Maps

This is a JupyterLab Notebook summarizing the code I wrote to make some maps of rivers using Python and Geopandas. But before we get to that, we should start with an outline of the general situation.

Background

On my machines, running macOS, I have Python 3 installed via Homebrew.

It is in the default locations. For the mini, that is `/usr/local/bin`, while on my new Macbook it is in `/opt/homebrew/bin`.

It seems that these python installations are only used with a virtual environment. To set one up, just `cd` into a convenient directory and do

```
/opt/homebrew/bin/python3 -m venv maps
```

That makes a virtual environment with all its supporting files stored in the `maps` directory under whatever directory you were in when you invoked this command.

I like working on the desktop so from `~/Desktop` do

```
source ~/Programming/maps/bin/activate
```

```
(maps) >
```

The prompt will change to `(maps) >`.

That's quite a long command. It's easy to make an alias in `~/.zshrc` such as `alias activate="source ~/Programming/maps/bin/activate"`.

Now that the venv is active you can do:

`(maps) > pip install --upgrade pip`

`(maps) > python -m pip install matplotlib`

`(maps) > python -m pip install geopandas`

`(maps) > python -m pip install jupyterlab`

The correct version of python (the one used to make the venv) can be called simply as `python`. Invoking `pip` as a module works better for me than calling it directly.

Geopandas

Pandas is a popular Python module for working with dataframes.

A dataframe is a table with possibly dissimilar columns. For example, one might have rows of individual amino acids, and columns with various things like molecular weight, hydrophobicity, and so on.

A GeoDataFrame (I often call the variable `gdf`) is a dataframe that contains, among other things, coordinates for geographical objects like polygons and line strings, which can represent state boundaries and rivers. Geopandas is a popular Python module for working with this kind of data.

In […

```
import matplotlib.pyplot as plt
import geopandas as gpd
```

We start with a geodataframe containg points along the boundaries of selected US states in the Pacific Northwest.

In [...
```
dbpath = '/Users/telliott/'
dbpath += 'Library/CloudStorage/Dropbox/data/'
fn = 'OR_WA_ID_MT_WY.shp.zip'
nw_states = gpd.read_file(dbpath + fn)
```

Various method exist to access the individual rows. The 'NAME' column contains the names of states. The 'STATE' column contains the FIPS code for each.

In [...
```
nw_states.columns
```

Out[...
```
Index(['GEO_ID', 'STATE', 'NAME', 'LSAD', 'CENSUSA
REA', 'geometry'], dtype='object')
```

In [...
```
nw_states['NAME']
```

Out[...
```
0        Oregon
1    Washington
2         Idaho
3       Montana
4       Wyoming
Name: NAME, dtype: object
```

In [...
```
nw_states['STATE']
```

Out[...
```
0    41
1    53
2    16
3    30
4    56
Name: STATE, dtype: object
```

In [...
```
result = nw_states[['STATE','NAME']]
result
```

Out[...

	STATE	NAME
0	41	Oregon
1	53	Washington
2	16	Idaho
3	30	Montana
4	56	Wyoming

The code in the cell above appears to access multiple columns. What it really does in addition is to construct and return a new GeoDataFrame.

The 'geometry' column contains objects representing the state outlines as POLYGON or MULTIPOLYGON objects. Washington is a MULTIPOLYGON because it includes a number of islands.

In [...

```
nw_states['geometry']
```

Out[...

```
0    POLYGON ((-121.92224 45.64908, -121.90827 45.
6...
1    MULTIPOLYGON (((-122.51953 48.28831, -122.522
7...
2    POLYGON ((-111.04416 43.02005, -111.04413 43.
0...
3    POLYGON ((-105.0384 45.00034, -105.07661 45.0
0...
4    POLYGON ((-110.04848 40.99755, -110.12164 40.
9...
Name: geometry, dtype: geometry
```

This dataframe has already been filtered from a larger one containing all 50 states plus DC and Puerto Rico. Let's start by loading the larger one and showing how to obtain what we have above.

