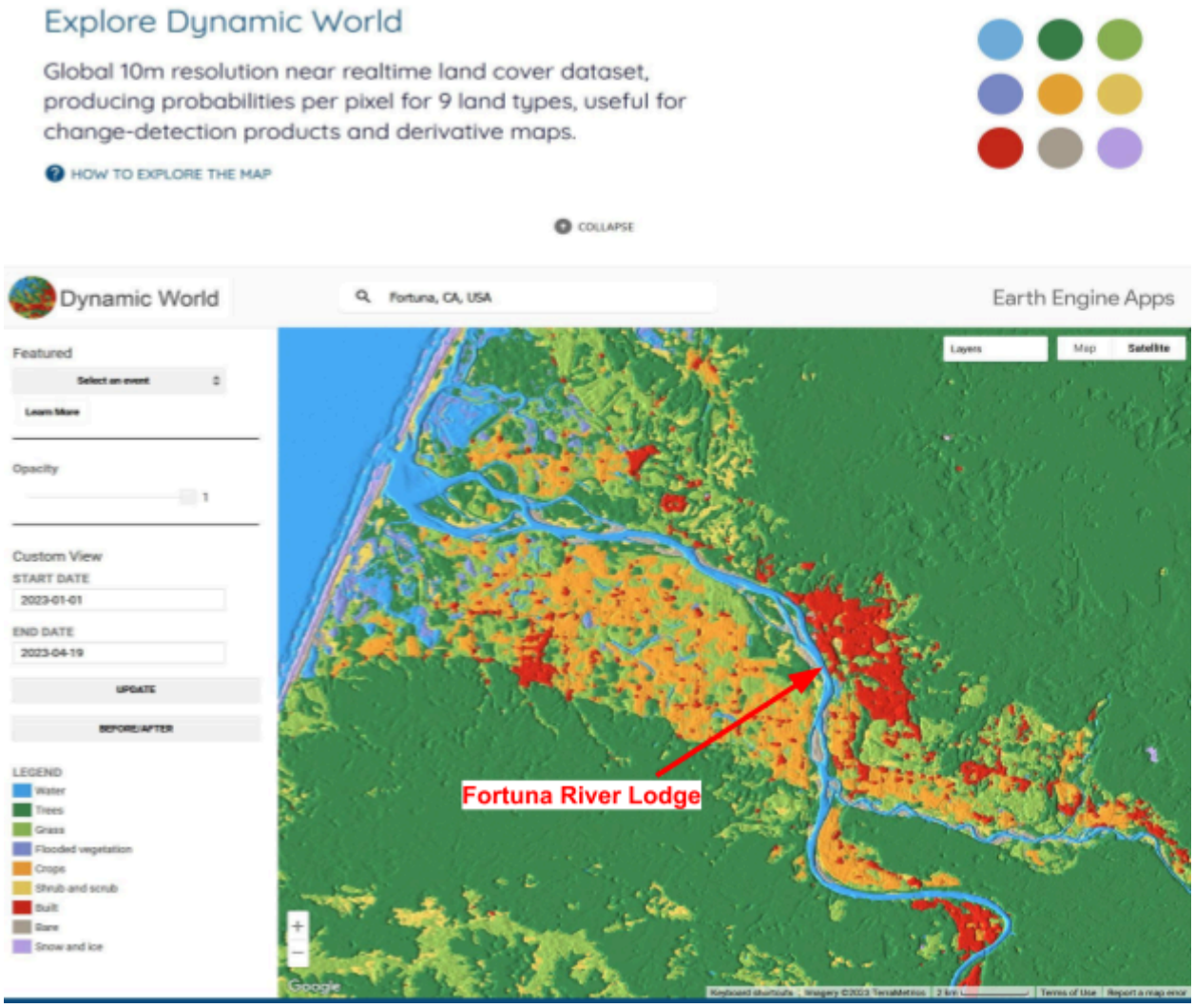
Description: The Rangeland Analysis Platform https://rangelands.app/rap/ examines trends at pasture, ranch, watershed, or broader scales. Datasets include annual 30-m resolution percent cover of four rangeland components (tree cover, shrub cover, herbaceous cover, etc.) for 1986–2021, based on Landsat satellites and ground-based plots. You can view data in online viewer, access summaries for a custom area (draw on map or upload shapefile), or download data. There are five video tutorials, each 2–5 minutes, and explanatory pages at https://support.rangelands.app/article/17-navigating-the-platform that explain how to use the platform, but it is also quite intuitive to use without tutorials (try it!). From the same web pages where the videos are posted, you can scroll down to read the explanations (will use less internet bandwidth than watching the videos). This illustrated screen shot shows increasing tree cover along Janes Creek as a result of City of Arcata riparian restoration efforts:



