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Visualisation in python (with Matplotlib)

Thanks to all contributors:

Ag Stephens, Stephen Pascoe.

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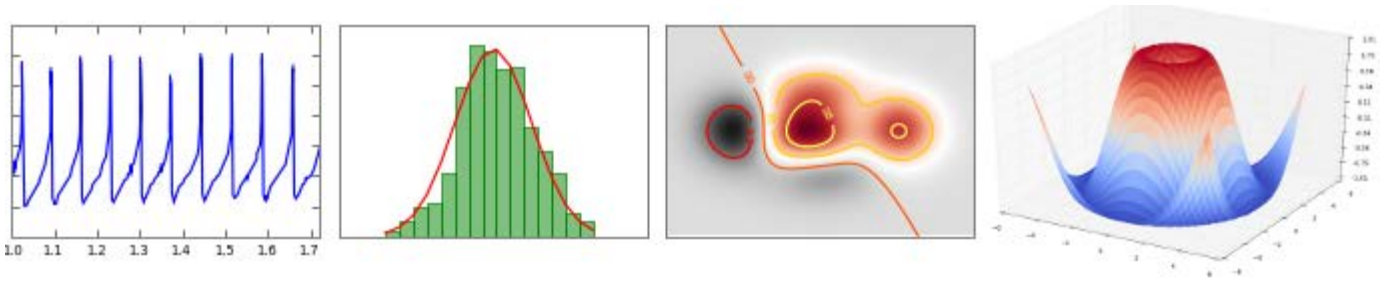
Introducing Matplotlib

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 six 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

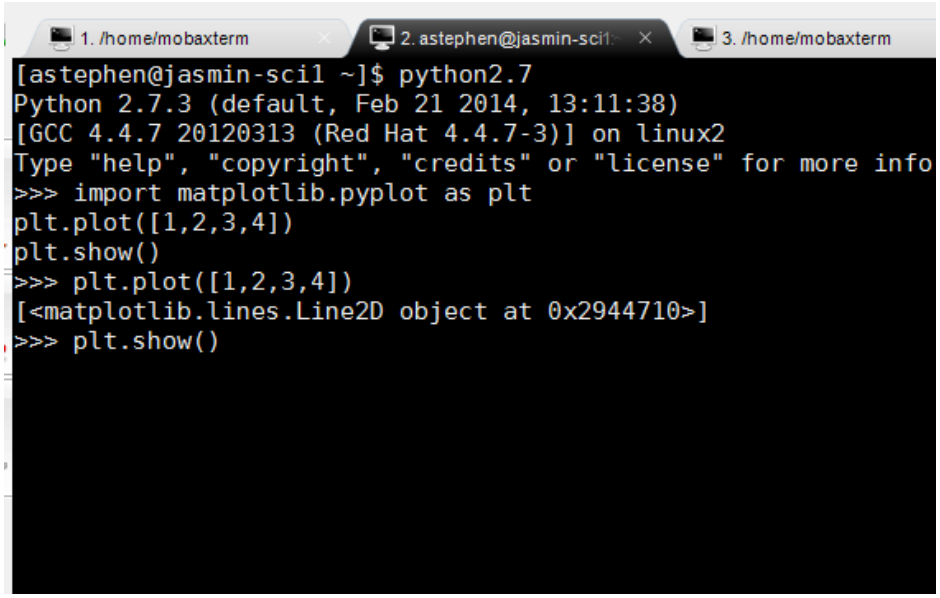
As with all open source Python tools there are other options and approaches available.

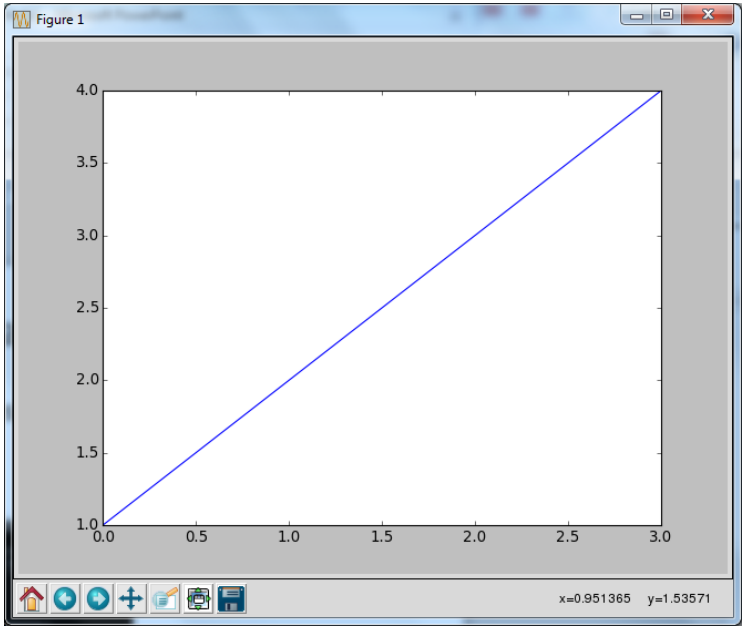
However, Matplotlib, like NumPy, has become the **clear leader** in its particular niche.

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

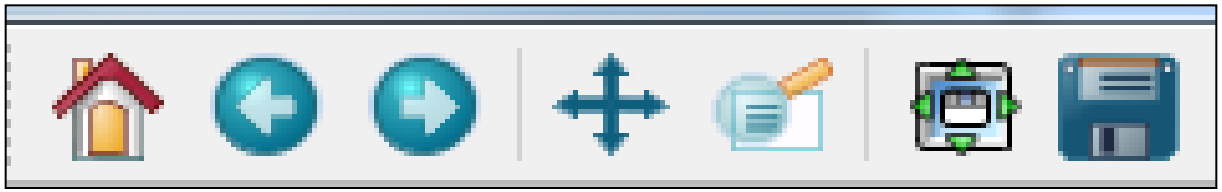
Using Matplotlib Interactively

- Matplotlib has it's own interactive plotting window:





Using Matplotlib Interactively



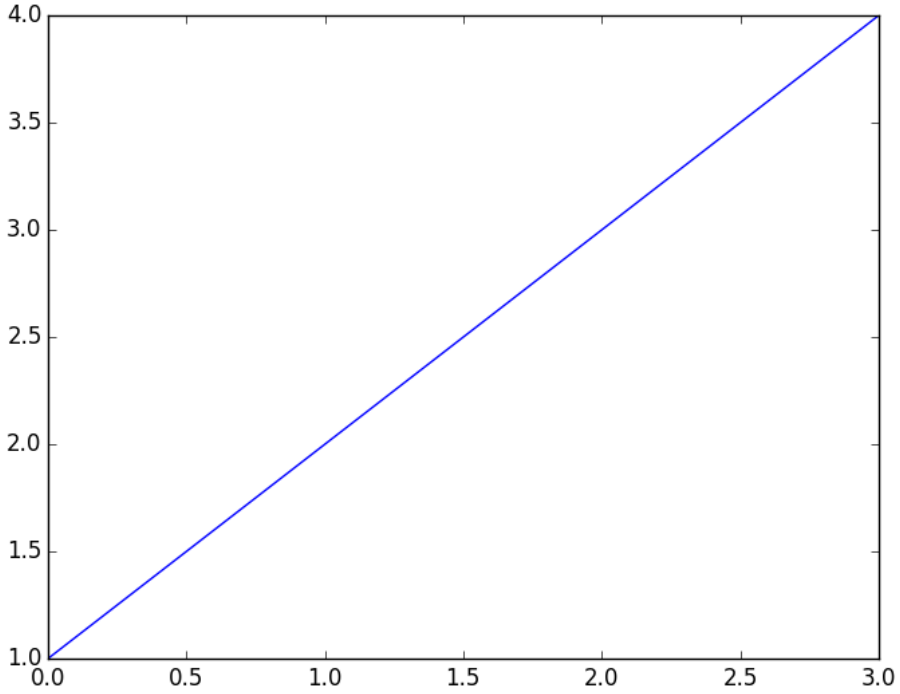
The buttons allow you to:

- 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).



!!!This slide is important!!!

