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Visualisation in Python

Matplotlib

Thanks to all contributors:

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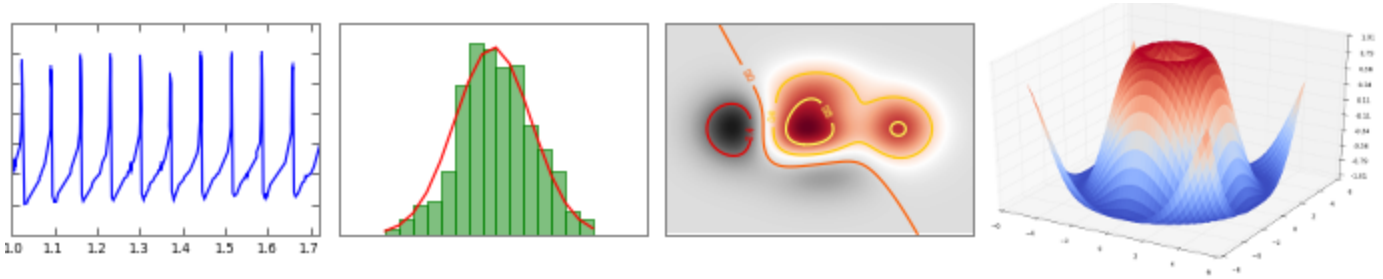
Introducing Matplotlib

Matplotlib is a python **2D plotting library** which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms. Matplotlib can be used in python scripts, the python shell, web application servers, and graphical user interface toolkits.



Introducing Matplotlib

Matplotlib enables you to generate **plots**, **histograms**, **power spectra**, **bar charts**, **error charts**, **scatterplots**, etc, with just a few lines of code.

For simple plotting the "pyplot" interface provides a **MATLAB-like interface**.

You also have full control of *line styles*, *font properties*, *axes properties*, etc, via an **object oriented interface** or via a set of functions familiar to MATLAB users.

Recommending Matplotlib

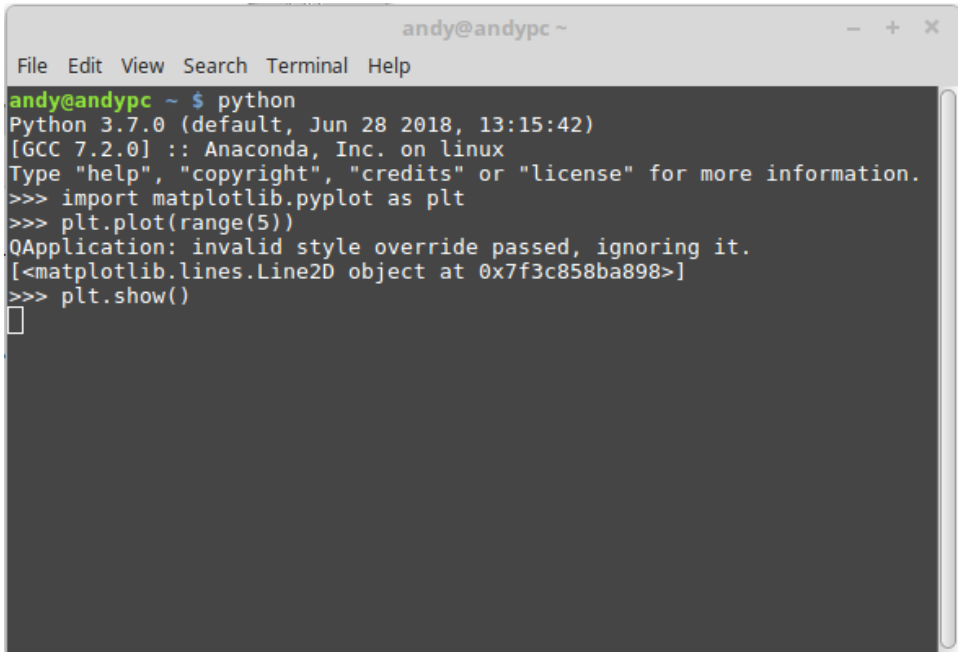
As with all open source Python tools there are other options and approaches available.

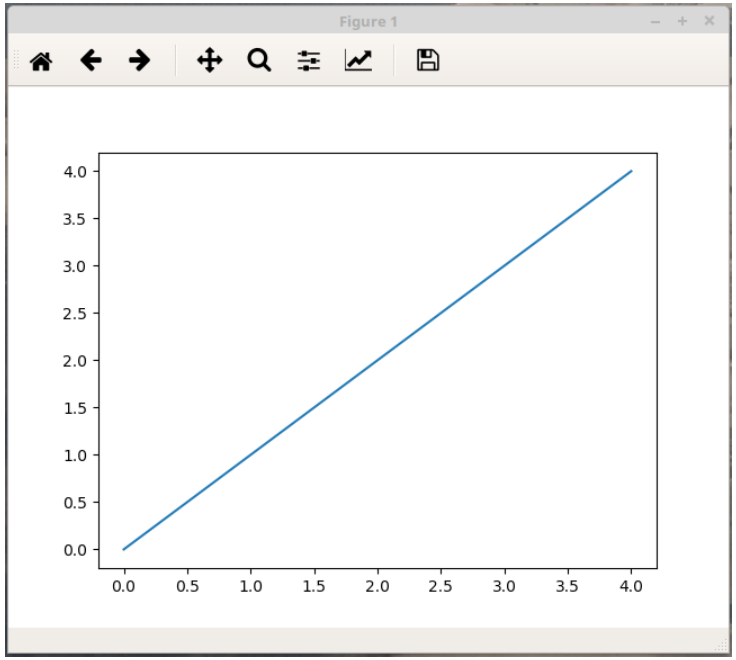
However, Matplotlib, like NumPy, has become the **clear leader** in its particular niche.

If you want to do (high quality) visualisation in Python – use Matplotlib!

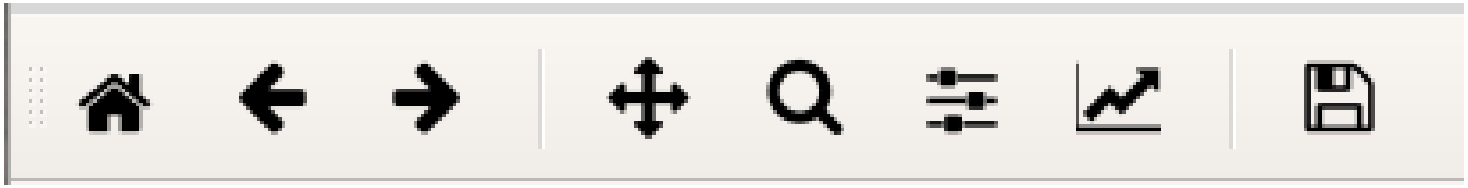
Using Matplotlib Interactively

- Matplotlib has its own interactive plotting window:





Using Matplotlib Interactively

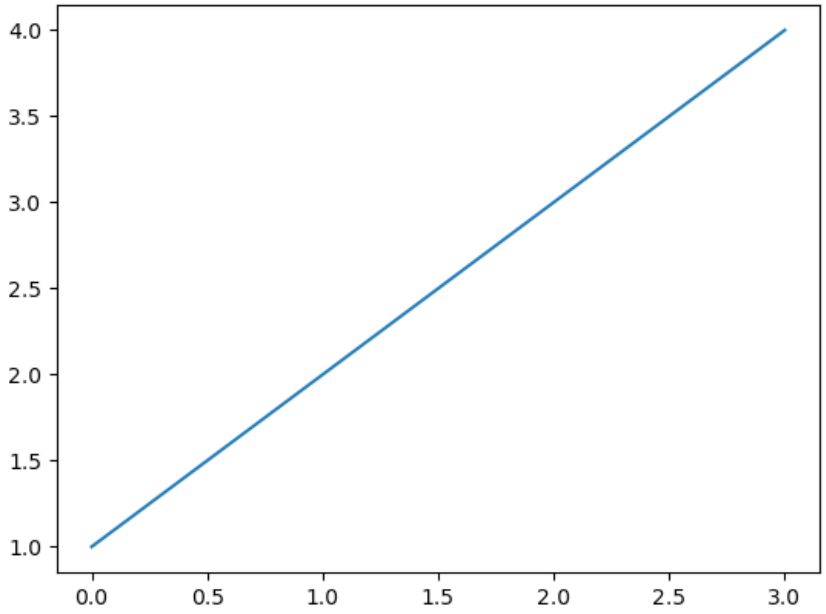


The buttons allow you to:

- Re-set the image
- Move between different plots in this session
- Scroll around the current plot
- Zoom in to specified region
- View whole plot
- Save the plot

The first plot: A simple line graph

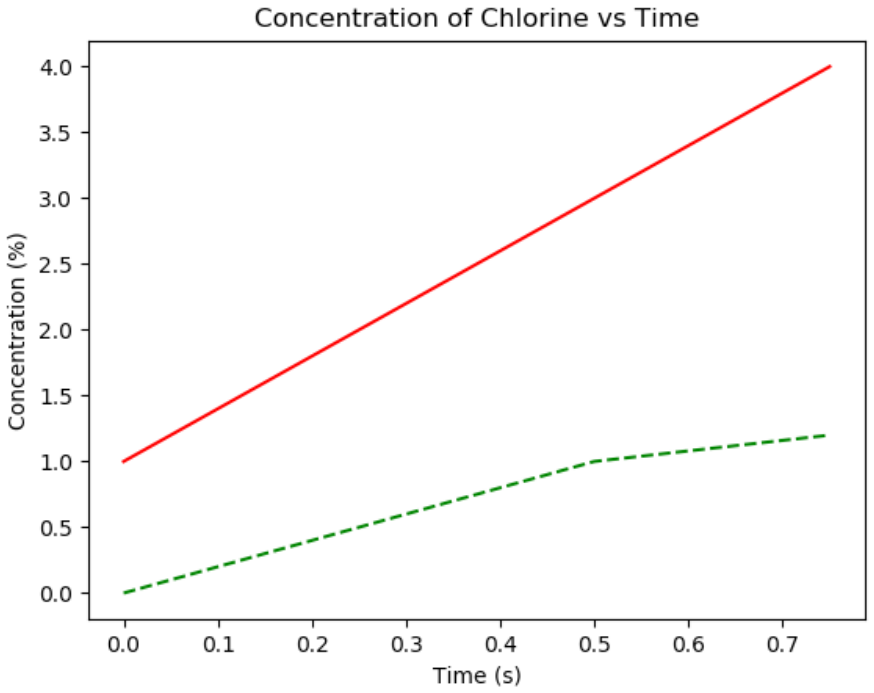
```
import matplotlib.pyplot as plt
plt.plot([1,2,3,4])
plt.show()
```



Defaults are used for things you do not specify (such as the x-axis values).

Two lines with axes and a title

```
times = [0, 0.25, 0.5, 0.75]
plt.plot(times, [0,0.5,1,1.2], 'g--')
Plt.plot(times, [1, 2, 3, 4],  'r')
plt.title('Concentration of Chlorine vs Time')
plt.ylabel('Concentration (%)')
plt.xlabel('Time (s)')
plt.show()
```

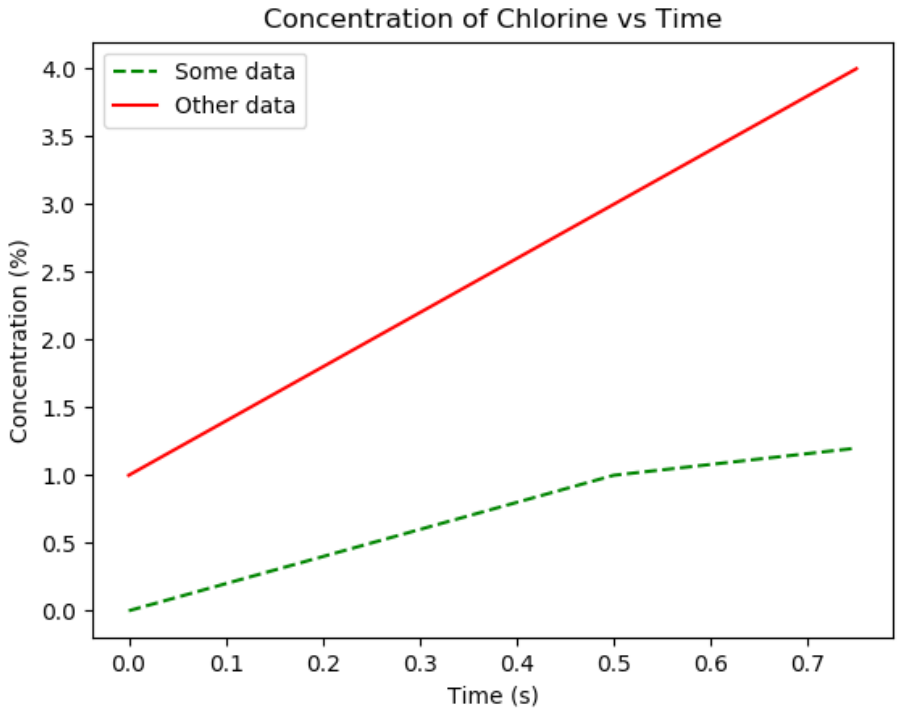


Assume we have always run:

```
import matplotlib.pyplot as plt
```

Add a legend

```
times = [0, 0.25, 0.5, 0.75]
plt.plot(times, [0,0.5,1,1.2], 'g--', label = "Some data")
plt.plot(times, [1, 2, 3, 4],  'r', label = "Other data")
plt.title('Concentration of Chlorine vs Time')
plt.ylabel('Concentration (%)')
plt.xlabel('Time (s)')
plt.legend()
plt.show()
```



Saving an image: savefig

- To save an image use:

```
plt.savefig("myplot.png")
```

- Optional arguments include:
  - `dpi`: resolution
  - `orientation`: "portrait" or "landscape"
  - `format`: "png", "pdf", "ps", "eps"

plt.figure – To plot **multiple figures** and change **size**

- To draw multiple plots from the same session:

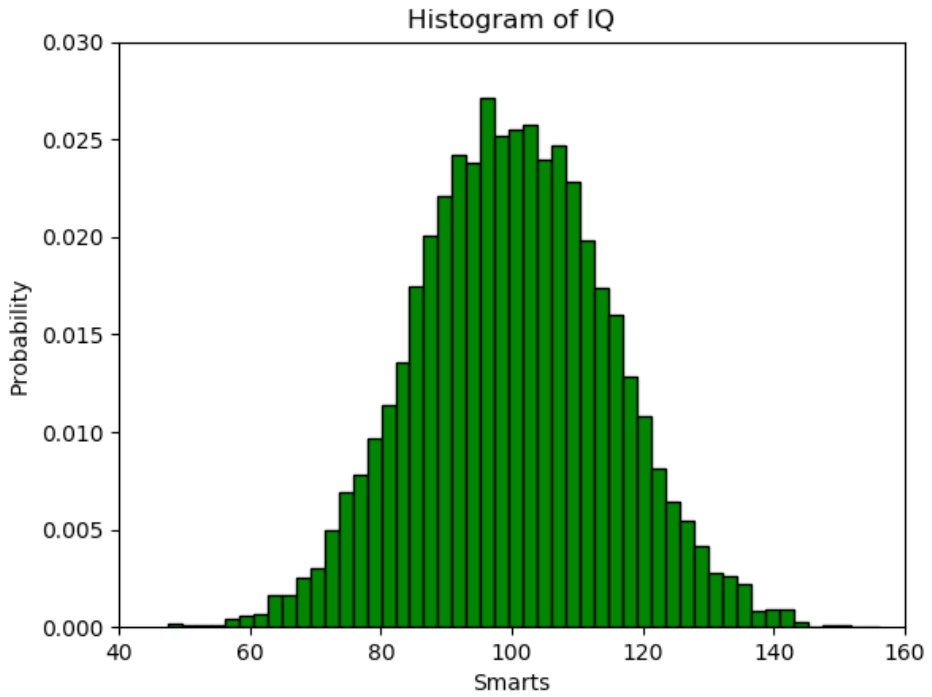
```
plt.figure()
plt.plot(range(5))
plt.figure(figsize = (10, 10)) # size in inches
plt.plot(range(100))
plt.show() # shows both figures
```

- plt.figure: returns a new figure so you can interact with them independently, e.g.:

```
f1 = plt.figure()
f2 = plt.figure()
```

Histogram plot

```
import numpy as np
import matplotlib.pyplot as plt
mu, sigma = 100, 15
x = mu + sigma * np.random.randn(10000)
n, bins, patches = plt.hist(x,50,density=1,color='g',
edgecolor='k')
plt.axis([40, 160, 0, 0.03])
plt.xlabel('Smarts')
plt.ylabel('Probability')
plt.title('Histogram of IQ')
plt.show()
```



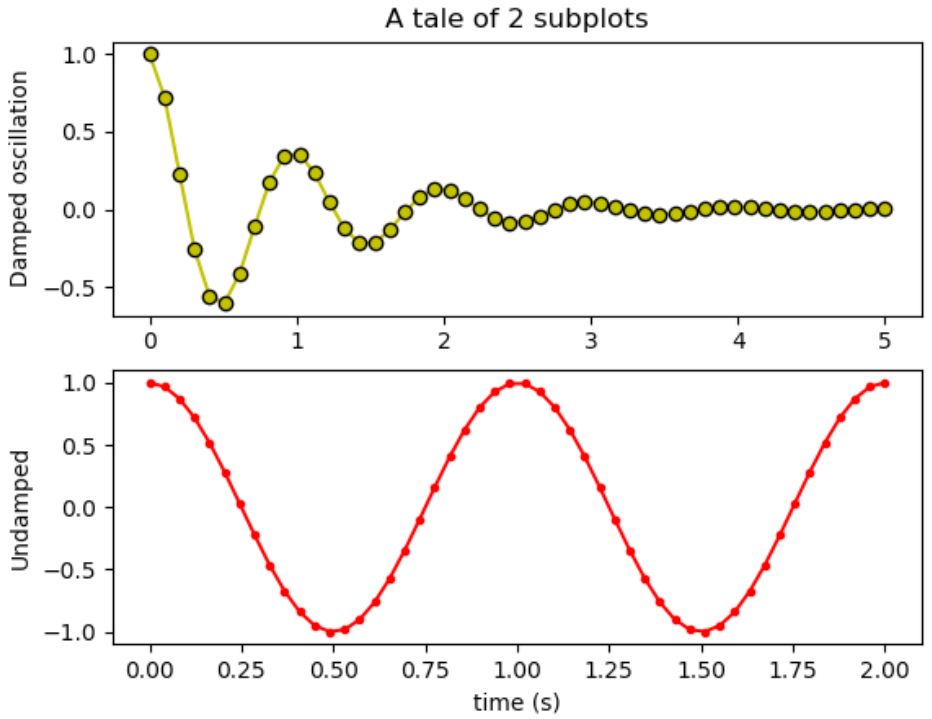
Multiple plots – data and subplot function (1)

```
import numpy as np
import matplotlib.pyplot as plt

x1 = np.linspace(0.0, 5.0)
x2 = np.linspace(0.0, 2.0)

y1 = np.cos(2 * np.pi * x1) * np.exp(-x1)
y2 = np.cos(2 * np.pi * x2)
```

The "subplot" function is defined as:
`subplot(nrows, ncols, plot_number)`
Here we define: 2 rows, 1 column.

Multiple plots using subplot (2)

```
plt.subplot(2, 1, 1)
plt.plot(x1, y1, 'yo-', markeredgecolor='k')
plt.title('A tale of 2 subplots')
plt.ylabel('Damped oscillation')

plt.subplot(2, 1, 2)
plt.plot(x2, y2, 'r.-')
plt.xlabel('time (s)')
plt.ylabel('Undamped')
plt.show()
```