In [...
```
fn='gz_2010_us_040_00_5m.zip'
gdf = gpd.read_file(dbpath + fn)
print(gdf.shape)
```

```
(52, 6)
```

So 52 entries as rows, and each with 6 columns of attributes. The states we want to select are: OR, WA, ID, MT, WY. Here is one way to do it.

In [...
```
L = ['Oregon','Washington','Idaho',
     'Montana','Wyoming']
sel = gdf['NAME'].isin(L)
```

In [...
```
sub = gdf[sel]
print(sub.shape)
```

```
(5, 6)
```

The `sel` variable is a series of boolean values. The code is otherwise straightforward except for the use of `isin`, which isn't standard Python but a Pandas thing.

In [...
```
sel.iloc[10:14]
```

Out[...
```
10    False
11    False
12     True
13    False
Name: NAME, dtype: bool
```

`gdf[sel]` filters for rows with a value of `True`.

`iloc` is a Pandas way of indexing by a numerical index. It is distinguished from `loc`, which uses labels.

`apply`

Another way to do the same thing is to supply a named function, or more Pythonically, a `lambda` expression.

In [...

```
sel = gdf['NAME'].apply(lambda r: r in L)
sub = gdf[sel]
print(gdf.shape, sub.shape)
```

```
(52, 6) (5, 6)
```

And yet a third way is to construct a series of logical expressions.

In [...

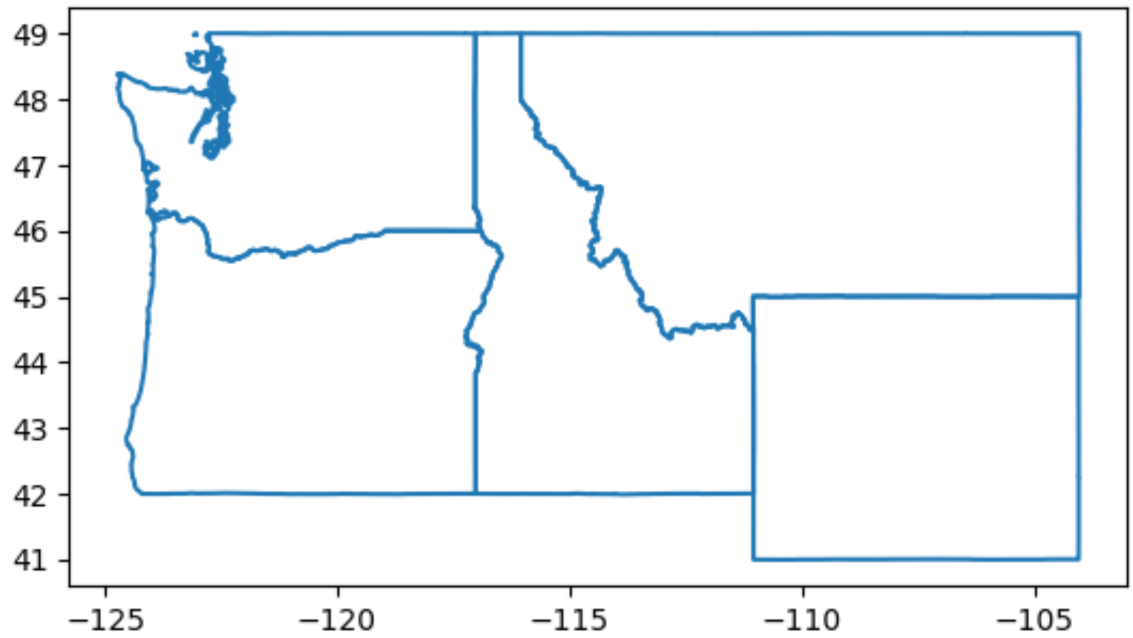
```
OR = gdf['NAME'] == 'Oregon'
WA = gdf['NAME'] == 'Washington'
ID = gdf['NAME'] == 'Idaho'
MT = gdf['NAME'] == 'Montana'
WY = gdf['NAME'] == 'Wyoming'
sub = gdf[OR | WA | ID | MT | WY]
print(gdf.shape, sub.shape)
```

```
(52, 6) (5, 6)
```

