Matplotlib

A python plotting suite

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Direction Informatique

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Outline

- What is Matplotlib ?
- Matplotlib basics
- Useful extensions
  - Images
  - Basemap
  - Going 3D
- Conclusion

What is Matplotlib ?

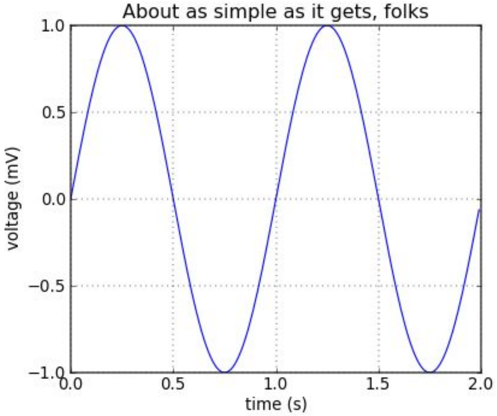
- From http://matplotlib.sourceforge.net/ : *matplotlib is a python 2D plotting library which produces publication quality figures in a variety of hardcopy formats and interactive environments across platforms*
- Not only :
  - for plotting : contains numerical functions mimicing matlab (useful in interactive environments)
  - can be used for animations
  - for 2D : has some *extensions* for 3D
  - a library : rather a suite. It has serveral interfaces

What is matplotlib

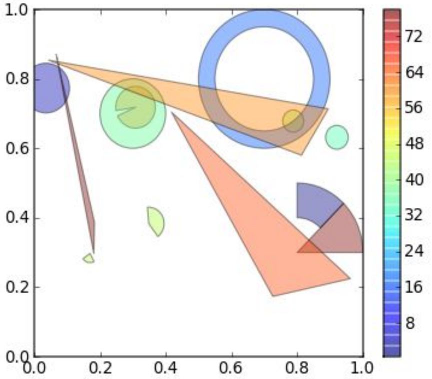
- As several python Numerics package, it relies on numpy
- Several others dependencies :
  - Output formats ⇒ *renderers* :
    - png library with high-quality anti-graining (Agg)
    - SVG
    - GDK (Gimp)
  - combined with Graphical user interfaces ⇒ *backends* :
    - QT, TK, GTK, macosX
- Several namespaces for the same functions

What is matplotlib

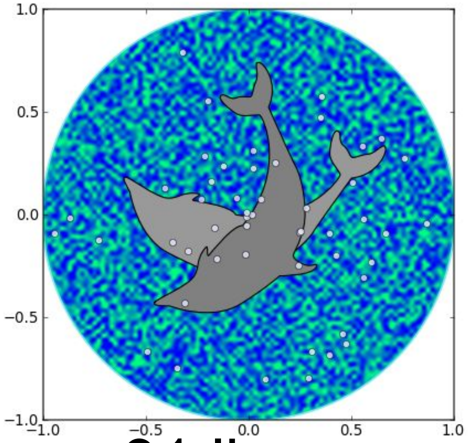
Examples (from the website)