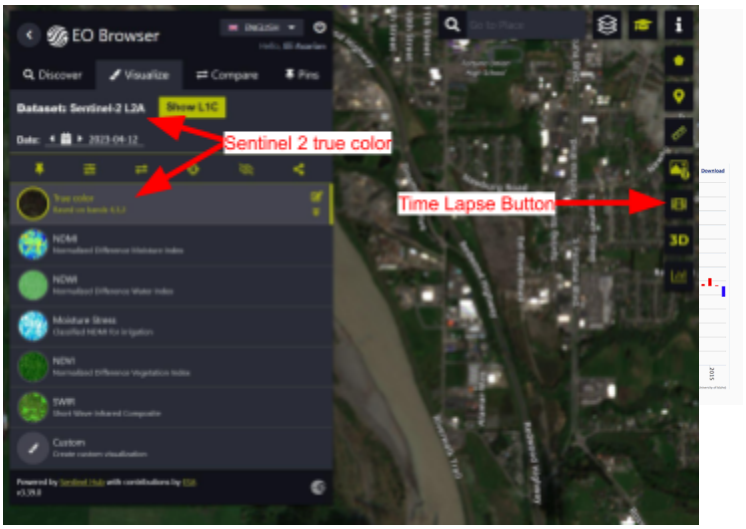
Browse near real-time 10-meter resolution land cover using the Dynamic World website (Tutorial 10)

Software: Website
Difficulty: Easy
Time: 15–20 minutes
Data needs: none
Lead: Eli

Description: Dynamic World (https://dynamicworld.app) is a website for browsing a near real time 10-meter resolution land cover dataset, 2015–present, approximately weekly, derived from Sentinel-2 satellite data. The online interface does not allow summarization or generating time series (that functionality is only available through coding in the Google Earth Engine). The interface is relatively intuitive, but a brief guide is available by clicking the "How to Explore Map" button at https://dynamicworld.app/explore. This screenshot show land cover for January-April 2023 in the lower Eel River including the Fortuna River Lodge, site of 2023 SRF conference:

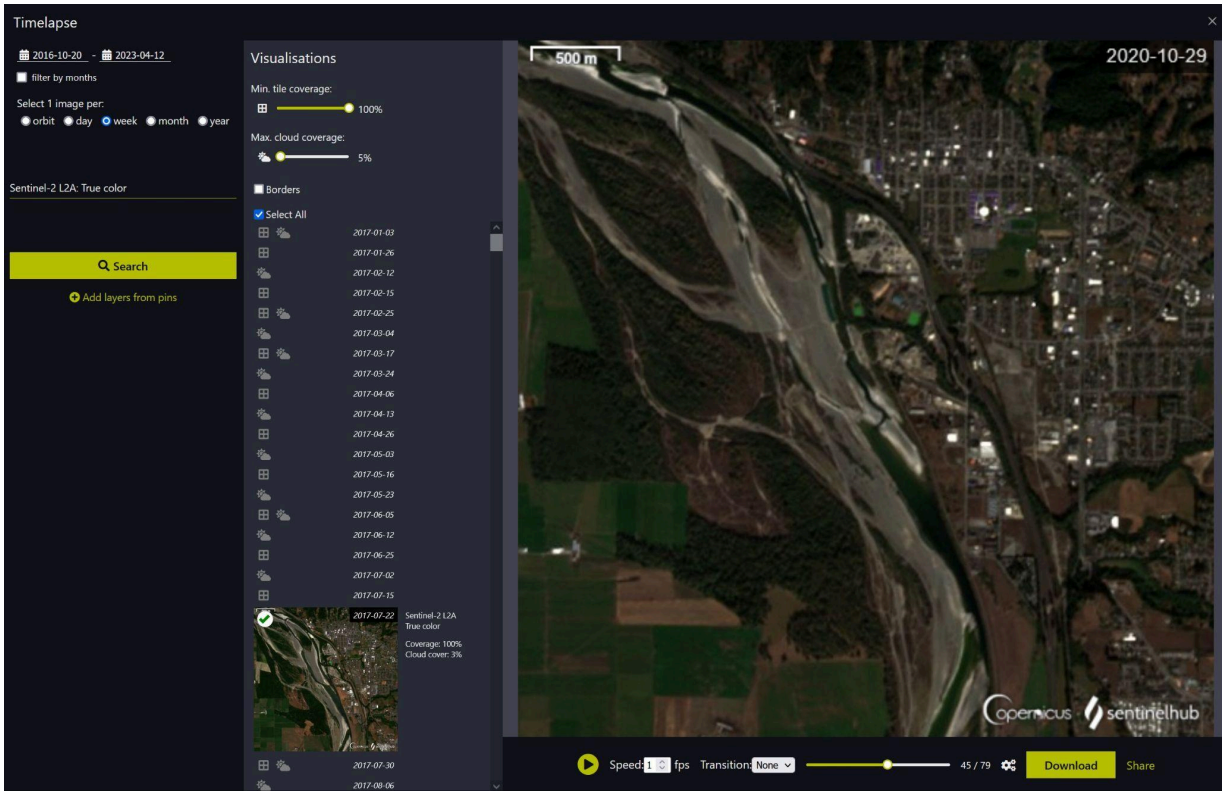


Create true-color time lapse movie using Sentinel EO Browser (Tutorial 11)



Software: Website (was previously free but now requires paid subscription login to download & view data, and is being depreciated)
Difficulty: Easy/moderate
Time: 20–45 minutes
Data needs: none
Lead: Eli

Description: Sentinel EO (https://apps.sentinel-hub.com/eo-browser/) is a web tool for browsing, downloading, and summarizing satellite data including Sentinel 2, Landsat, and MODIS. It includes a Time Lapse feature that allows creation of animated movies from the 10-meter resolution Sentinel 2. You must create a free account and login before you can create a Time Lapse. Follow instructions at: https://www.esa.int/ESA_Multimedia/Videos/2020/05/How_to_create_a_time_lapse_on_EO_Browser to login, create an area of interest, and generate a Time Lapse movie. The following example shows a screen shot from a weekly 2017–2023 animation of the lower Eel River including the Fortuna River Lodge, using a maximum cloud coverage of 5% and minimum tile coverage of 100% (watch at: https://sentinelshare.page.link/Pn3h):

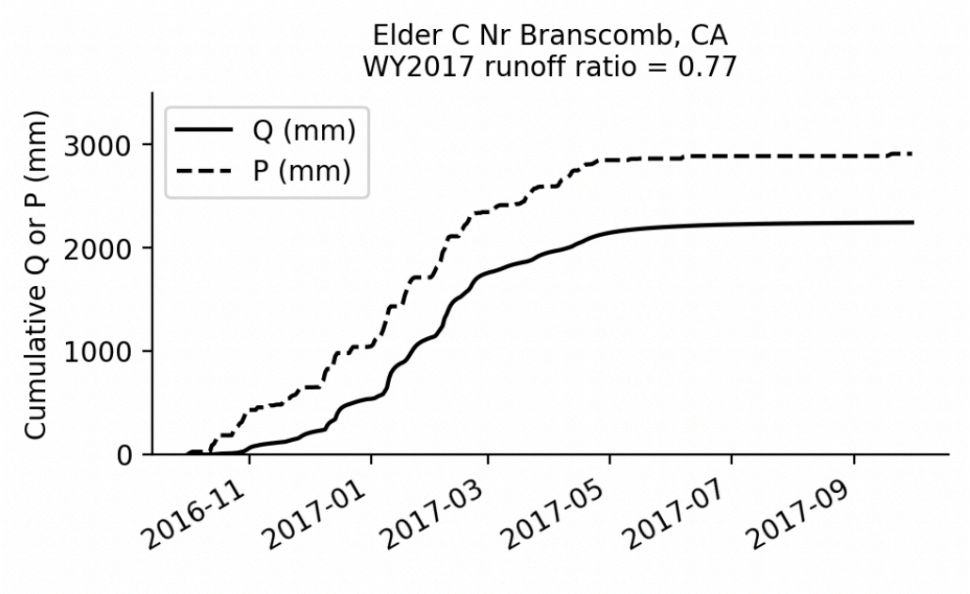


Hydrology and climate time series

Use Python's HyRiver packages to calculate watershed runoff ratios and evapotranspiration (Tutorial 12)

Software: Google Colab / Python (requires a Google login)
Difficulty: Easy if you want to just run the stock code, Hard if you want to edit/add content
Time: 20 minutes
Data needs: none
Lead: David

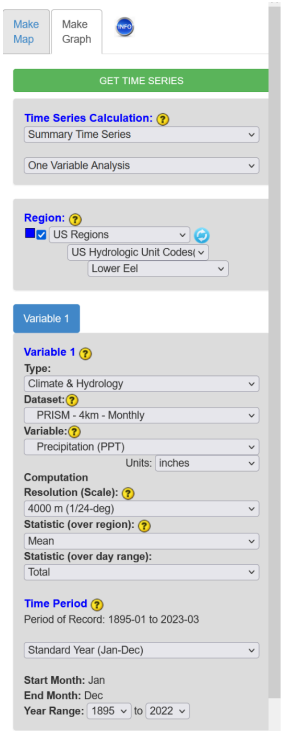
Description: Using a Google Colab Python notebook, we'll grab runoff and precipitation data from a USGS-gauged watershed and calculate runoff ratios (also known as water yield) and estimate evapotranspiration using a water balance. You can find the Colab notebook HERE. A more advanced notebook for analyzing hydrological signatures among multiple watersheds can be found HERE.