Since we have `matplotlib`, let's plot the data. A simple approach is:

In [...

```
nw_states.boundary.plot()
ofn = 'example.png'
plt.show()
```



To save the plot to a file

In [...
```
ofn = 'example.png'
plt.savefig(ofn,dpi=300)
```

```
<Figure size 640x480 with 0 Axes>
```

It would be nice to have some labels. Let's add a column to the data with the two letter abbreviations.

In [...
```
L = ['OR','WA','ID','MT','WY']
nw_states = nw_states.assign(abbrev = L)
nw_states['abbrev']
```

Out[...
```
0    OR
1    WA
2    ID
3    MT
4    WY
Name: abbrev, dtype: object
```

In [...
```
def f(e):
    return e.representative_point().coords[:][0]
```

The `[0]` at the end is because the coordinates are like `[(x,y)]`.

In [...

```
nw_states['coords'] = nw_states['geometry'].apply(1
nw_states['coords']
```

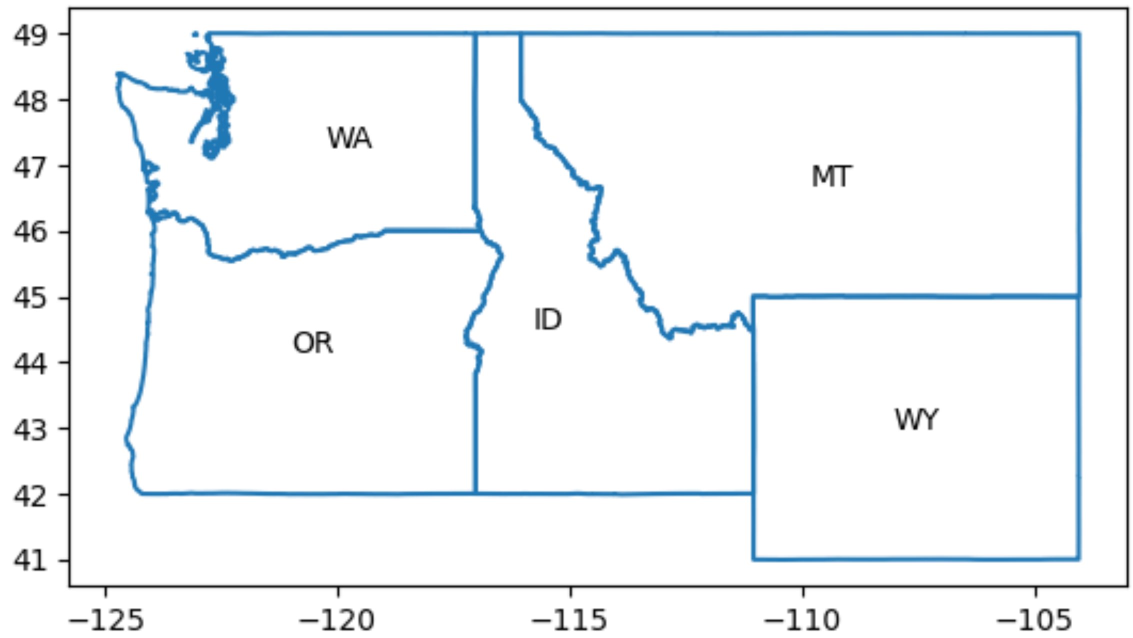
Out[...

```
0    (-120.51490187597771, 44.139333893360046)
1      (-119.73301862372591, 47.2734280475521)
2    (-115.46324561457074, 45.494265999999996)
3    (-109.34110685676336, 46.681627999999996)
4               (-107.54854862632588, 42.987824)
Name: coords, dtype: object
```

One can use `iterrows` to iterate through the data. We adjust the position of the label for Idaho.