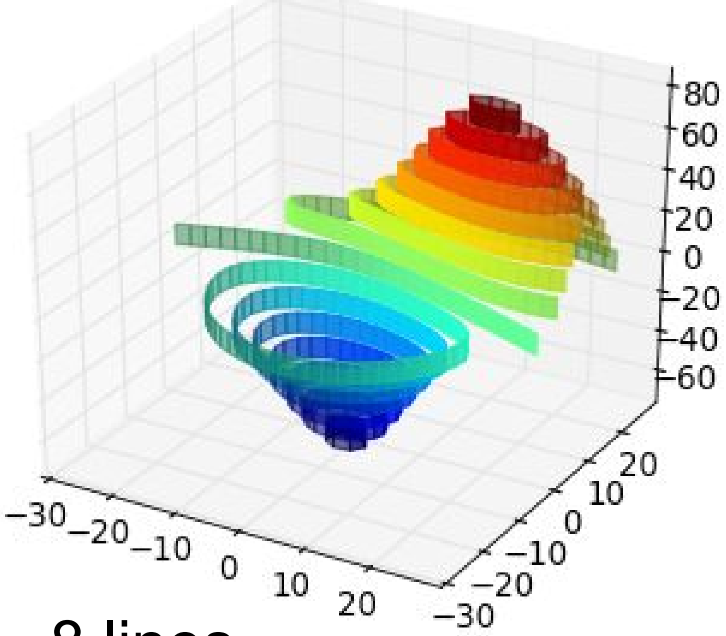
9 lines of code



46 lines



91 lines



8 lines

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Matplotlib basics

- Matplotlib basics functions are included in the pyplot sub-package :

  ```
  import matplolib.pyplot as plt
  ```

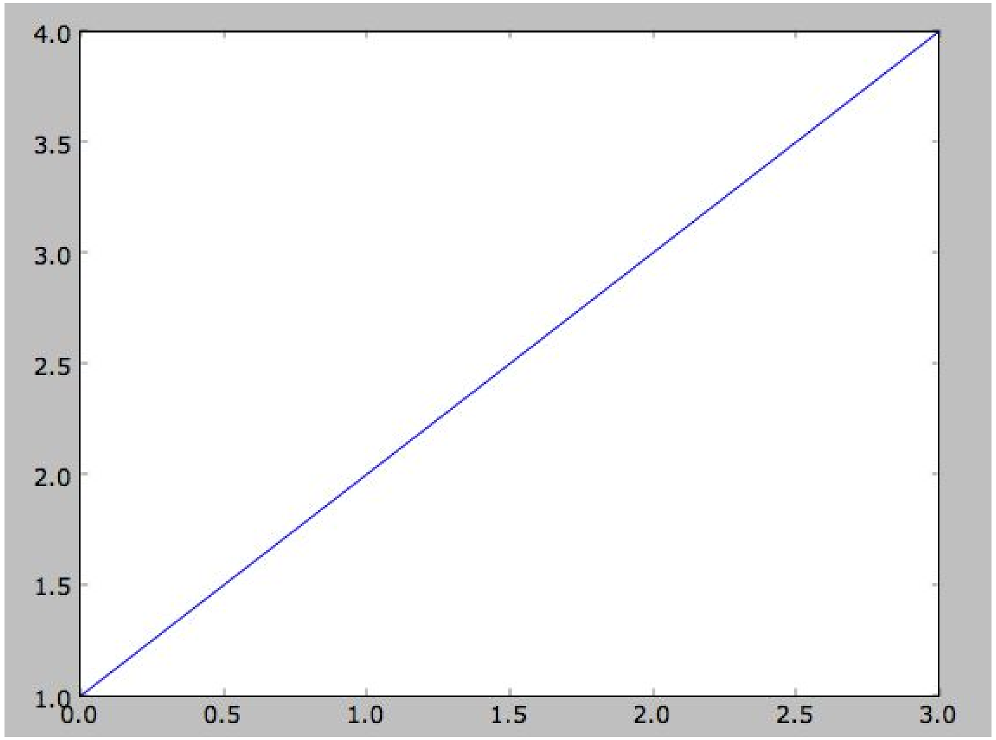
- pyplot is designed to look like matlab
- basic command : `plot`
- plots lines with optionnaly markers
- markers and linestyle are documented using the `help (plt.plot)` statement
- The plot command applies to the last plot you modified (stateful)

Matplotlib basics

- Plot example :

```
plt.plot([1,2,3,4])
```

- Defaults behaviour :
  - Line style : blue, continous
  - X data : from 0,1,2,3, computed from the number of values to plot