Before we go any further…

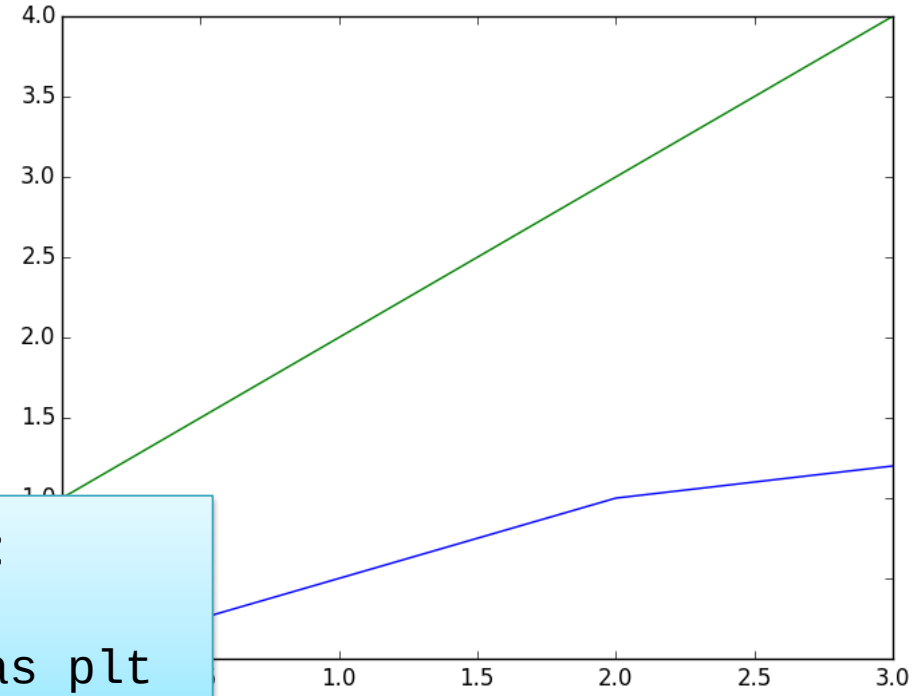
In the environment you are working with it is useful to be able to work in Python without closing your interactive window. **Here's how you do it:**

```
>>> import matplotlib.pyplot as plt # The standard import
>>> plt.plot(range(5))              # Generate a plot
>>> plt.pause(0.1)                  # Show the plot but split
                                    # focus with python shell
# Now you can continue to modify the plot in python
>>> plt.clf()                       # Clears the figure
>>> plt.pause(0.1)                  # Updates the (clear) plot
>>> plt.plot([1, 10, 3, 4, 9])      # Plot something different
>>> plt.pause(0.1)                  # Show the plot in the
                                    # window.
```

!!!This slide is important…if a bit of a kludge!!!

Two lines

```
plt.plot([0,0.5,1,1.2])
plt.plot([1,2,3,4])
plt.show()
```

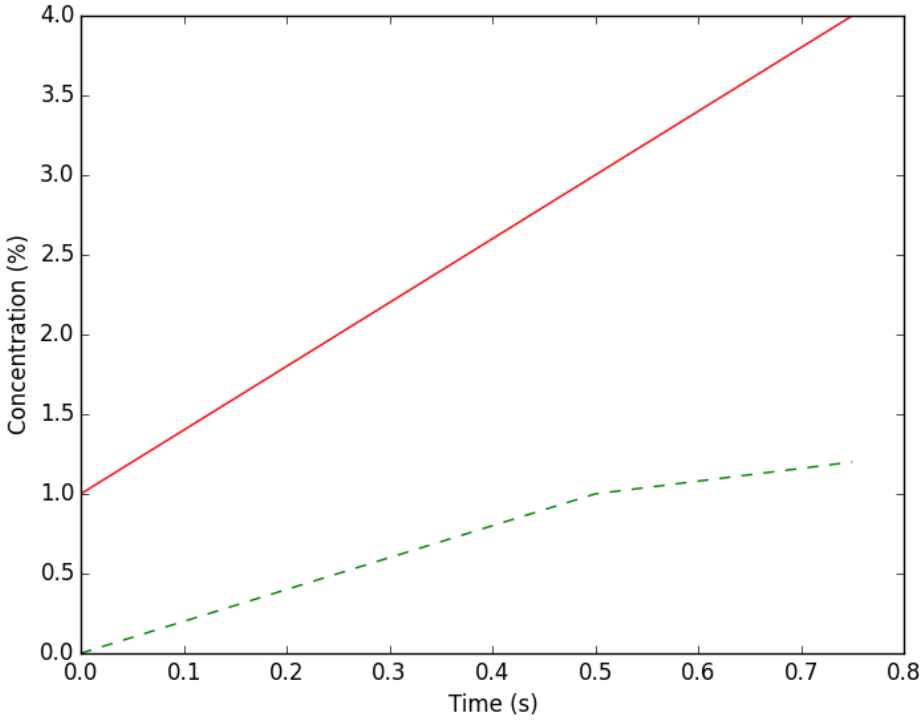


Assume we have always run:

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

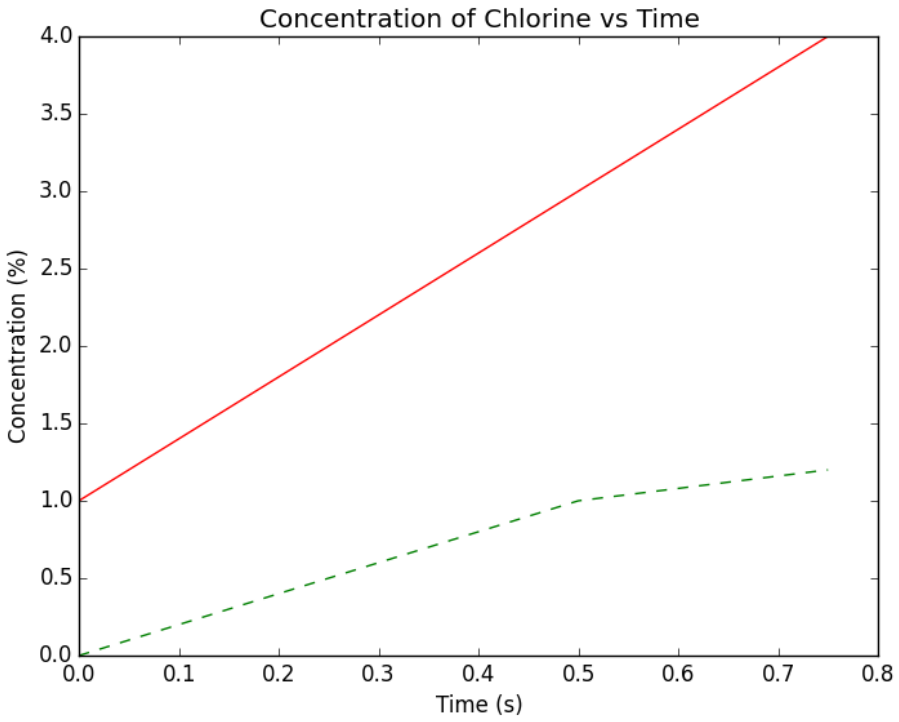
Two lines formatted – with axes

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



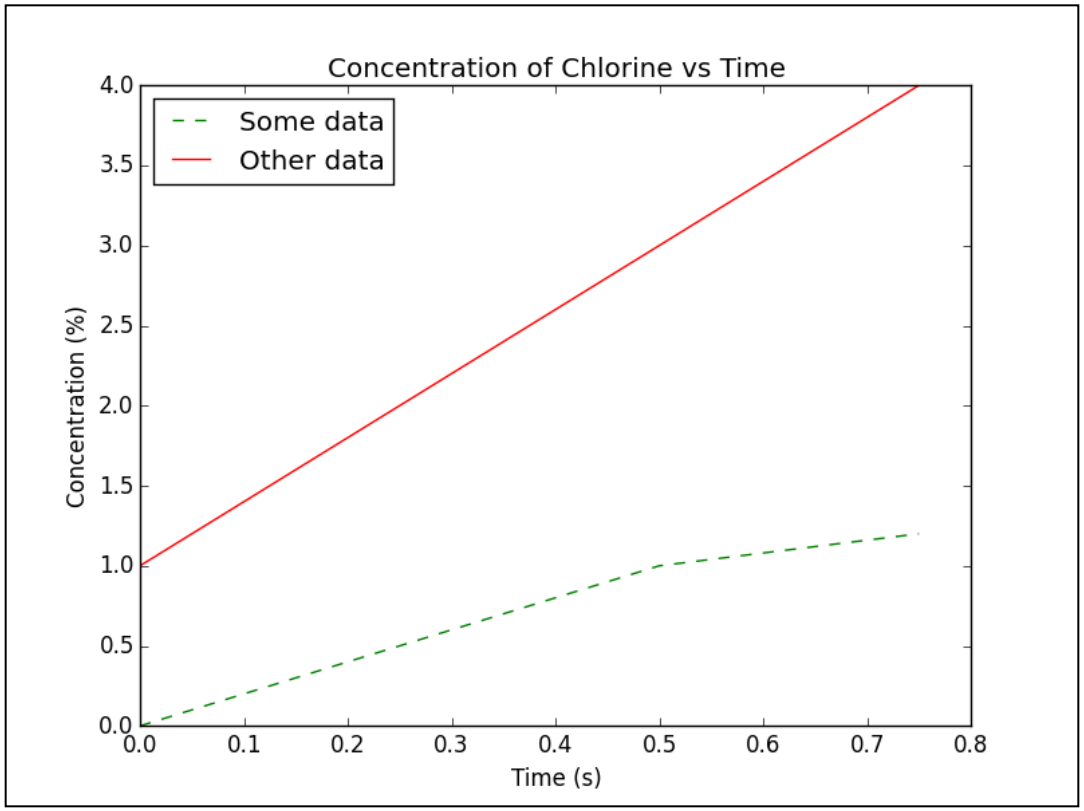
Add a title

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



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" or "svg"
  - And more…

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()
```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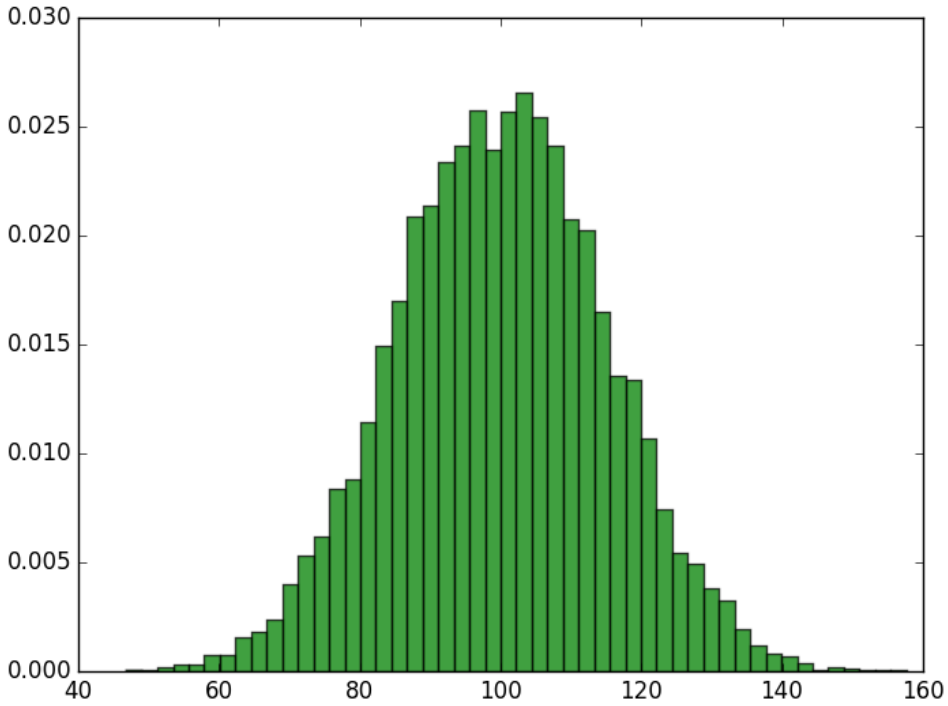
Histogram – prepare the data

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

mu, sigma = 100, 15
x = mu + sigma * np.random.randn(10000)
```

The above code will be assumed for all the following histogram examples.

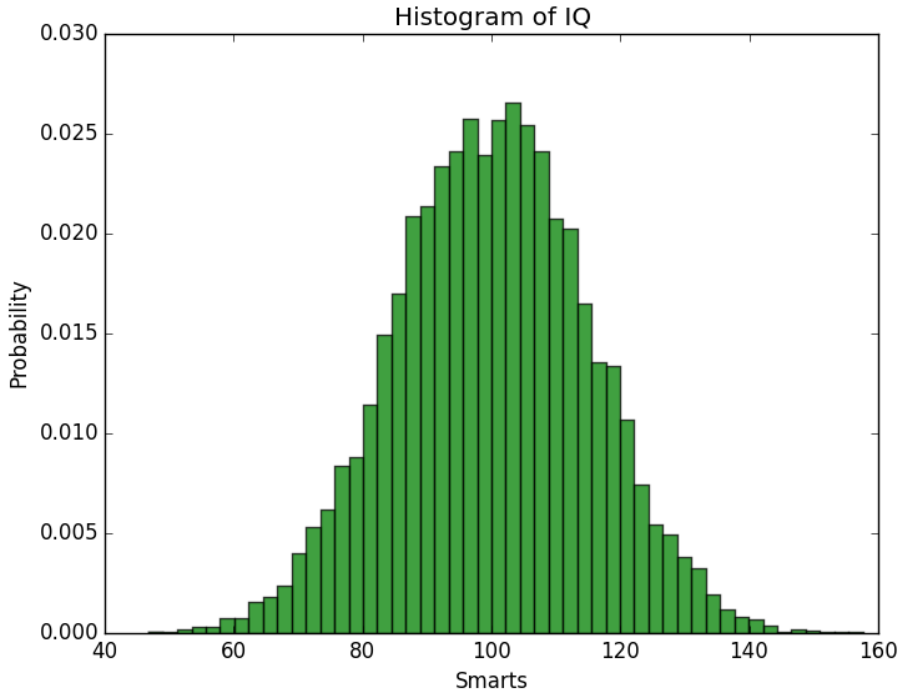
Histogram - basic

```
n, bins, patches = plt.hist(x, 50, normed=1,
                            facecolor='g', alpha=0.75)
plt.axis([40, 160, 0, 0.03])
plt.show()
```



Histogram – annotated

```
n, bins, patches = plt.hist(x, 50, normed=1,
                            facecolor='g', alpha=0.75)
plt.xlabel('Smarts')
plt.ylabel('Probability')
plt.title('Histogram of IQ')
plt.axis([40, 160, 0, 0.03])
plt.show()
```



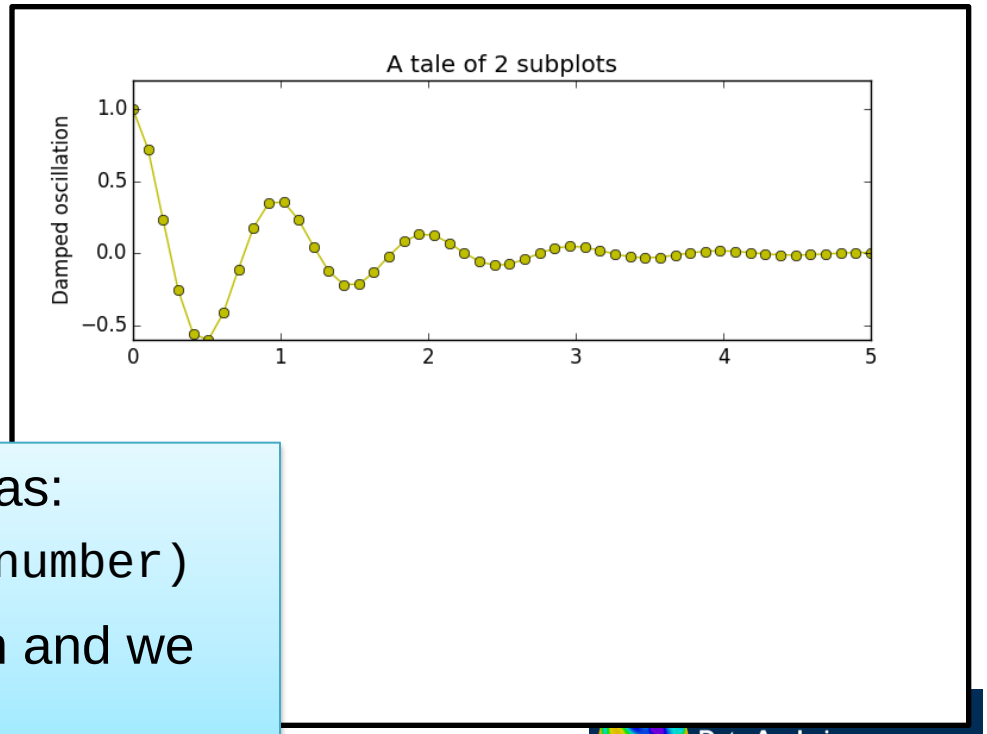
Multiple plots – prepare data

```
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 above code will be assumed for all the following multiple plot examples.

Multiple plots (using subplot)

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



The "subplot" function is defined as:

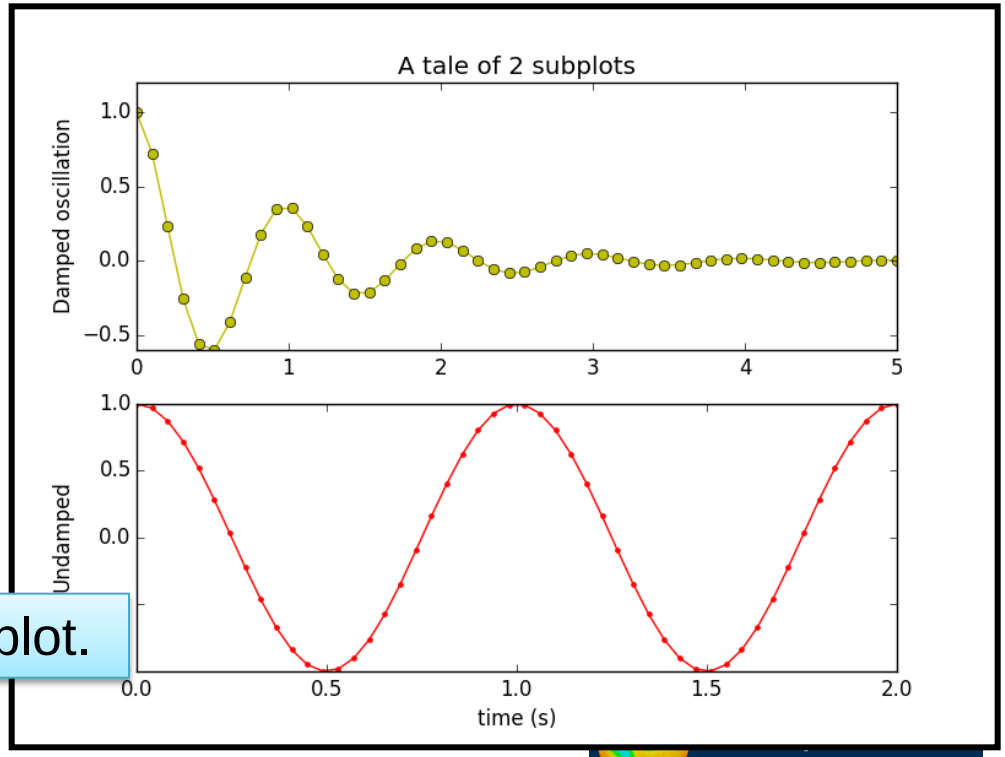
`subplot(nrows, ncols, plot_number)`

Here we define: 2 rows, 1 column and we add the first plot.

Multiple plots (using subplot)