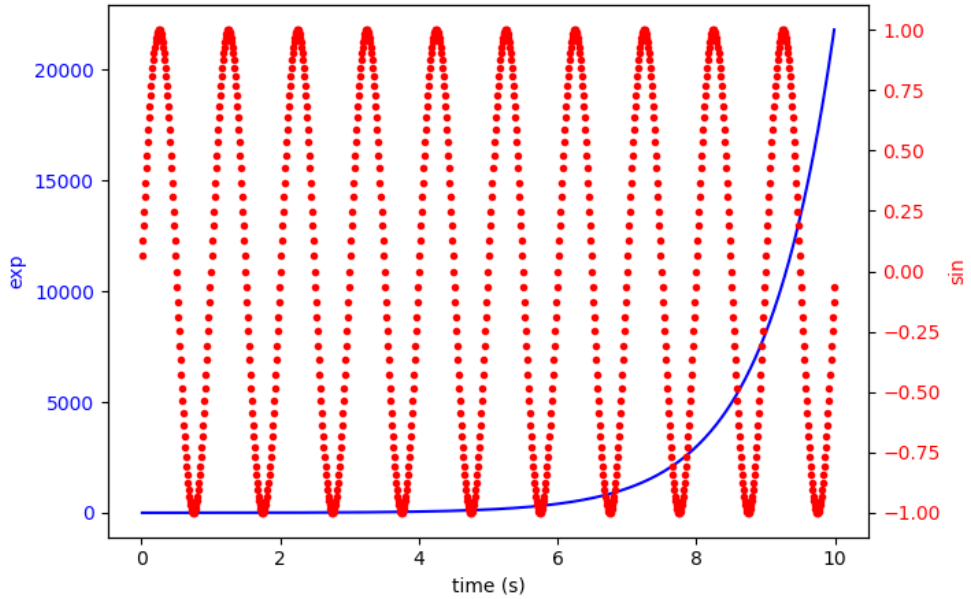


Multiple axes on one plot (1)

```
import numpy as np
import matplotlib.pyplot as plt
fig, ax1 = plt.subplots()
t = np.arange(0.01, 10.0, 0.01)
s1 = np.exp(t)
ax1.plot(t, s1, 'b-')
ax1.set_xlabel('time (s)')

# Make the y-axis label and tick labels match the line color.
ax1.set_ylabel('exp', color='b')
for tl in ax1.get_yticklabels():
    tl.set_color('b')
```

Multiple axes on one plot (2)

```
ax2 = ax1.twinx()
s2 = np.sin(2*np.pi*t)
ax2.plot(t, s2, 'r.')
ax2.set_ylabel('sin', color='r')
for tl in ax2.get_yticklabels():
    tl.set_color('r')

plt.show()
```



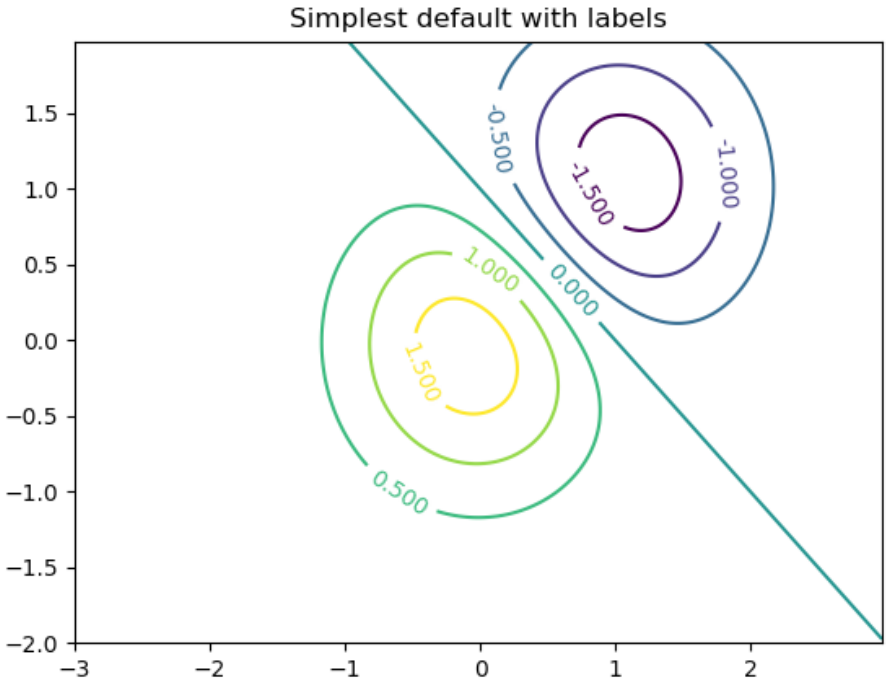
Contour plot – prepare data

```
import matplotlib
import numpy as np
import matplotlib.cm as cm
import matplotlib.pyplot as plt

delta = 0.025
x = np.arange(-3.0, 3.0, delta)
y = np.arange(-2.0, 2.0, delta)
X, Y = np.meshgrid(x, y)

# Make field to contour
Z1 = np.exp(-X**2 - Y**2)
Z2 = np.exp(-(X - 1)**2 - (Y - 1)**2)
Z = (Z1 - Z2) * 2
```

Assume this code applies to all contour examples.

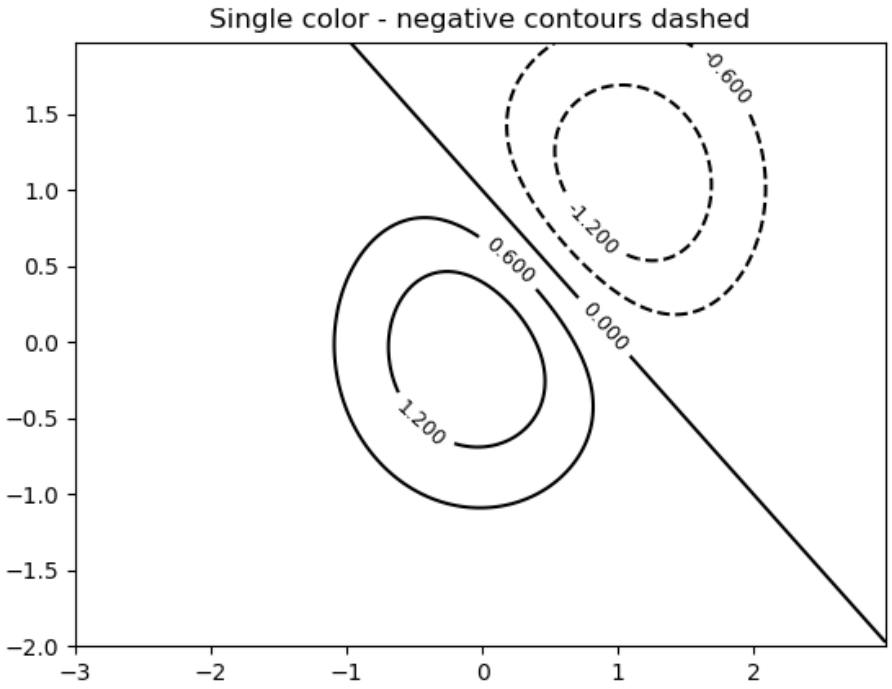
Contour plot – default colours

```
CS = plt.contour(X, Y, Z)
plt.clabel(CS, inline=1, fontsize=10)
plt.title('Simplest default with labels')
plt.show()
```