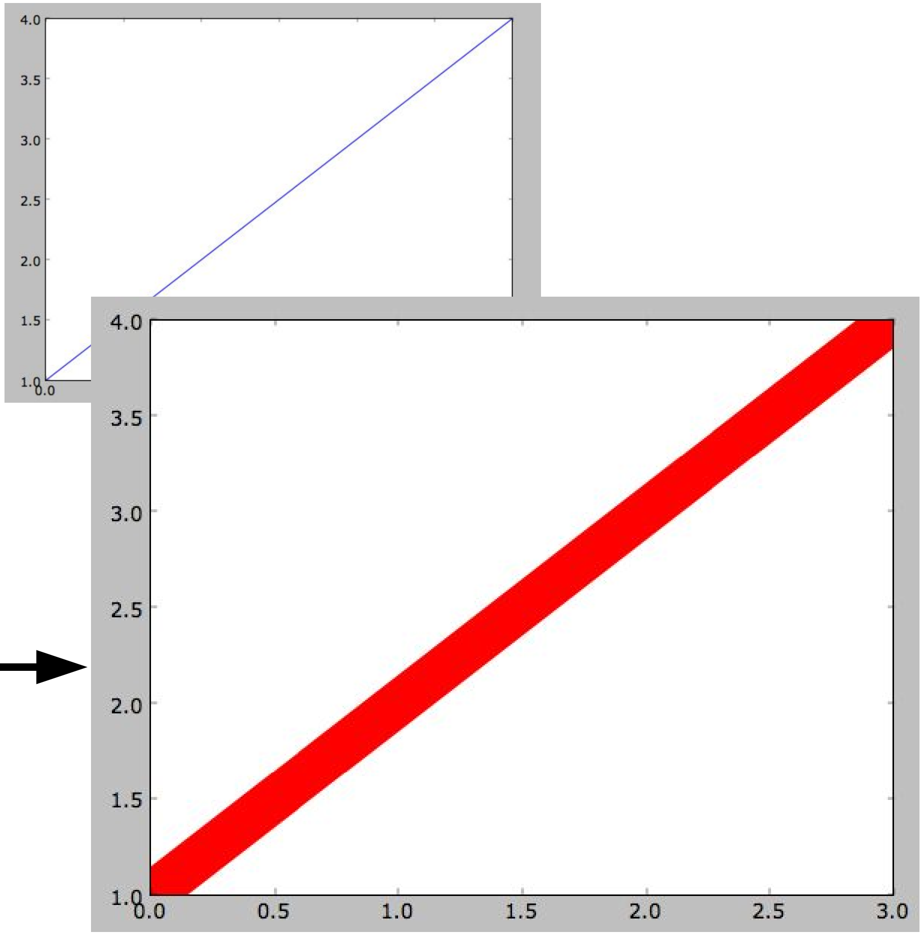
- Without defaults

```
plt.plot([0,1,2,3],
   [1,2,3,4],'b-')
```

Matplotlib basics

- The plot function returns an variable with type Lines2D, which can then be modified

```
line=plt.plot([1,2,3,4])
# Python style
plt.setp(line, color='r',
  linewidth=2.0)
# Matlab style
plt.setp(line,
  'color','r',
  'linewidth',2.0)
```



Same function, different argument style

Matplotlib (advanced) basics

- There are several other functions available in the plt namespace

List available using `help (plt.plotting)`:

- autocorrelation,
- contour
- histograms
- pie charts
- plotfile

- Some of the functions make useful computations on data
- **Matplotlib uses numpy arrays**

Matplotlib in programs

- Up to now, the basic workflow was as follows :

```
import matplotlib.pyplot as plt
plt.plot(something)
```

- In order to use this in a (text) program, you have to :
  - use a backend without a gui
  - add a savefig command
- The program rewrites into :