```
plt.subplot(2, 1, 1)
plt.plot(x1, y1, 'yo-')
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()
```



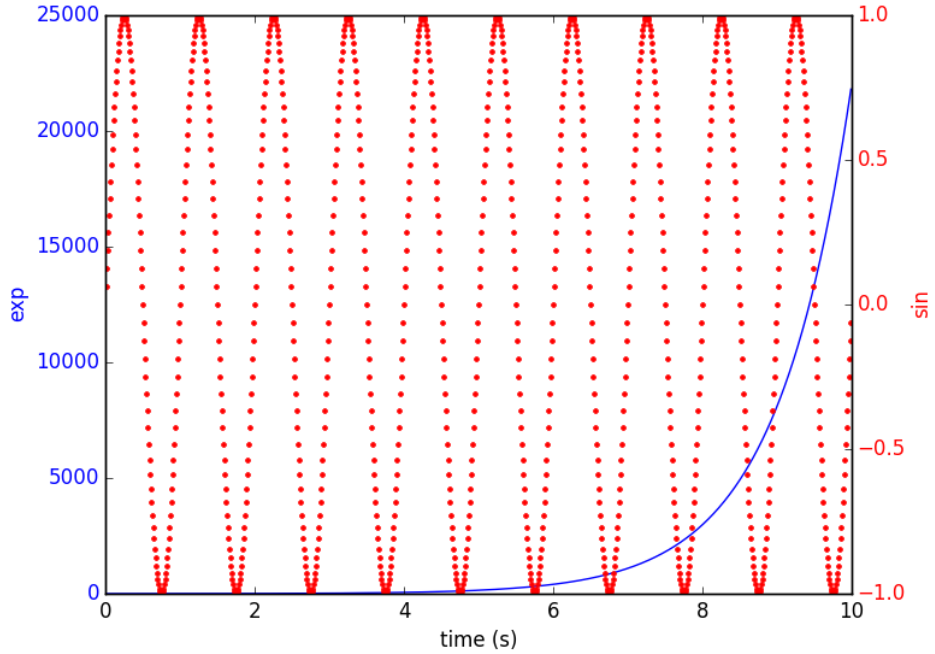
Now we have added the second plot.

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()
```

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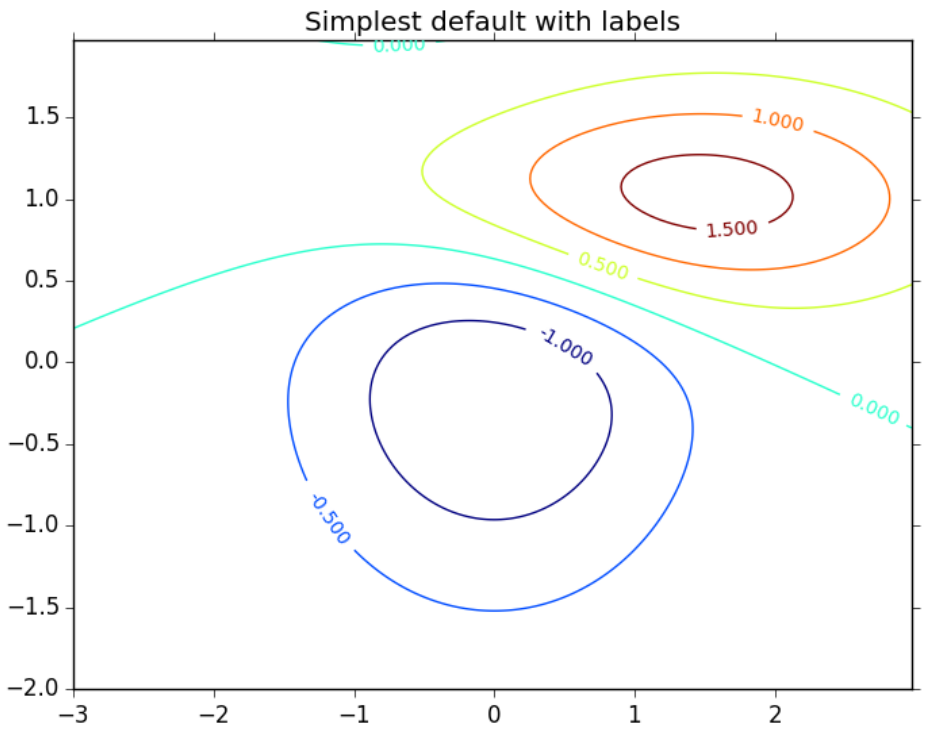
Contour plot – prepare data

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

matplotlib.rcParams['xtick.direction'] = 'out'
matplotlib.rcParams['ytick.direction'] = 'out'

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)
Z1 = mlab.bivariate_normal(X, Y, 1.0, 1.0, 0.0, 0.0)
Z2 = mlab.bivariate_normal(X, Y, 1.5, 0.5, 1, 1)
# difference of Gaussians
Z = 10.0 * (Z2 - Z1)
```

Assume this code applies to all contour examples.

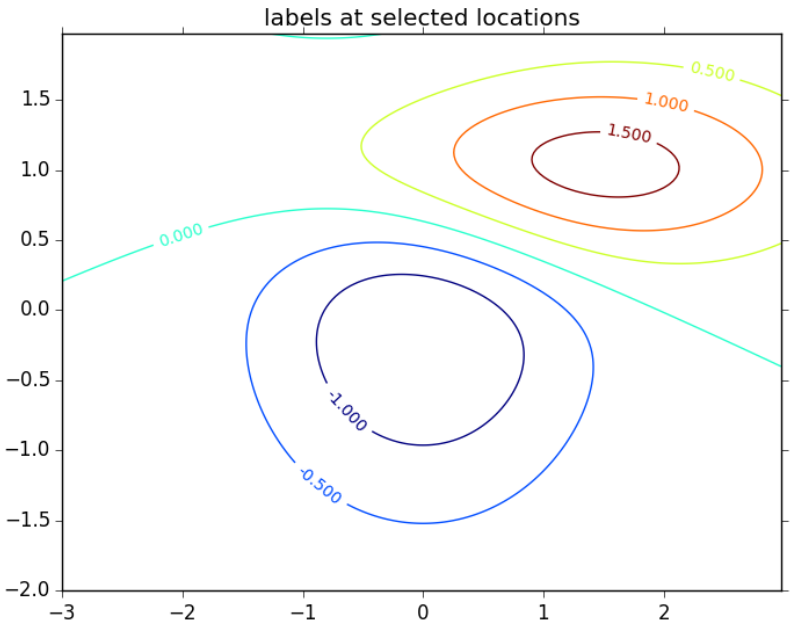
Contour plot – default colours

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



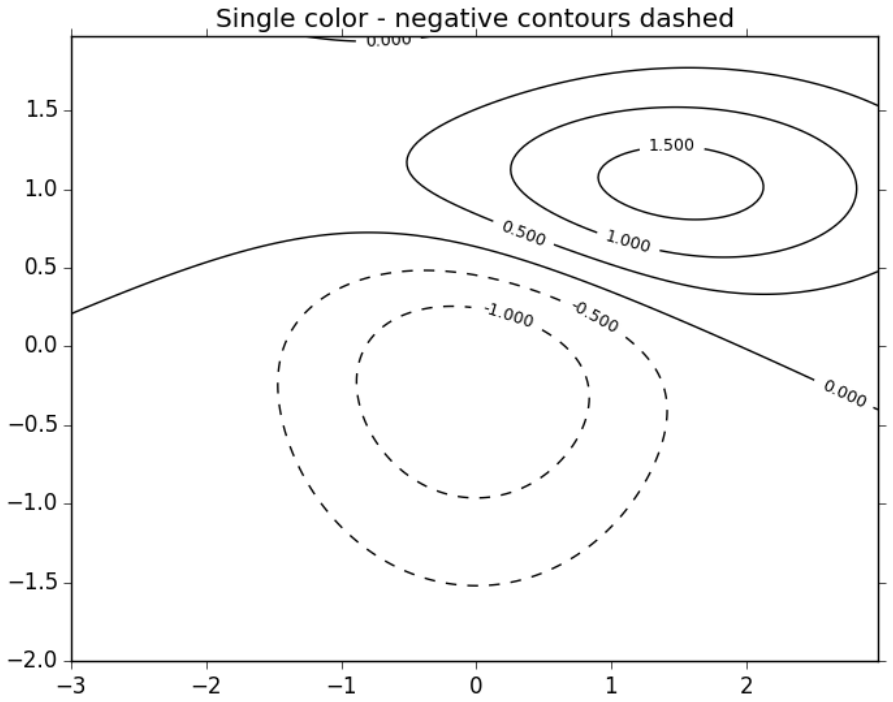
Contour plot – control labels