In [...

```
nw_states.boundary.plot()
for i,row in nw_states.iterrows():
    x,y = row['coords']
    if row['NAME'] == 'Idaho':
        y -= 1
    plt.annotate(text=row['abbrev'],
        xy=(x,y),
        horizontalalignment='center')

plt.show()
```



Let's add a river. The original data is in a file named 'North_America_Lakes_and_Rivers.zip'. I have filtered the data to retain only the rivers in the Pacific Northwest.

In [...

```
fn = 'nw_rivers.shp.zip'
nw_rivers = gpd.read_file(dbpath + fn)
```

It's important to match the coordinate representation system (CRS) for `nw_states` and `nw_rivers`. The code shows they are already matched, so the `to_crs` call isn't really necessary.

In [...

```
print(nw_states.crs)
print(nw_rivers.crs)
mycrs = nw_rivers.crs
nw_states.to_crs(mycrs,inplace=True)
```

```
EPSG:4269
EPSG:4269
```

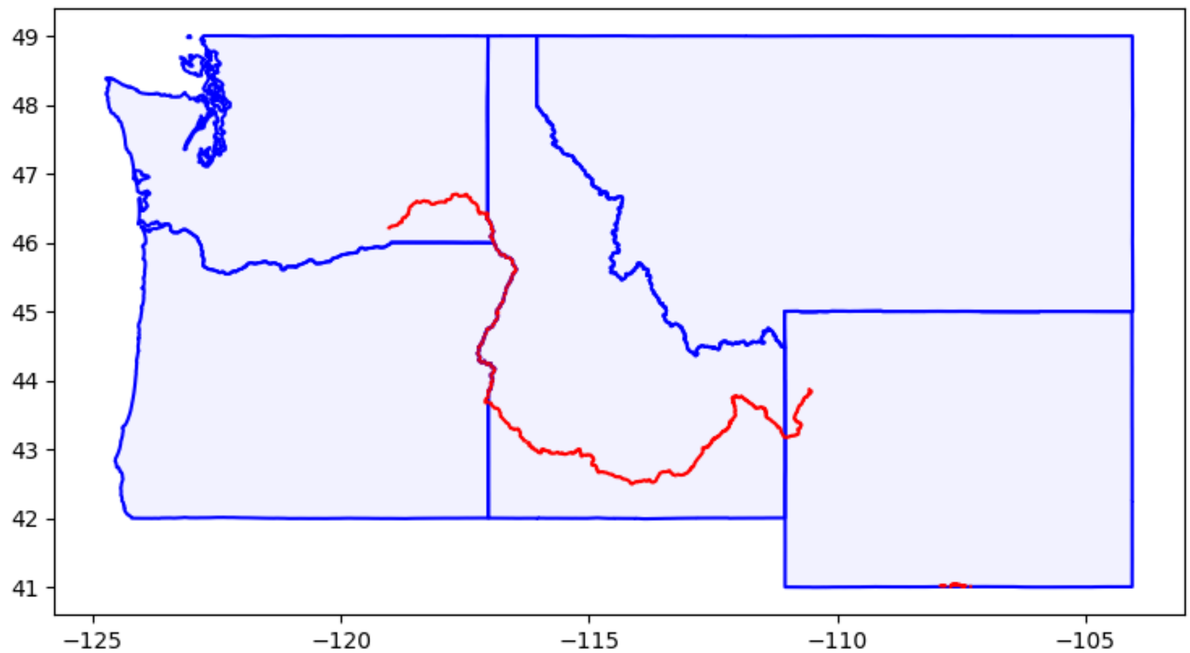
In [...

```
```

In [...

```
def sel(s):
    return nw_rivers['NameEn'].str.contains(s)
```

```
Snake = nw_rivers[sel('Snake')]

# remove some small waterways
Snake = Snake[Snake['LengthKm'] > 200]

ax = nw_states.boundary.plot(
    figsize=(9, 9),color='blue')
nw_states.plot(ax=ax,color='b',alpha=0.05)
Snake.plot(ax=ax,color='red')
plt.savefig('snake.png',dpi=300)
```



There is one more item to be cleaned up --- the small object at the bottom of Wyoming.