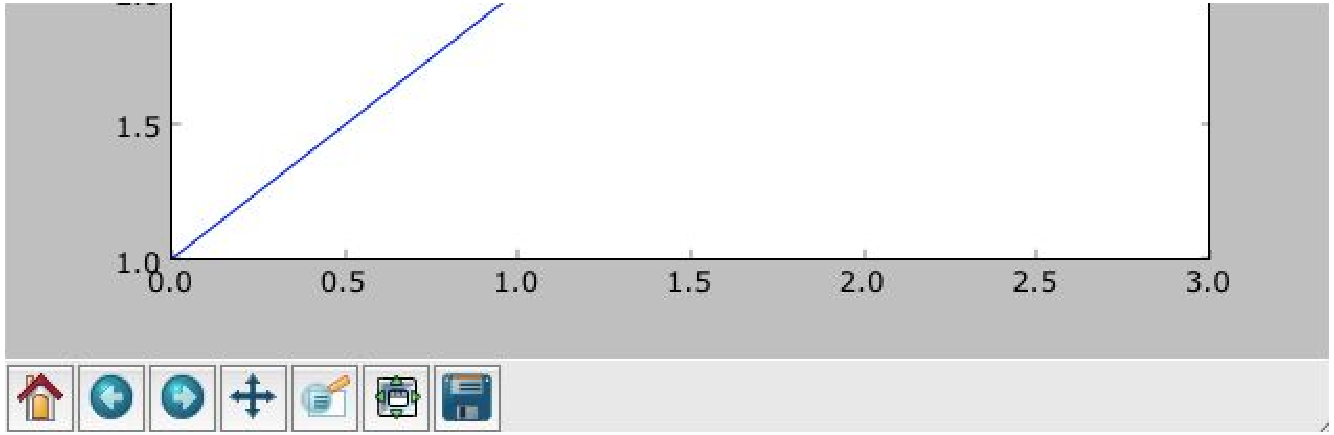
```
import matplotlib as mp
mp.use('agg') # mp.use() : matplotlib configuration
import matplotlib.pyplot as plt
plt.plot(something)
plt.savefig('something.png')
```

Interacting with Matplotlib

- Onclick (zoom)
- Default GUI
- ipython

Interactive Matplotlib

- In interactive mode, plot commands spawn a window :



- In interactive mode, it is common to import a pylab module.
- Pylab = matplotlib.pyplot + matplotlib.mlab numpy
- `from matplotlib.pylab import *` brings everything in the same namespace

Interactive Matplotlib

- Matplotlib is integrated in several python scientific environments providing editting and interactive features :
    - Interactive python *ipython*, http://ipython.org/
    - spyder, an IDE with matlab-like features, http://packages.python.org/spyder/
- The `-pylab` flag of ipython imports * from matplotlib.pylab at interpreter startup, thus bringing a lot of useful functions in the `__main__` namespace
- `ipython -pylab` is the recommended way of using ipython for exploration
- pydev in Eclipse

Interactive Matplotlib

- The **matplotlib.mlab** module provide 10 functions with matlab names, implemented on top of numpy
- It provides other helper functions to deal with text-files containing numerical values or some math functions needed by the authors of Matplotlib
- **mlab** is included when using pylab
- The module can be used with **mpl_toolkits.exceltools** : record arrays can be written out to Excel files with the `rec2excel` method