```
CS = plt.contour(X, Y, Z)
manual_locations = [(-1, -1.4), (-0.62, -0.7), (-2, 0.5),
                    (1.7, 1.2), (2.0, 1.4), (2.4, 1.7)]
plt.clabel(CS, inline=1, fontsize=10,
           manual=manual_locations)
plt.title('labels at selected locations')
plt.show()
```



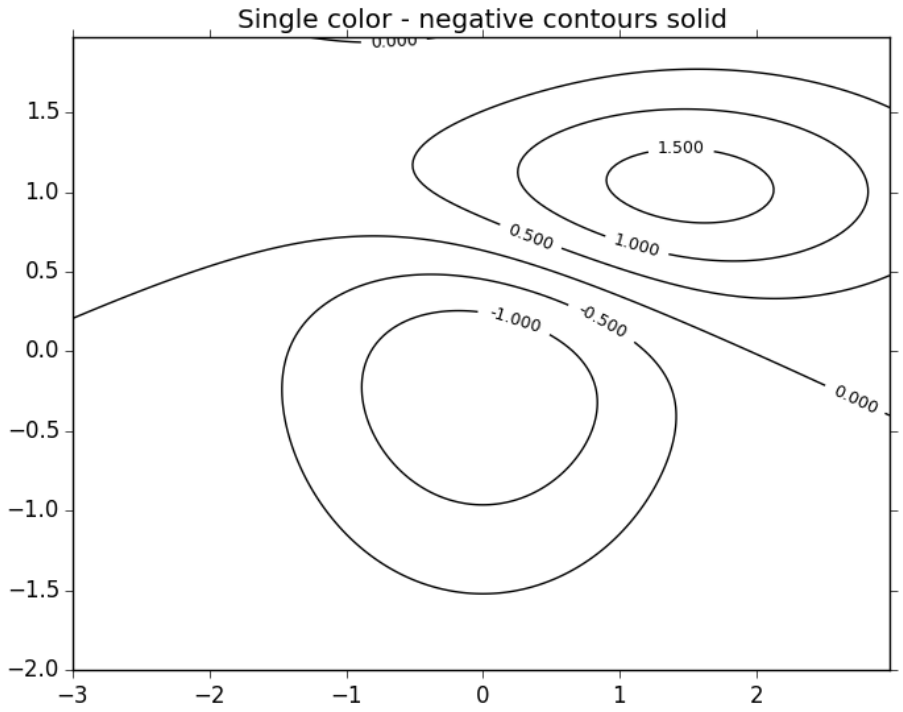
Contour plot – with negative values

```
# 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()
```



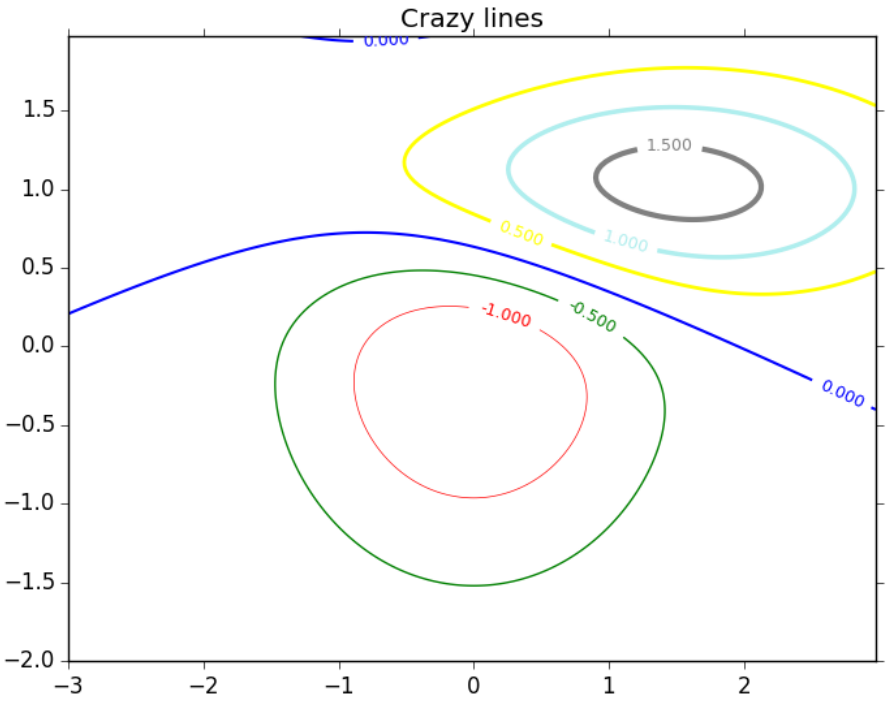
Contour plot - set negative line style

```
# 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()
```



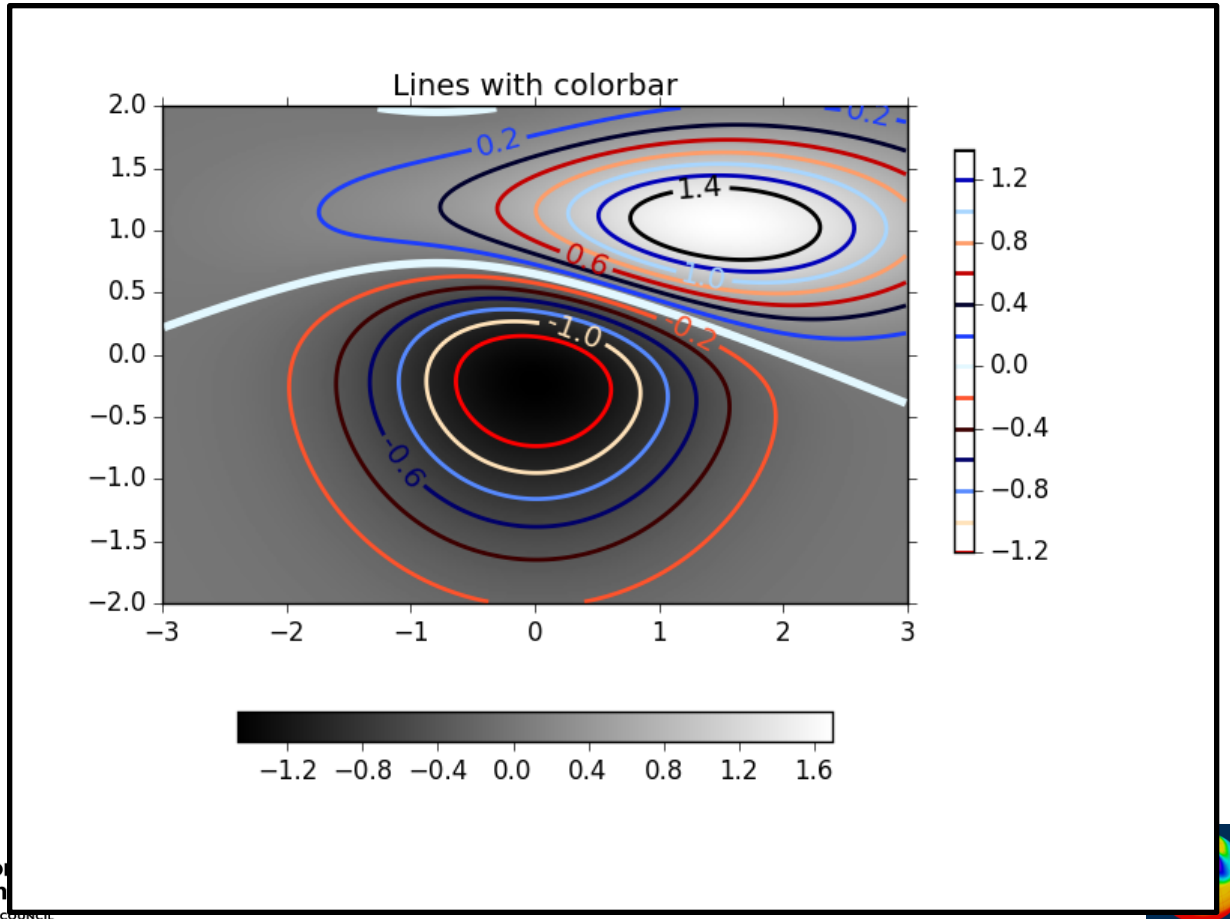
Contour plot – specify colours