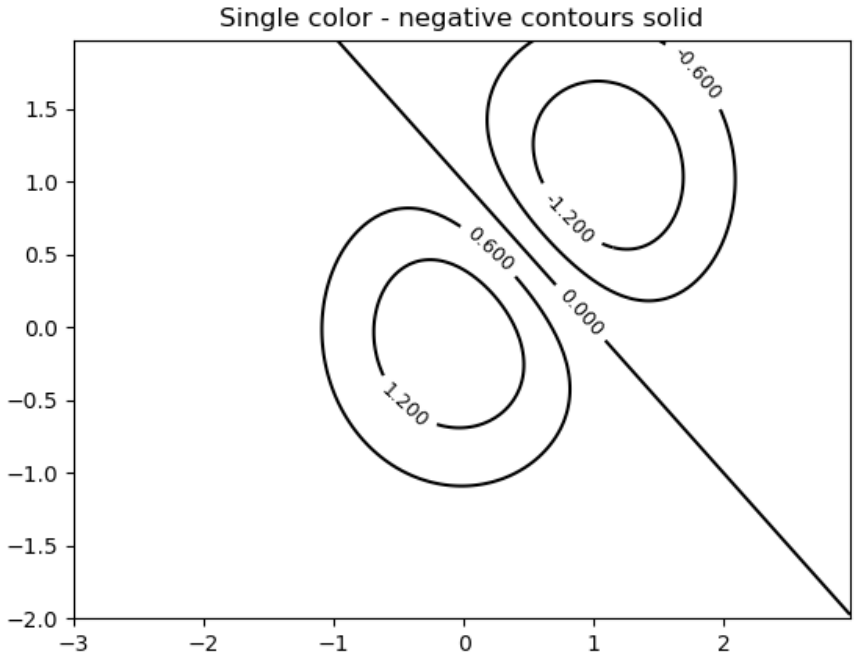
Contour plot – with negative values

```
# This time negative contours will be dashed by default
CS = plt.contour(X, Y, Z, 6, colors='k')
plt.clabel(CS, fontsize=9, inline=1)
plt.title('Single color - negative contours dashed')
plt.show()
```



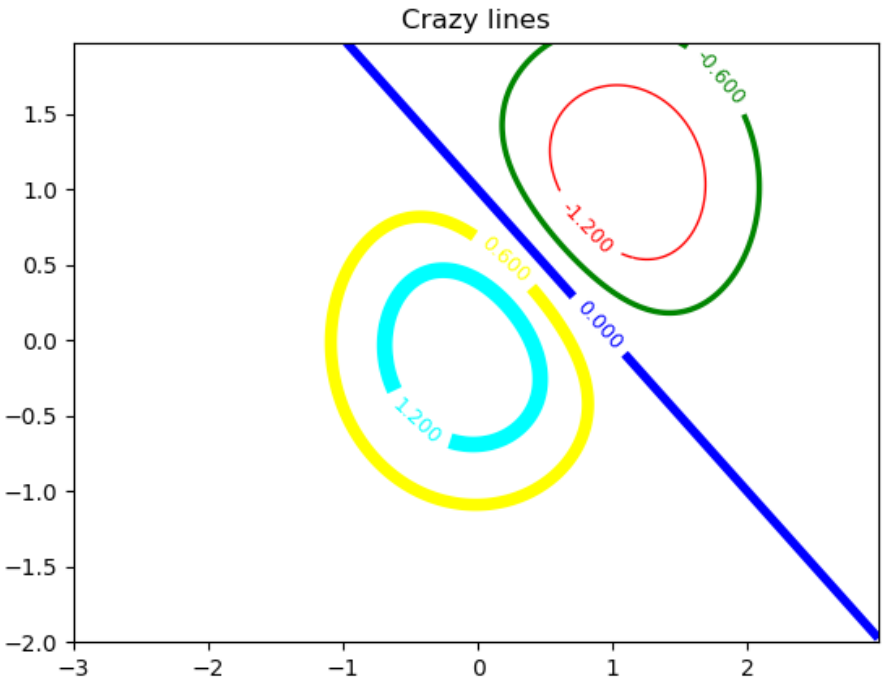
Contour plot - set negative line style

```
# Override negative contours – use solid lines
matplotlib.rcParams['contour.negative_linestyle'] = 'solid'
CS = plt.contour(X, Y, Z, 6, colors='k')
plt.clabel(CS, fontsize=9, inline=1)
plt.title('Single color - negative contours solid')
plt.show()
```



Contour plot – specify colours

```
CS = plt.contour(X, Y, Z, 6, linewidths=np.arange(1, 8, 1.5),
colors=('r', 'green', 'blue', 'yellow', 'cyan', 'wheat'))
plt.clabel(CS, fontsize=9, inline=1)
plt.title('Crazy lines')
plt.show()
```

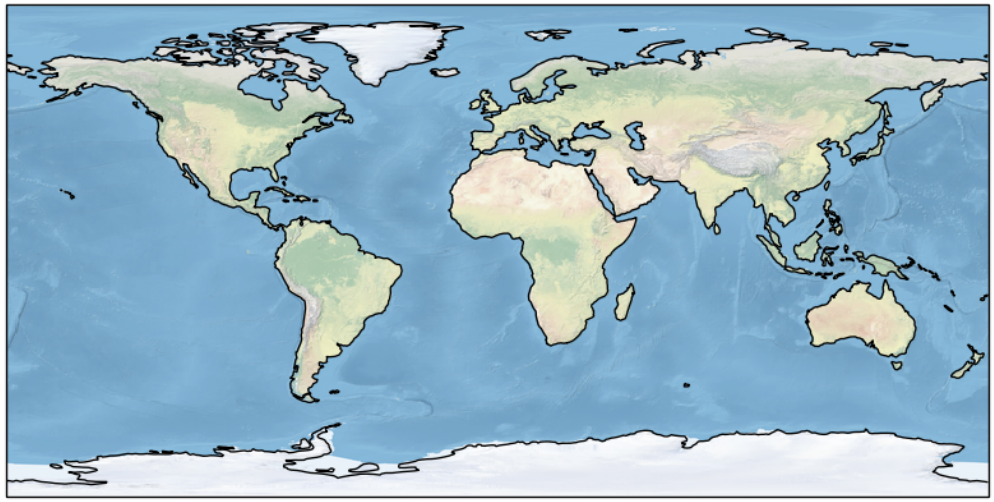


Introducing **cartopy**

- **cartopy** is a Python package designed for geospatial data processing in order to produce maps and other geospatial data analyses.
- **cartopy** does not do any plotting on its own, but provides the facilities to transform coordinates to one of 33 different map projections.
- **matplotlib** is then used to plot contours, images, vectors, lines or points in the transformed coordinates. Shoreline, river and political boundary datasets are provided within **cartopy**, along with methods for plotting them.