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Useful extensions - Images

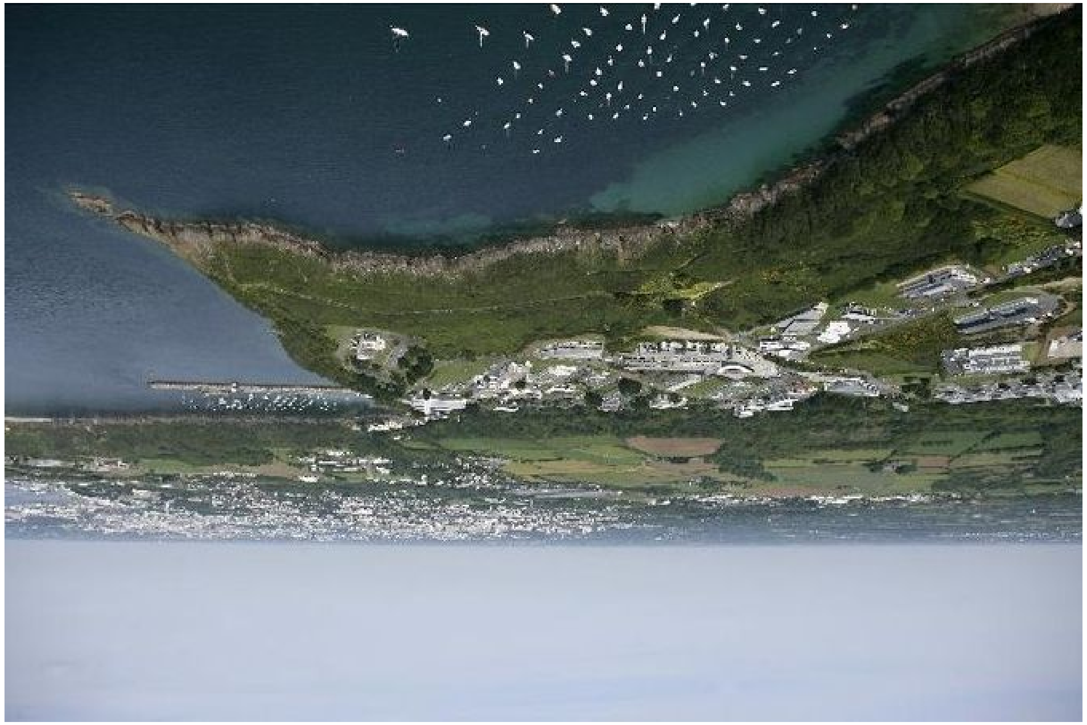
- As working on images is a common task, there are helpers in matplotlib
- These helpers rely on the Python Imaging Library (PIL), http://www.pythonware.com/products/pil/
- The functions are contained in the matplotlib.pyplot module
  - work on images as 3D (R,G,B) arrays of real numbers in [0:1[
  - images are stored as numpy arrays

Useful extensions - Images

- Displaying an image

```
import matplotlib.pyplot as plt
plt.imshow(plt.imread("ifremer.jpg"))
```

- Surprising, isn't it (not a bug in the slide) ?



Useful extensions - Images

- More functions :
  - changing the colormap
  - roating, resizing image
  - interpolating on pixels
- Note that the imaging facilities are a subpart of the pyplot package, tightly coupled with PIL for dealing with formats other than PNG

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Basemap Toolkit

- Similar to matlab mapping toolbox
- Transforms coordinate of map projections into data than can be plotted by matplotlib (pre-processing)
- Contains political boundaries, rivers, shorelines, taken frome the GMT suite
- Connected to standard formats :
  - OpenDAP for data exchange
  - NetCDF (via pure python library)
  - Shapefiles
- Written by Jeffrey Whitaker (http://www.esrl.noaa.gov/psd/people/jeffrey.s.whitaker/)

Basemap Toolkit : Workflow

- Create a projection (29 available) :

```
from mpl_toolkits.basemap import Basemap
# setup lambert azimuthal equal area
  basemap.
# lat_ts is latitude of true scale.
# lon_0,lat_0 is central point.
m = Basemap(width=12000000,height=8000000,

  resolution='l',projection='laea',\
            lat_ts=50,lat_0=50,lon_0=-107.)
```

- Plot data (with coordinates) on the projection

Basemap Toolkit : Workflow

- 29 Available projections can be listed accessing online help (65 in Matlab)

```
import mpl_toolkits.basemap
print basemap.supported_projections
```

- Azimuthal, Polyconic, Gnomonic, Mollweide, Transverse, North-Polar Lambert, Gall, Miller, Mercator, Stereographic, North-Polar Stereographic, Geostationary

Near-Sided, van der Grinten, Lambert Azimuthal Equal Area ,

McBryde-Thomas, Sinusoidal, South-Polar, Lambert, North-Polar Azimuthal Equidistant, Equidistant, Cylindrical, Oblique