```
CS = plt.contour(X, Y, Z, 6, linewidths=np.arange(.5, 4, .5),
                 colors=('r', 'green', 'blue', (1, 1, 0),
                         '#afeeee', '0.5'))
plt.clabel(CS, fontsize=9, inline=1)
plt.title('Crazy lines')
plt.show()
```



Contour plot - smart

And you can keep going…

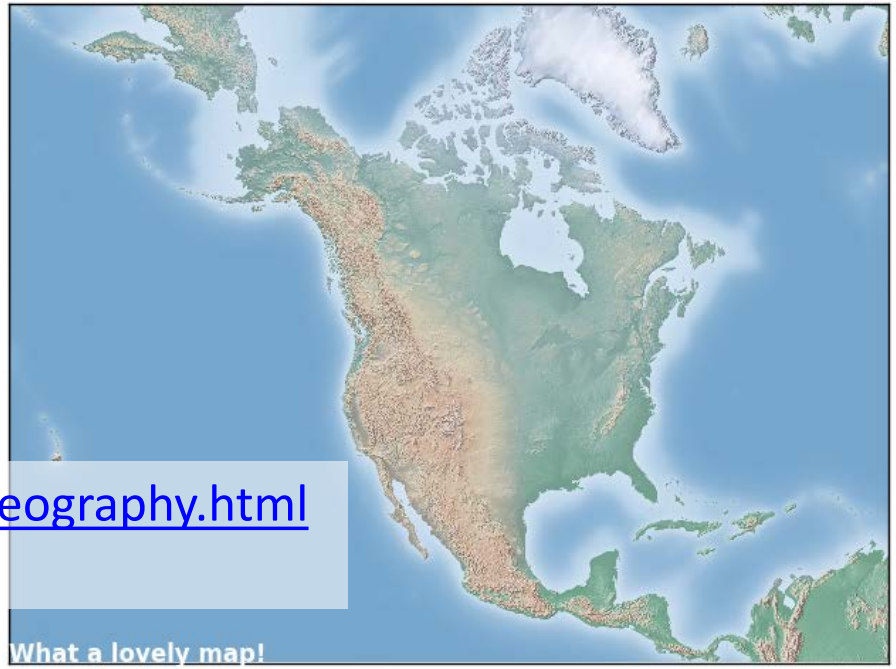


Introducing **Basemap**

- The matplotlib **`basemap`** toolkit is a library for plotting 2D data on maps in Python.
- It is similar in functionality to the *MATLAB mapping toolbox*.
- **Basemap** does not do any plotting on its own, but provides the facilities to transform coordinates to one of 25 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, along with methods for plotting them.

Plotting maps – using Basemap

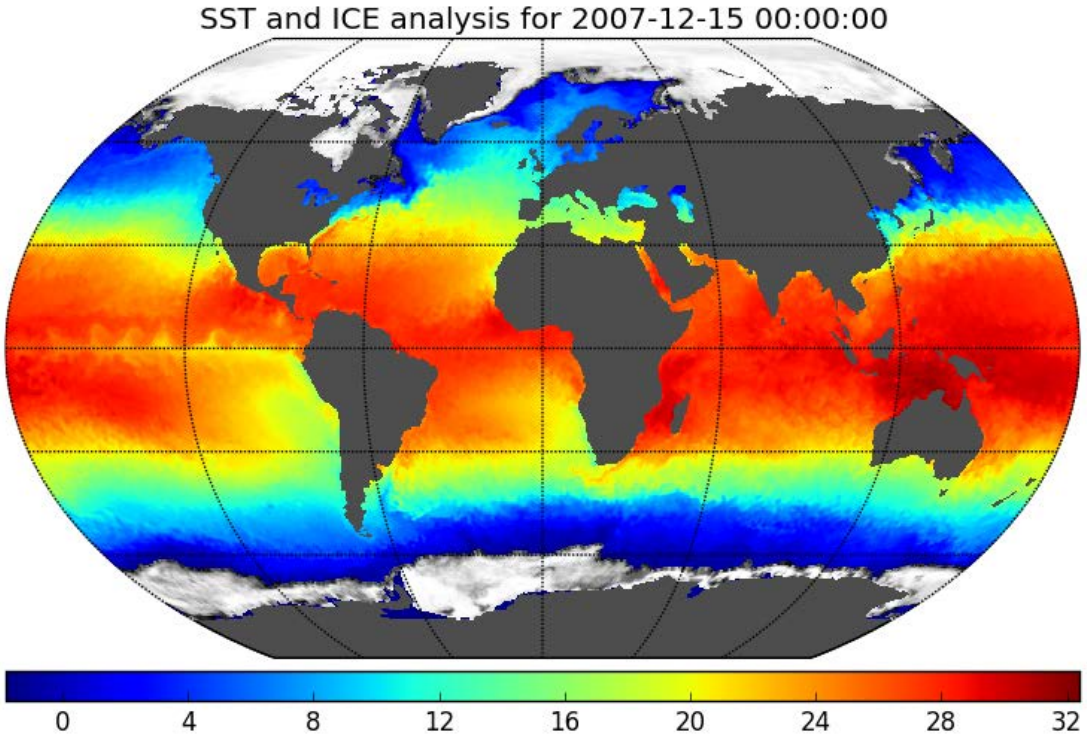