Plotting maps using **cartopy**

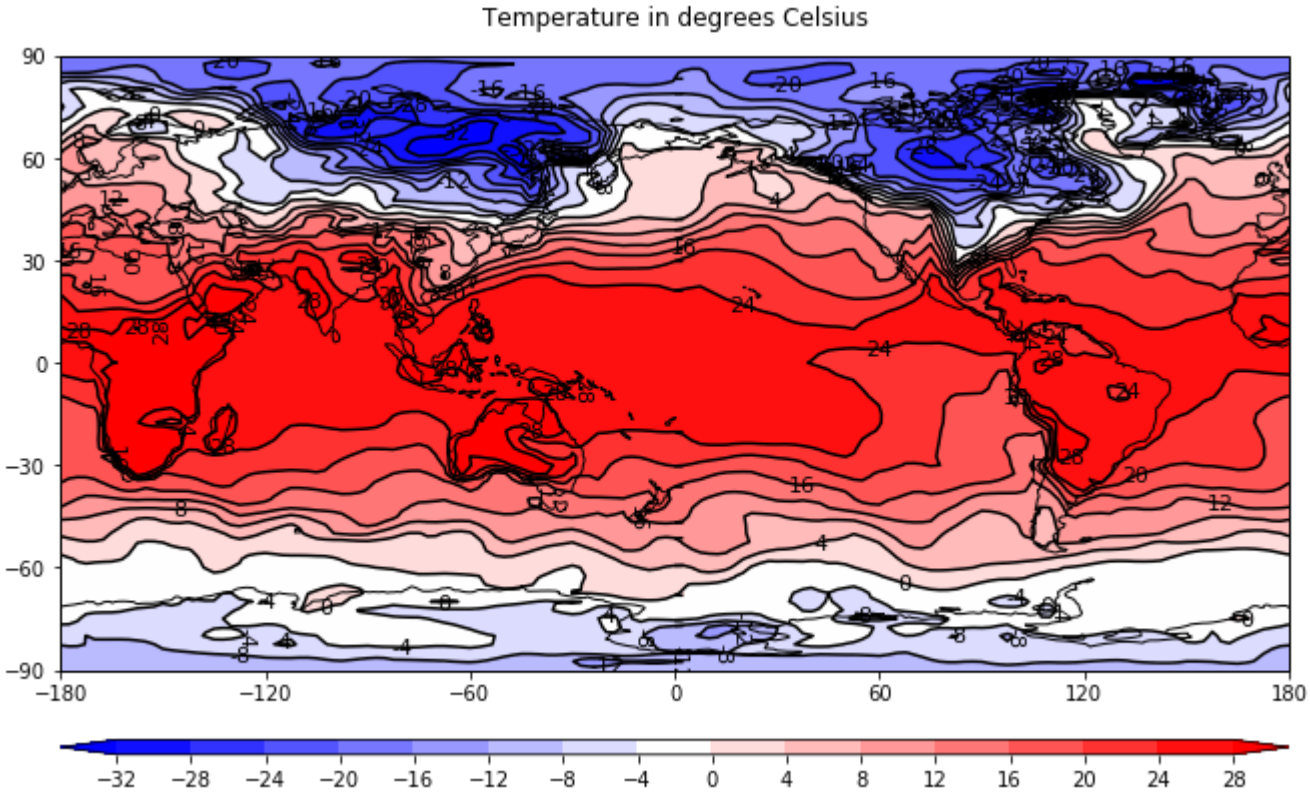
```
import matplotlib.pyplot as plt
import cartopy.crs as ccrs
fig = plt.figure(figsize=(10, 5))
ax = fig.add_subplot(1, 1, 1, projection=ccrs.PlateCarree())
ax.set_global()
ax.stock_img()
ax.coastlines()
fig.show()
```



https://scitools.org.uk/cartopy/docs/latest/gallery/index.html

Plotting data on maps

With **31 lines of code** you can extract the Air Temperature from a netCDF file and plot on a required projection:



Plotting data on maps – code 1/2

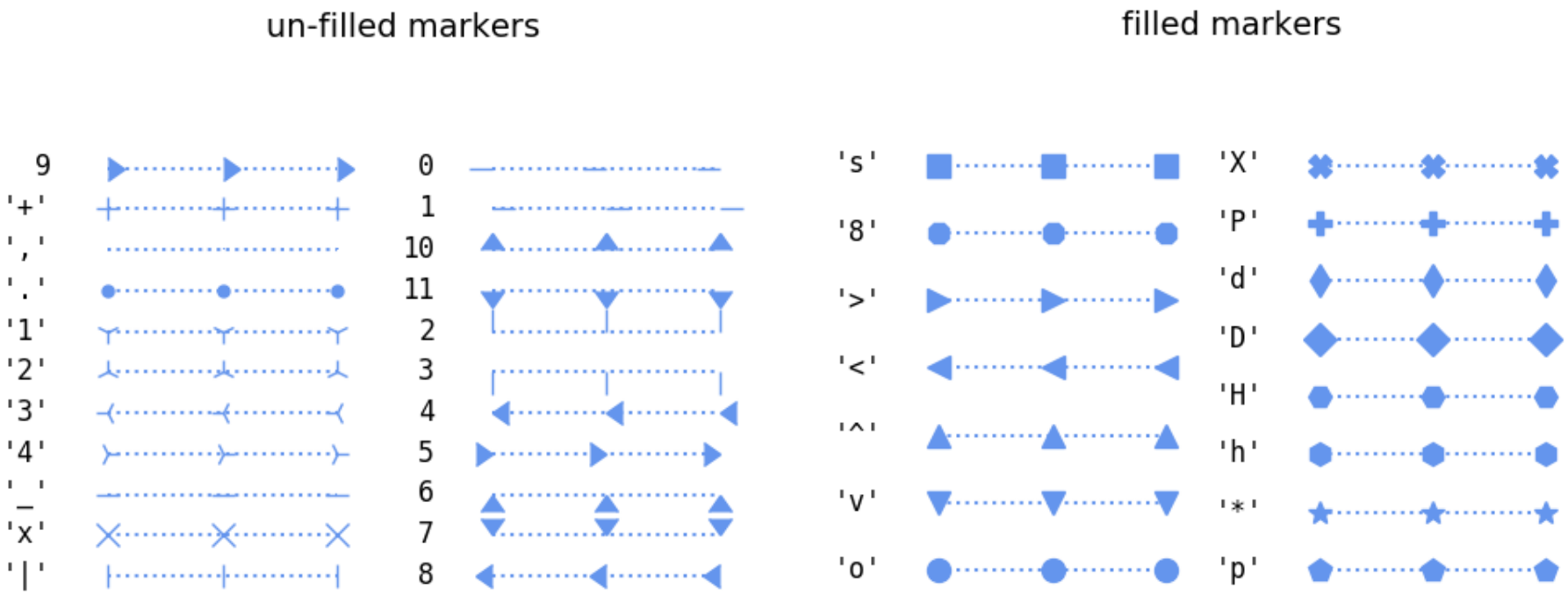
```
# import libraries
import matplotlib.pyplot as plt
import cartopy
import cartopy.crs as ccrs
import cartopy.util as cartopy_util
import numpy as np
from netCDF4 import Dataset as ncfile

# read in data
nc = ncfile('/home/andy/gdata.nc')
lons=nc.variables['lon'][:]
lats=nc.variables['lat'][:]
field=nc.variables['temp'][0,:,:]

# add cyclic point
lonrange = np.max(lons)-np.min(lons)
if lonrange <= 360:
    field, lons = cartopy_util.add_cyclic_point(field, lons)

# open a figure
plot=plt.figure(figsize=(11, 8))

# set plot limits
lonmin=0
lonmax=360
latmin=-90
latmax=90
lon_0=(lonmax-lonmin)/2.0+lonmin
```