Albers, South-Polar, Orthographic, Cassini-Soldner, South-Polar, Robinson

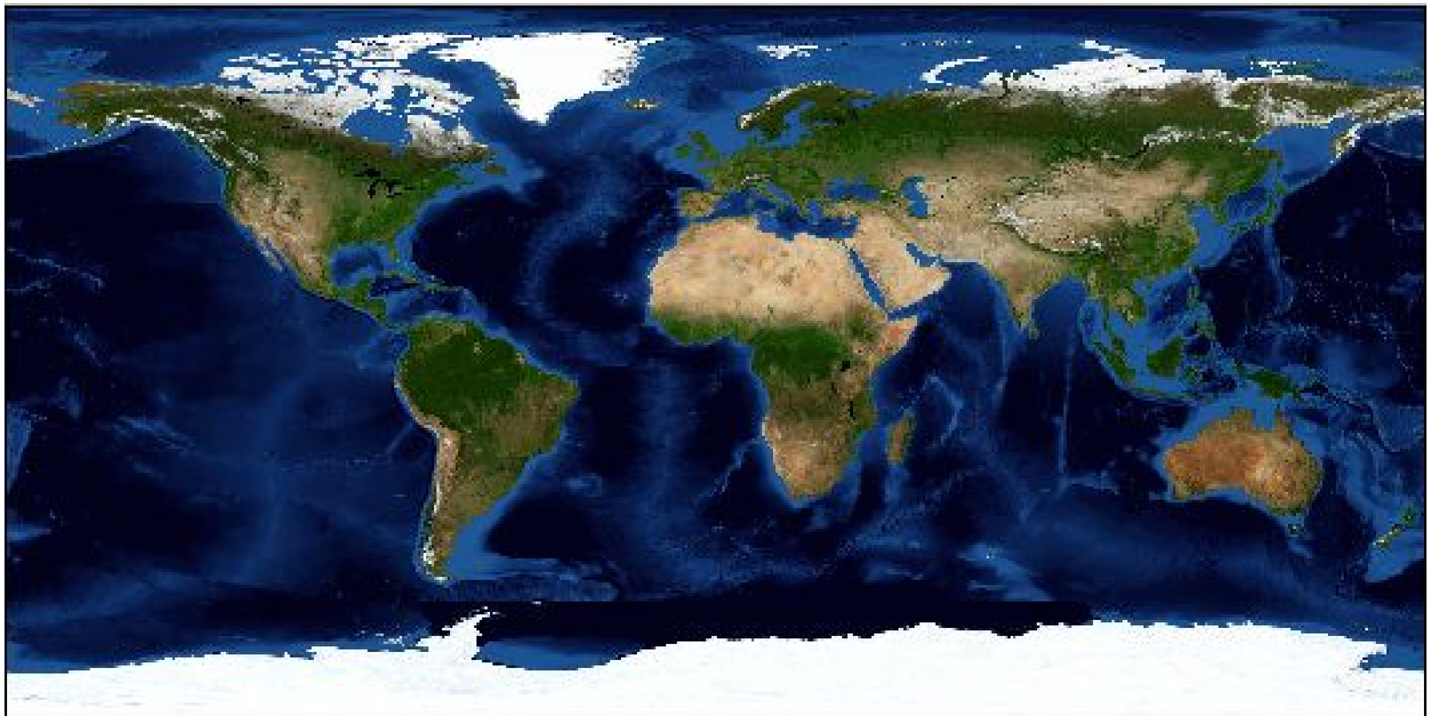
Basemap Toolkit

- The Basemap object instances contains several functions, including :
  - (filled) contour drawing
  - geographic drawings : coastlines, boundaries great circles, rivers, parallels, meridians...
  - `is_land(x,y)` : x,y are in projection coordinates, returns True/False
  - reading and plotting shapefiles
  - computing earth areas in the shadow at a given time
  - making nice plots : adding images as map background

Basemap Toolkit : Example

- Using Nasa Blue Marble as a backgroud :