In [...

```
Snake['NameEn']
```

Out[...

```
1220    Little Snake River
1275           Snake River
1276           Snake River
1277           Snake River
1278           Snake River
Name: NameEn, dtype: object
```

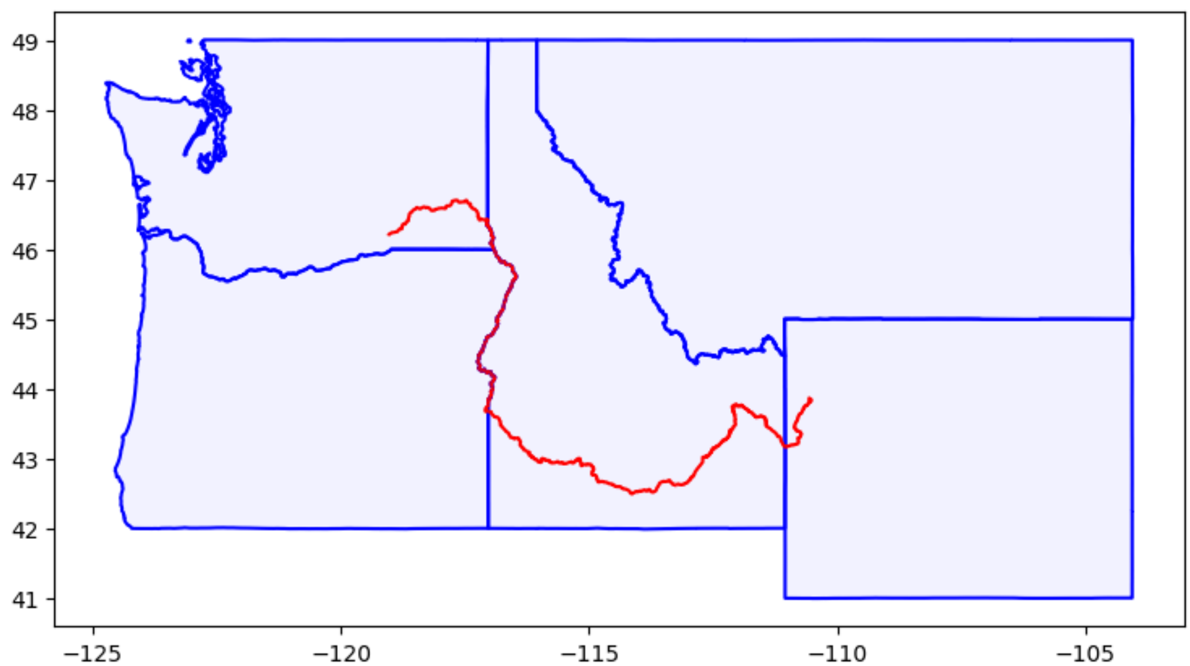
In [...

```
t = 'Little Snake River'
Snake = Snake[Snake['NameEn'] != t]
```

In [...
```
Snake['NameEn']
```

Out[...
```
1275    Snake River
1276    Snake River
1277    Snake River
1278    Snake River
Name: NameEn, dtype: object
```

In [...
```
ax = nw_states.boundary.plot(
    figsize=(9, 9),color='blue')
nw_states.plot(ax=ax,color='b',alpha=0.05)
Snake.plot(ax=ax,color='red')
plt.show()
```



Note: the original rivers data is quite a large file. I filtered it for data in a restricted geographic region and then saved it as a shapefile.