Plotting data on maps – code 2/2

```
# set the map
proj=ccrs.PlateCarree(central_longitude=lon_0)
mymap = plot.add_subplot(1,1,1, projection=proj)
mymap.set_extent((lonmin, lonmax, latmin, latmax), crs=proj)

# contour the data
clevs=np.arange(-32, 32, 4) # levels
cs = mymap.contourf(lons, lats, field, clevs,extend='both', transform=ccrs.PlateCarree(),
cmap='bwr')
cb = plot.colorbar(cs, orientation='horizontal', aspect=75, pad=0.08, ticks=clevs)
cs = mymap.contour(lons, lats, field, clevs, colors='k', linestyles='solid',
transform=ccrs.PlateCarree())
plt.clabel(cs, fmt = '%d', colors = 'k', fontsize=11)

# axes
mymap.set_xticks(np.arange(-180, 181, 60), crs=proj)
mymap.set_yticks(np.arange(-90, 91, 30))

# coastlines
mymap.coastlines(resolution='110m')

# plot title
title = plt.title('Temperature in degrees Celsius', y=1.03)
```

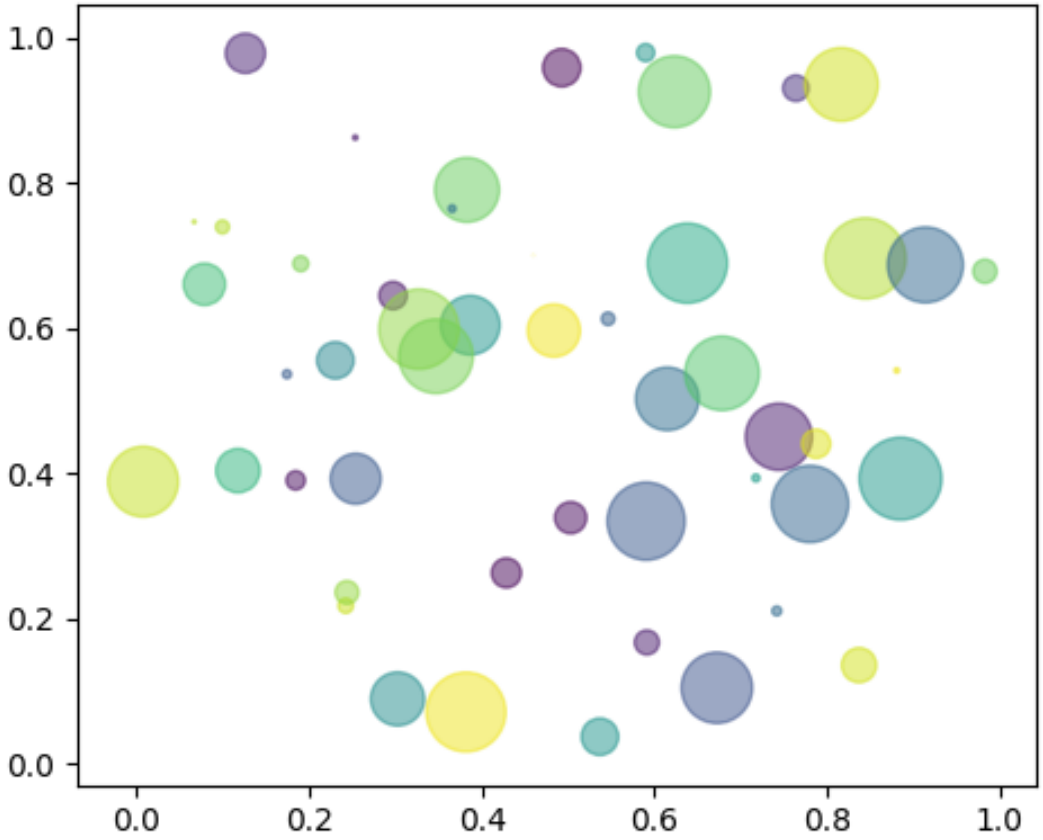
Useful features: Markers

https://matplotlib.org/examples/lines_bars_and_markers/marker_reference.html



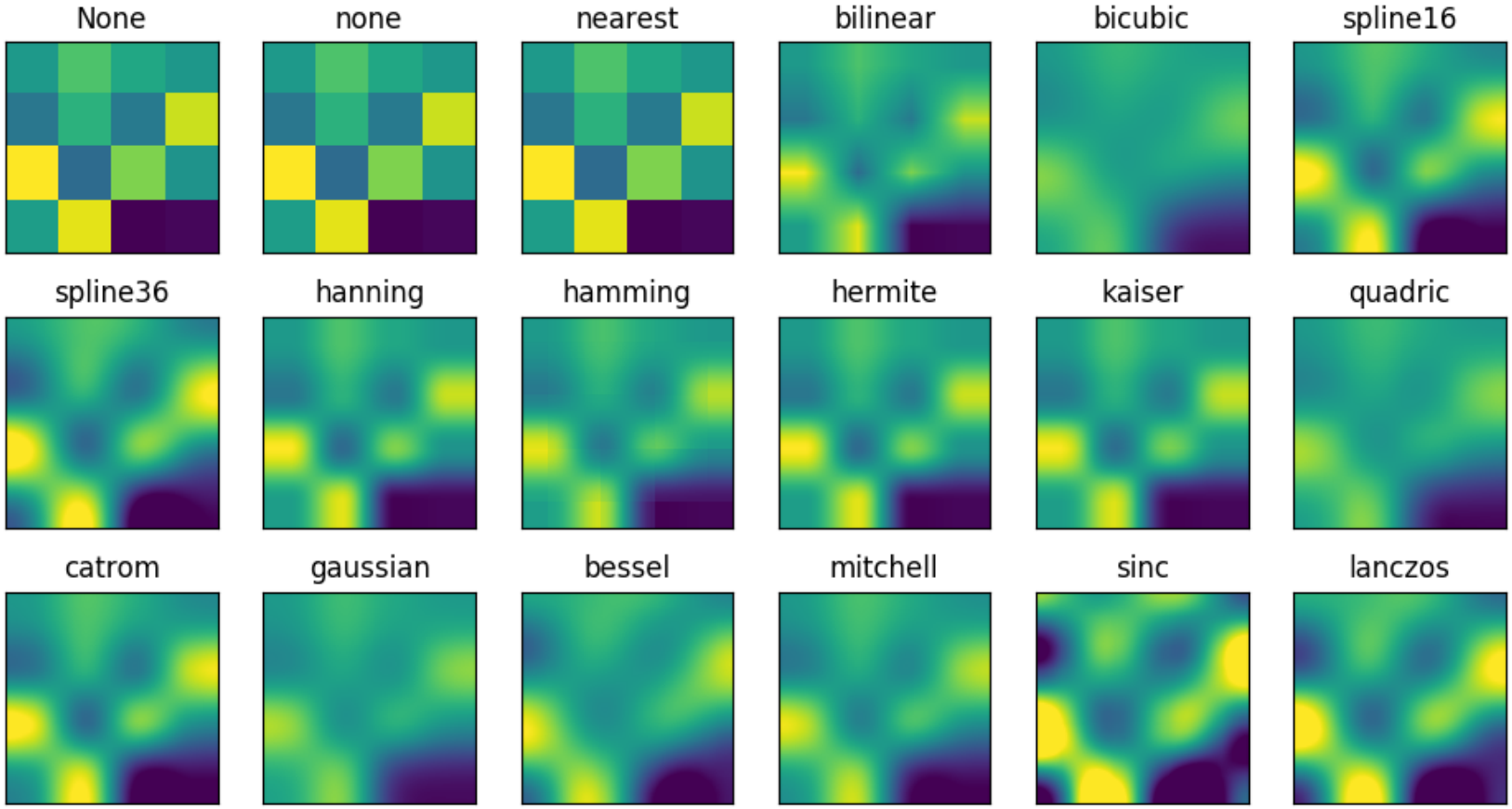
Useful features: Scatter plots

https://matplotlib.org/examples/shapes_and_collections/scatter_demo.html



Useful features: Interpolation