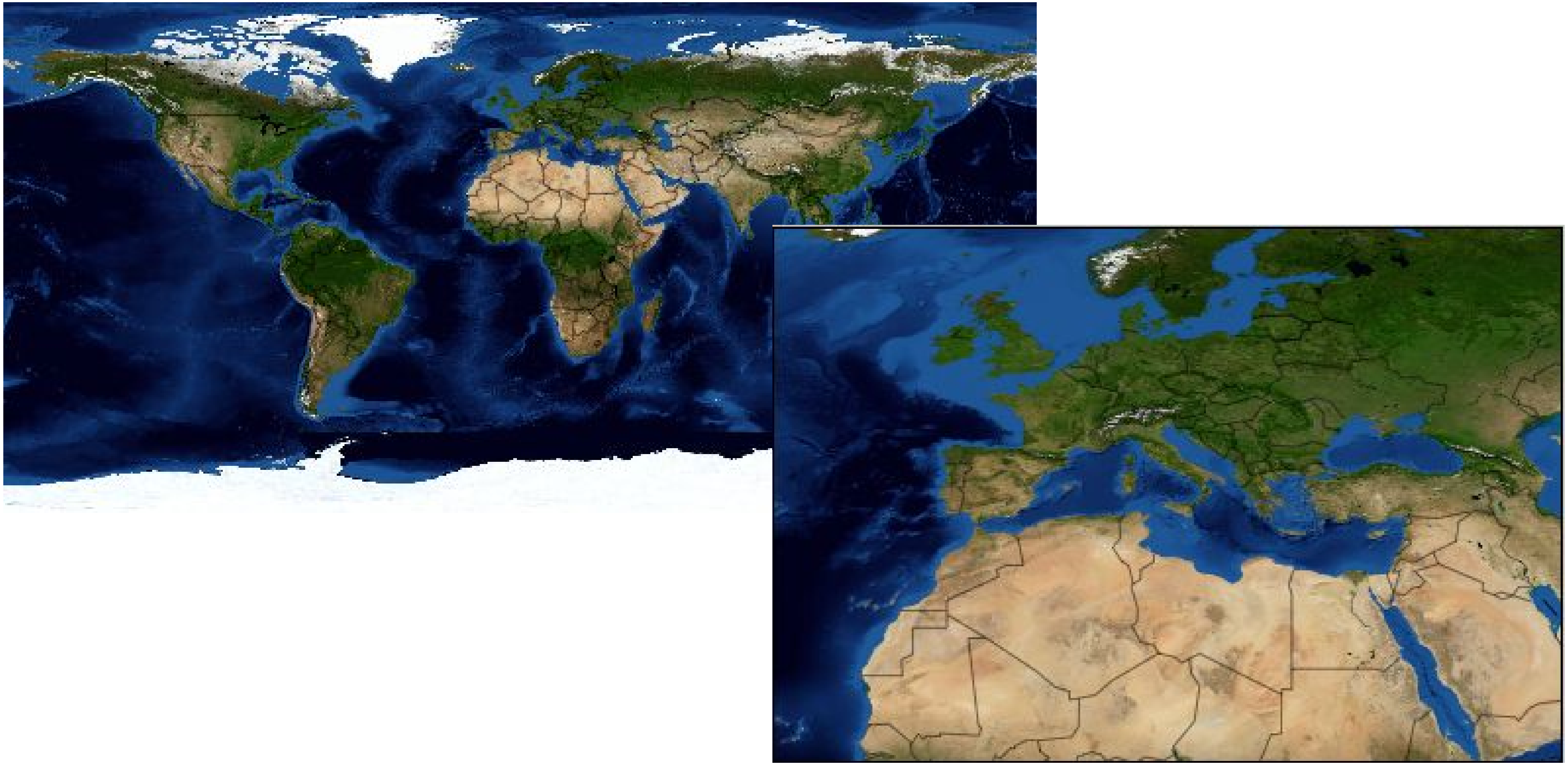
```
import mpl_toolkits.basemap
b=mpl_toolkits.basemap.Basemap()
b.bluemarble()
```