In [...
```
fn = 'North_America_Lakes_and_Rivers.zip'
na_rivers = gpd.read_file(dbpath + fn)
na_rivers = na_rivers.to_crs(mycrs)
nw_rivers = na_rivers.overlay(nw_states,
    how='intersection')
```

```
nw_rivers.to_file(
    filename='nw_rivers.shp.zip',
    driver='ESRI Shapefile')
```

In […
```
na_rivers.shape
```

Out[…
```
(5811, 7)
```

In […
```
nw_rivers.shape
```

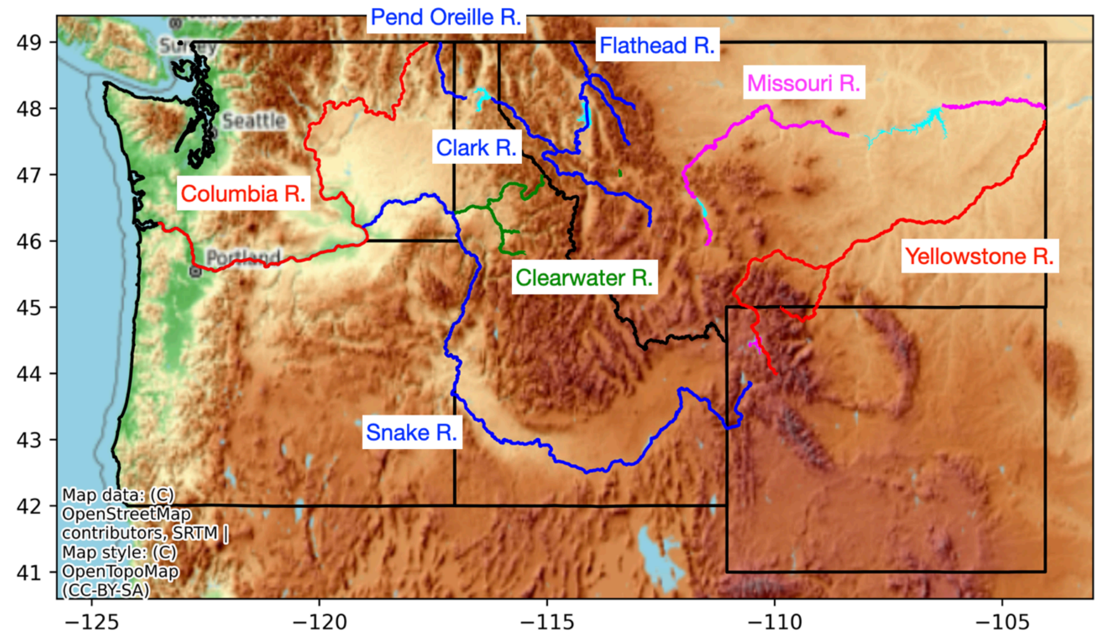
Out[…
```
(492, 14)
```

In […
```
nw_rivers.columns
```

Out[…
```
Index(['FID', 'Country', 'NameEn', 'NameEs', 'Name
Fr', 'LengthKm', 'GEO_ID',
       'STATE', 'NAME', 'LSAD', 'CENSUSAREA', 'abb
rev', 'coords', 'geometry'],
      dtype='object')
```

I've picked up some extra columns. I think this happened because I included rivers in British Columbia and Alberta, although we aren't plotting them.