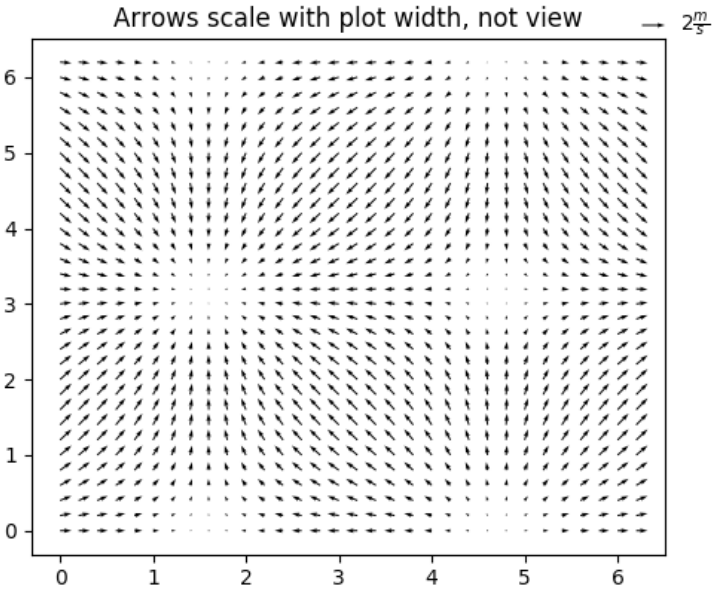
https://matplotlib.org/examples/images_contours_and_fields/interpolation_methods.html

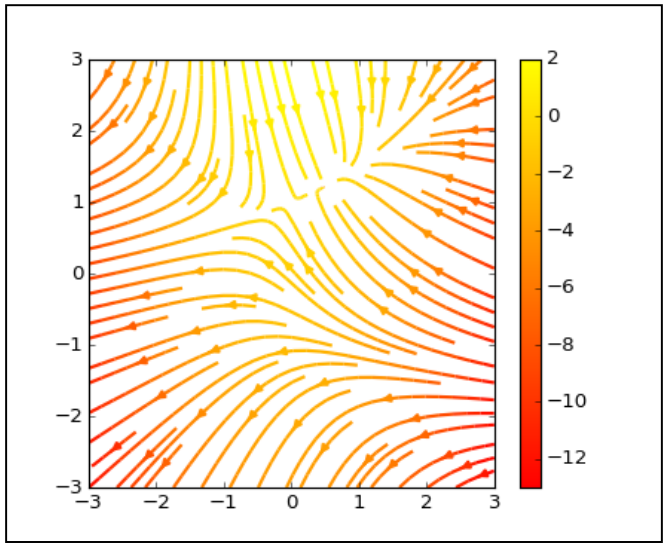


Useful features: quiver and stream plot

https://matplotlib.org/examples/pylab_examples/quiver_demo.html

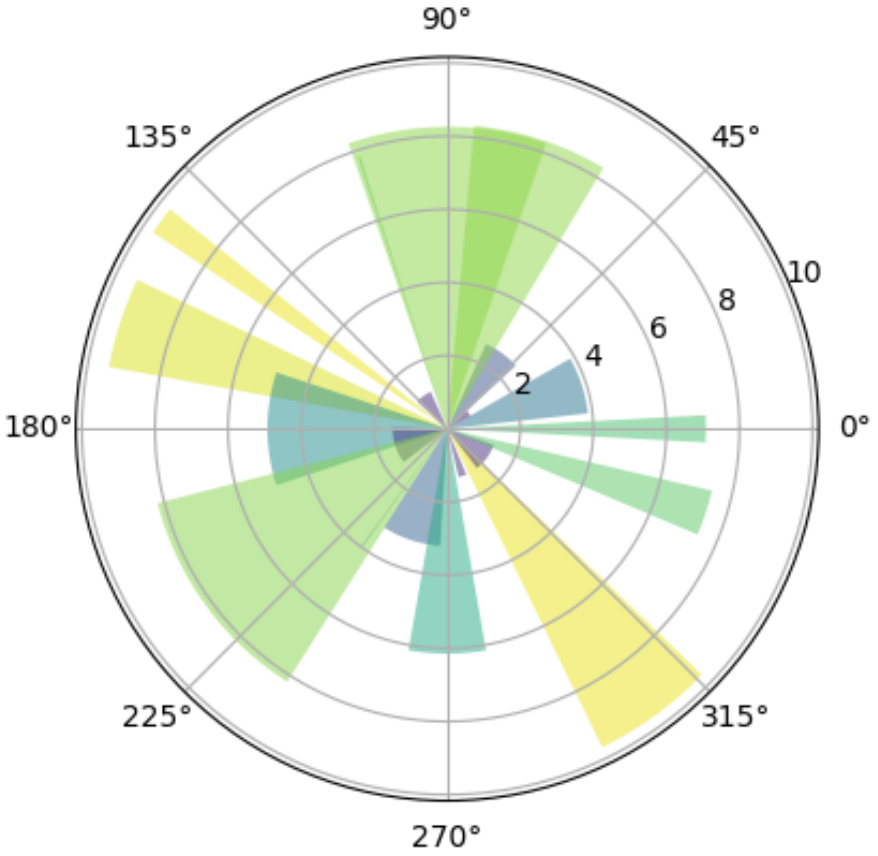
https://matplotlib.org/examples/images_contours_and_fields/streamplot_demo_features.html





Useful features: Polar bar

https://matplotlib.org/examples/pie_and_polar_charts/polar_bar_demo.html



One last word: the OOP interface

We have demonstrated Matplotlib using the "pylab" interface (which aims to mimic that of MATLAB).

You can interact with Matplotlib using its OOP interface (known as the *Matplotlib API*). This is a different interface to the same functionality.

Over time you may wish to use the OOP interface for complex plotting applications.

More info

Matplotlib:
https://matplotlib.org

Matplotlib gallery:
https://matplotlib.org/gallery

Pyplot reference:
https://matplotlib.org/api/pyplot_summary.html

Cartopy:
https://scitools.org.uk/cartopy/docs/latest/index.html

Books, videos and tutorials:
https://matplotlib.org/resources/index.html