```
from mpl_toolkits.basemap import Basemap
import matplotlib.pyplot as plt
m = Basemap(width=12000000,height=9000000,projection='lcc',
     resolution=None,lat_1=45.,lat_2=55,lat_0=50,lon_0=-107.)
m.shadedrelief()
plt.text(0.2, 0.2, "What a lovely map!", color="white",
         weight="bold")
plt.show()
```



http://matplotlib.org/basemap/users/geography.html

Plotting maps – and data

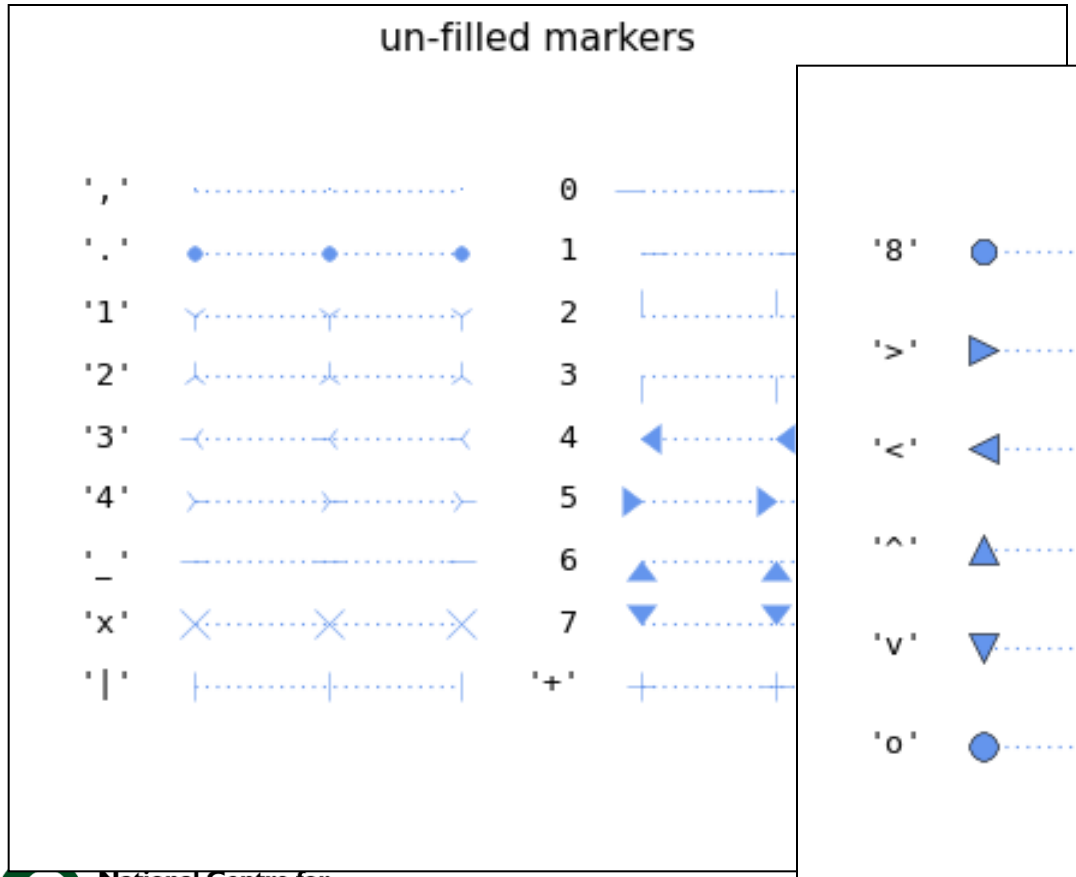
With about **30 lines of code** you can extract Sea Surface Temperature and Ice from a file and plot on a required projection:

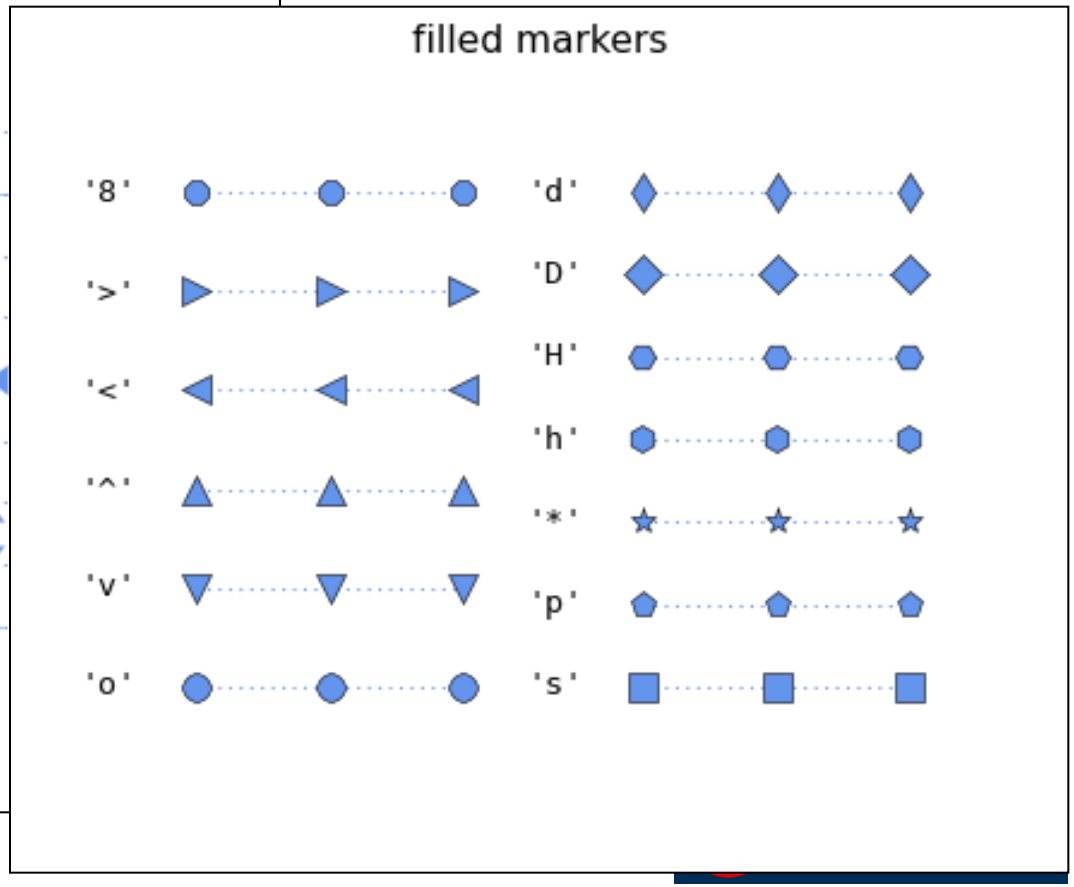


http://matplotlib.org/basemap/users/examples.html

Useful features: Markers

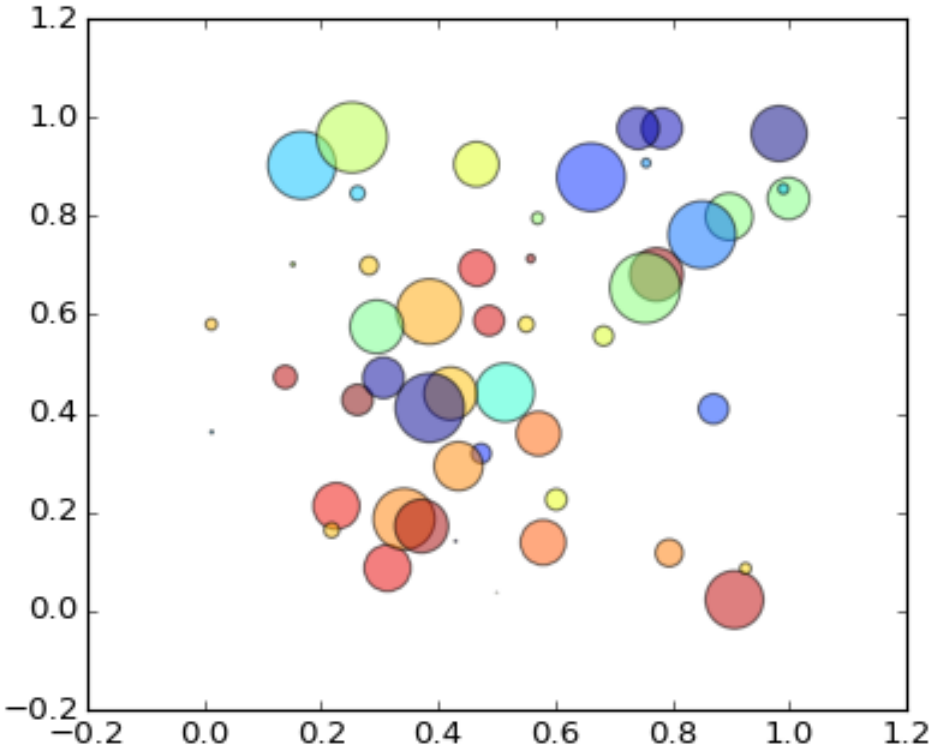
http://matplotlib.org/examples/lines_bars_and_markers/marker_reference.html