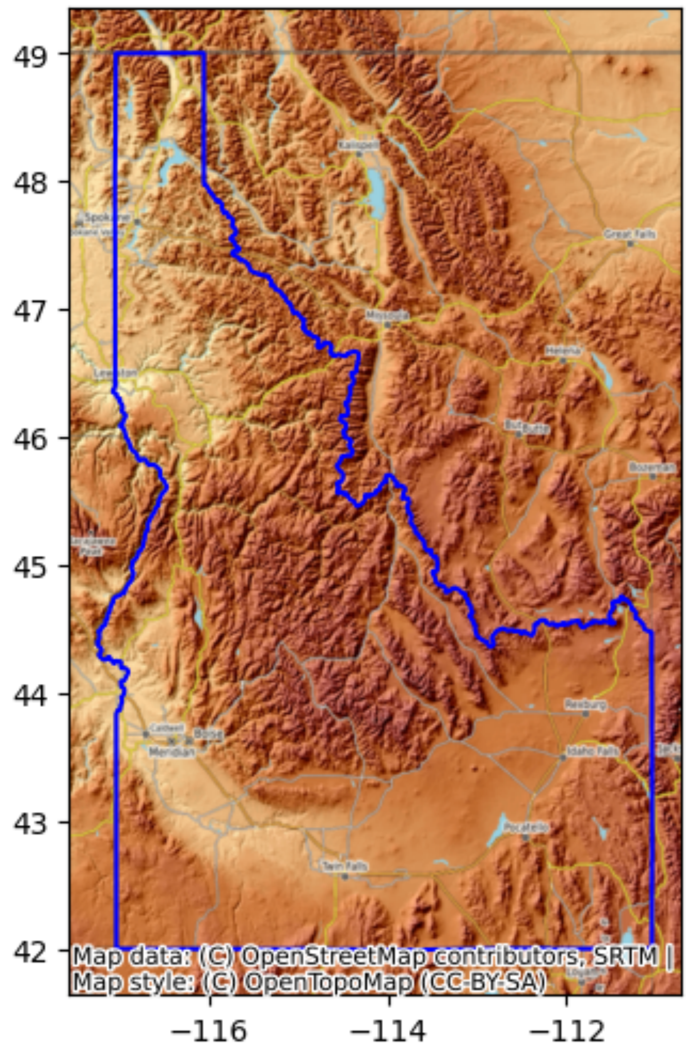
One last thing. Various basemaps are available. Sometimes it works. This is a figure annotated using a separate application (Keynote).



Sometimes the basemap call doesn't work. Something about the zoom level. The code is pretty trivial.

In [...

```
import geopandas as gpd
import matplotlib.pyplot as plt
import contextily as cx

dbpath = '/Users/telliott/Library/CloudStorage/Drop
fn = 'OR_WA_ID_MT_WY.shp.zip'
gdf = gpd.read_file(dbpath+fn)
ID = gdf[gdf['NAME'] == 'Idaho']
ax=ID.boundary.plot(color='b',figsize=(6,6))
cx.add_basemap(ax,source =cx.providers.OpenTopoMap,
plt.show()
```