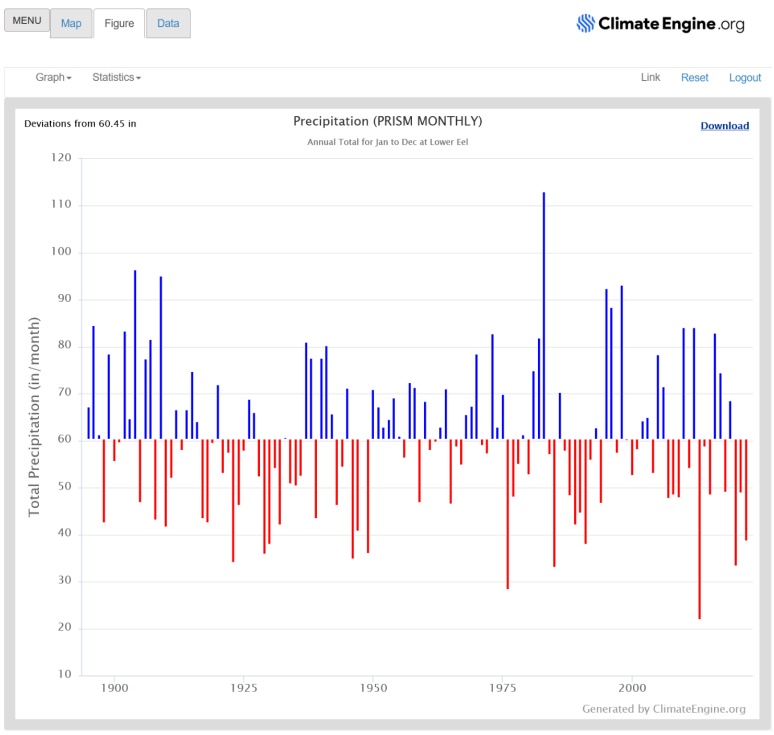


Generate a time series of annual precipitation (from PRISM model) using Climate Engine website (Tutorial 13)

Software: Website (requires free login)
Difficulty: Easy/moderate
Time: 15–30 minutes
Data needs: none
Lead: Eli

Description: The Climate Engine Research App (https://app.climateengine.org/climateEngine) generates a table with summarized time series (or maps or charts) of remote sensing datasets and climate data for an area of interest that can be drawn on map, uploaded from a shapefile, or chosen from pre-selected options like HUCs. It offers no-code access to summarize many (but not nearly all) datasets from the Google Earth Engine catalog. Climate datasets include precipitation and air temperature from several models including PRISM (daily and monthly), or remote sensing satellite data like Landsat NDVI. *The Research App is only free for academic and non-commercial use*. You must have a Google account (i.e., gmail or other Google-run organizational account) and login to use the App. When you enter the App, the welcome pop-up has two green buttons: Video Tours has two 5-minute narrated videos (Graphs and Maps), and Guided Tours has a clickable guided tour. Please try to Guided Tours first instead of the video, to conserve internet bandwidth. If needed, additional help is available at: https://support.climateengine.org/article/14-get-started. Watch the Graph video, then create an annual Summary Time Series of monthly PRISM Precipitation for your geographic area of interest. This example shows the Lower Eel HUC8 for 1895-2023:





Generate evapotranspiration time series for a farm field using OpenET website (Tutorial 14)

Software: Website
Difficulty: Easy
Time: 10–20 minutes
Data needs: none
Lead: Eli

Description: OpenET (https://openetdata.org/) provides consumptive water use (i.e., evapotranspiration, ET) data at different scales. You can view the data summarized for millions of individual agricultural fields or in the original raster format, or you can create a custom report to define your own boundaries, time frames, and data summaries. ET estimates are based on thermal and optical sensors aboard the 30-meter resolution Landsat satellites. The “Watch Video” link on https://openetdata.org provides an overview of the context and value of OpenET (or just browse the web pages). The map interface is available at https://explore.etdata.org, where we recommend you start clicking the “Field View” option. A guided tour to the map interface is available by clicking the "New here? Take a tour" button in the upper-right corner of the map https://explore.etdata.org. Zoom to your geographic area of interest and then click on a field polygon to see a time series of monthly ET estimates for that field.