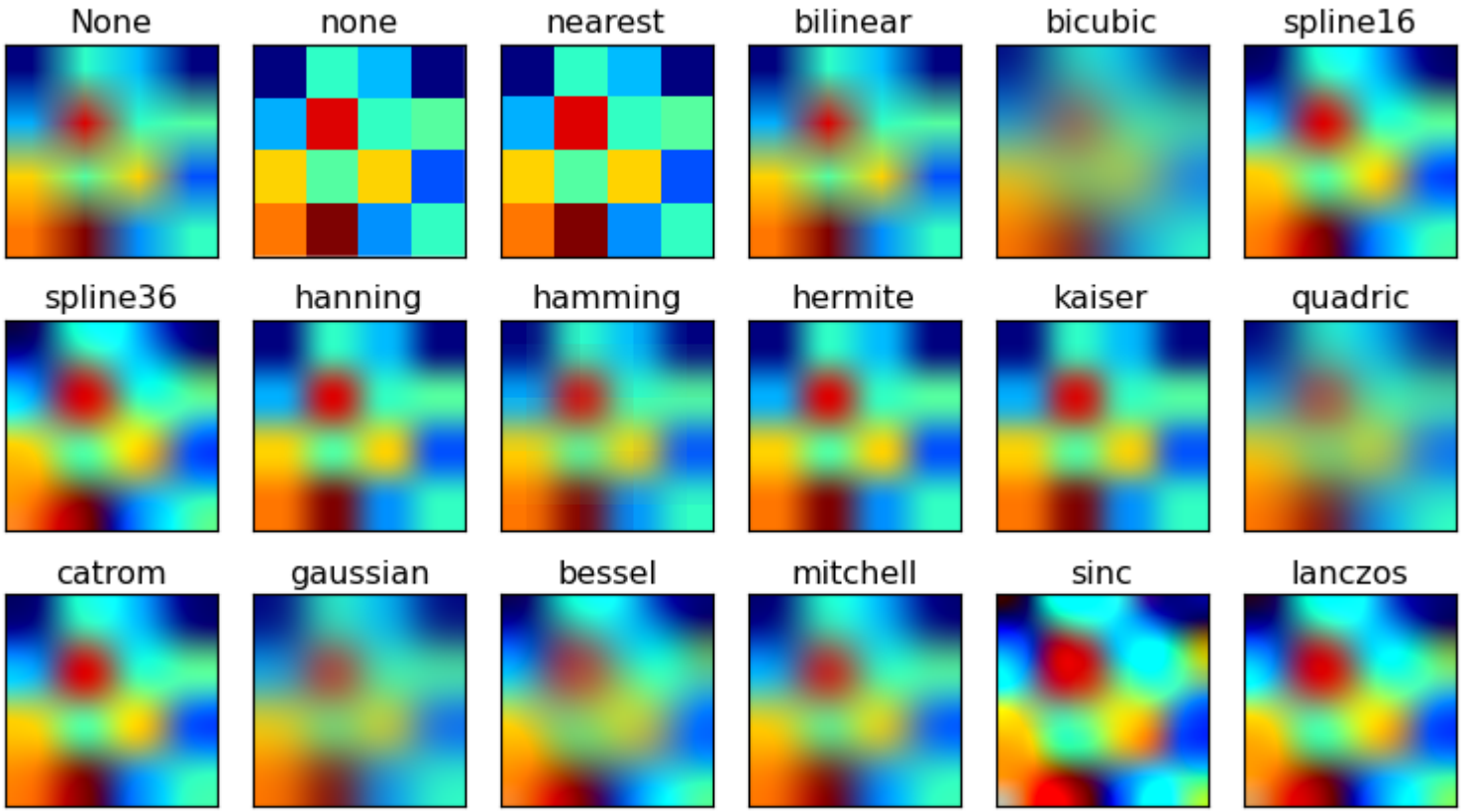
Useful features: Scatter plots

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



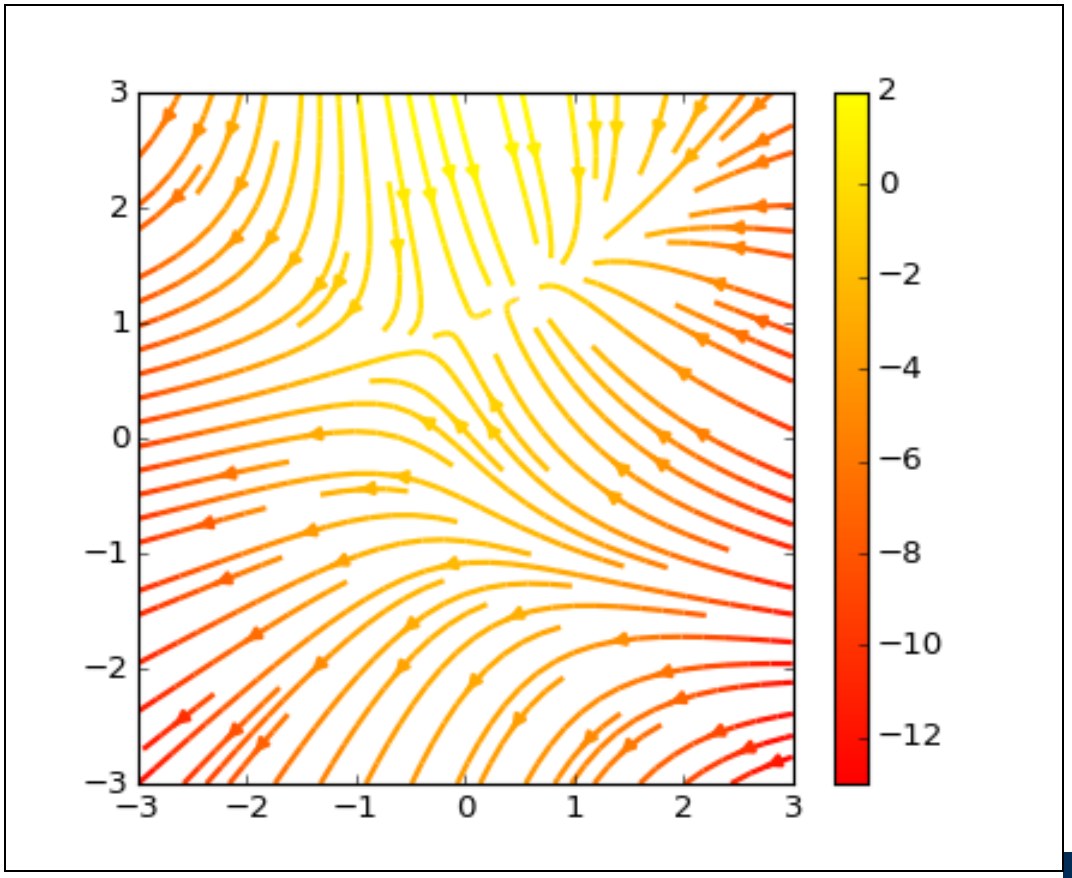
Useful features: Interpolation

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



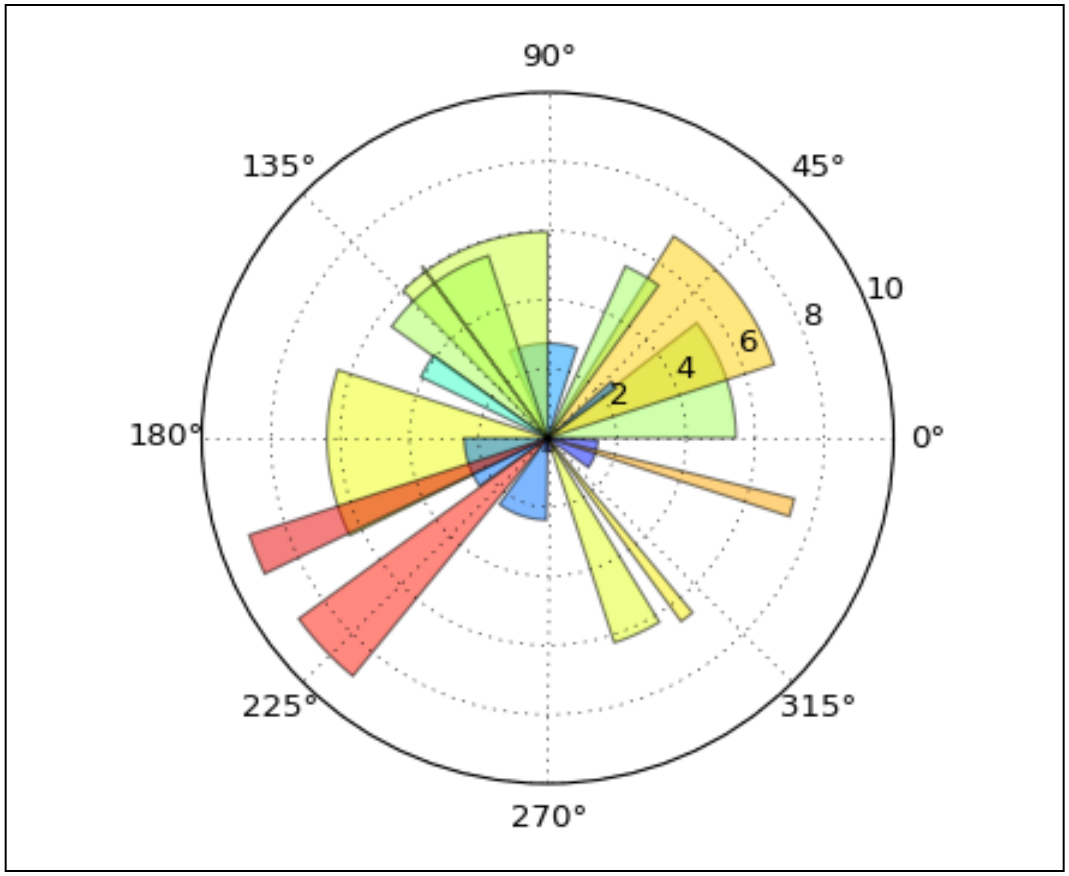
Useful features: Stream plot

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



Useful features: Polar bar

http://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:
  - http://matplotlib.org
- Matplotlib gallery:
  - http://matplotlib.org/gallery.html
- Pyplot reference:
  - http://matplotlib.org/api/pyplot_summary.html
- Basemap toolkit (for map plotting):
  - http://matplotlib.org/basemap/
- Books, videos and tutorials:
  - http://matplotlib.org/1.4.3/resources/