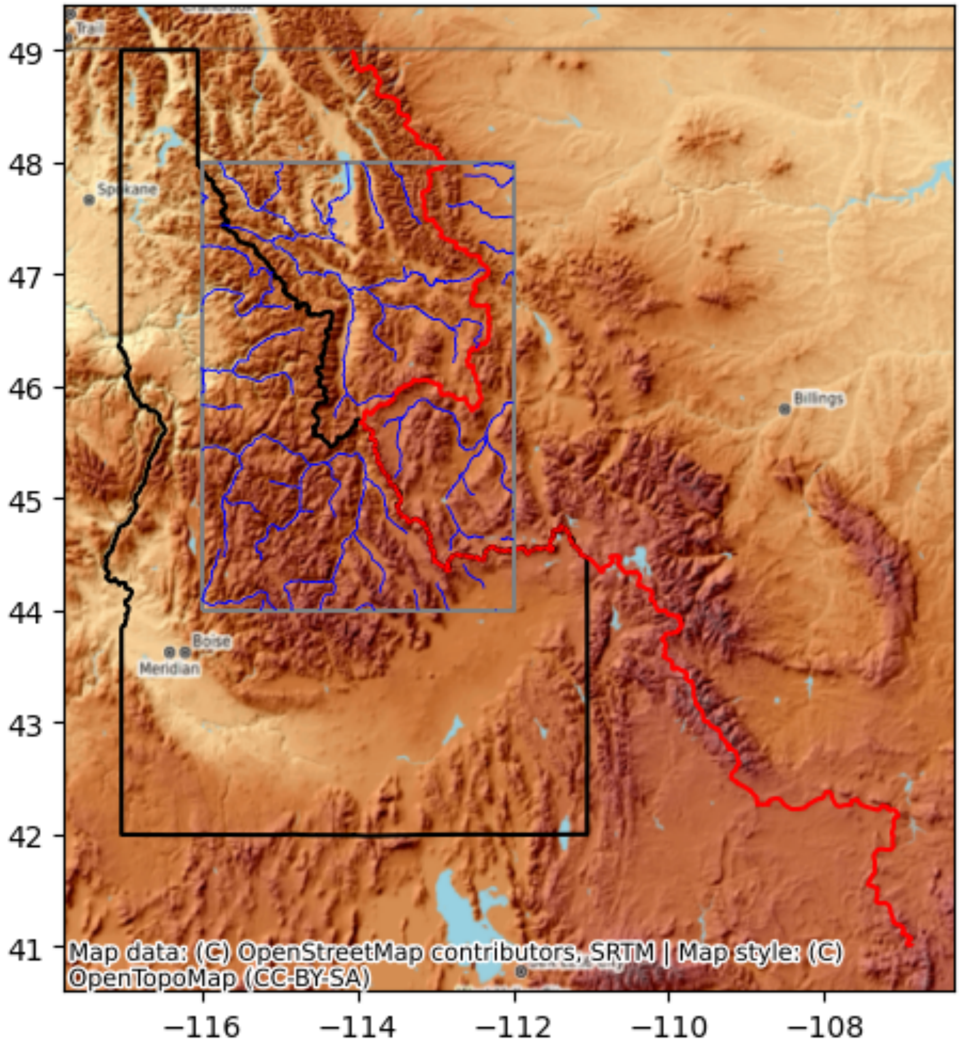


You do have to match the CRS or change (warp) it for the basemap. Here is a more extensive example.

In […

```
import geopandas as gpd
import pandas as pd
import matplotlib.pyplot as plt
import contextily as cx

dbpath = '/Users/telliott/'
dbpath += 'Library/CloudStorage/Dropbox/data/'
fn = 'OR_WA_ID_MT_WY.shp.zip'
gdf = gpd.read_file(dbpath + fn)

# CRS
# OpenTopoMap uses Web Mercator ('EPSG:3857')
# gdf is NAD 83 ('EPSG:4269')
```

```
my_crs = 'EPSG:4269'

ID = gdf[gdf['NAME'] == 'Idaho']
MT = gdf[gdf['NAME'] == 'Montana']

fn = 'nw_rivers.shp.zip'
nw_rivers = gpd.read_file(dbpath + fn)
nw_rivers = nw_rivers.to_crs(my_crs)

# restrict the rivers to a bounding box
xmin, ymin, xmax, ymax = -116, 44, -112, 48
from shapely.geometry import Polygon
poly = Polygon([(xmin,ymin),(xmax,ymin),(xmax,ymax)
gs = gpd.GeoSeries(poly)
bbox = gpd.GeoDataFrame({'geometry': gs})
bbox = bbox.set_crs(my_crs)
sub = nw_rivers.overlay(bbox, how='intersection')

# continental divide
fn = 'Continental_Divide-Pacific_Atlantic.zip'
cdiv = gpd.read_file(dbpath + fn)
cdiv = cdiv.to_crs('EPSG:4269')
cdiv = cdiv.overlay(gdf, how='intersection')

ax=ID.boundary.plot(color='k',figsize=(6,6))
cdiv.plot(ax=ax,color='r')
bbox.boundary.plot(ax=ax,color='gray')
sub.plot(ax=ax,color='b',lw=0.6)

cx.add_basemap(ax,
    source =cx.providers.OpenTopoMap,
    crs=ID.crs)

plt.show()
```



The code illustrates the use of a bounding box and the `.cx` method of a gdf. I've followed the convention for contextily and imported the name as `cx`, even though this could be confusing. Since the method is qualified, Python keeps it all straight.

The red line is the continental divide. This makes it easier to understand which way the rivers must flow.

To convert this notebook to html do:

`jupyter nbconvert --execute --to html explore.ipynb`

One can print directly to a pdf, but I found the font is too big and I haven't found a way to control it.