Basemap Toolkit : Example

- Adding political boundaries

```
b.drawcountries()
```

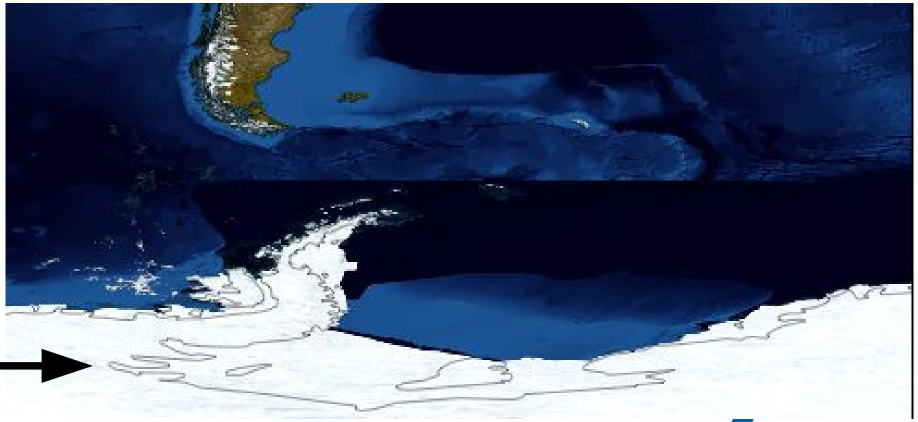


Basemap Toolkit : Shapefiles

- The shapefile interface is :

```
b.readshapefile("landeareas", "lands",
  drawbounds=True, zorder=None, linewidth=0.5,
  color='k', antialiased=1, ax=None)
```

- `shapefile` : basename of the 3 components of the file
- `name` : (string) name of the attribute that will be added to the Basemap. This attribute holds the data of the shapefile



Land boundaries on the Antarctic

Basemap Toolkit : Shapefiles

- The data hold by the "lands" attribute of the Basemap instance is made of a list of vertices

```
print b.lands
 [(-96.36414655167492, 68.47130097246468),
  (-96.70338706497459, 68.48849366276391),
  (-97.14621337170688, 68.57308500473383),...
```

- a list of attributes of the shapes

```
print b.lands_info
{'RINGNUM': 1, 'Name': 'Greenland', 'SHAPENUM': 4}
{'RINGNUM': 1, 'Name': 'Australia', 'SHAPENUM': 5}
```

- and a list of (low-level) geoslib polygons

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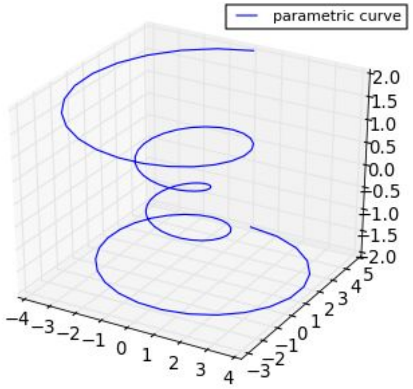
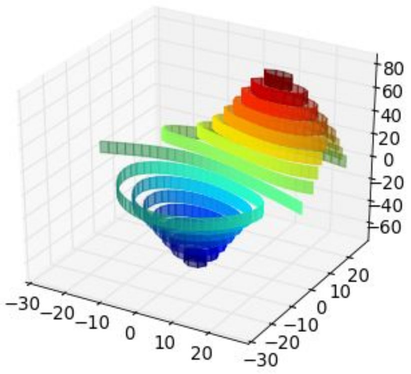
mplot3d Toolkit

- Basic matplotlib handles only plotting 2D datasets x,y
- Plotting of x,y,z relies on the mplot3d toolkit, computing 2D projections of 3D data
- It works by adding a *3d projection* axe to the figure (since matplotlib 1.0.0)
- 3D plotting methods are available from the `Axes3D` instance
- Gallery :





mplot3d Toolkit : Workflow

- Get a 3D axe :

```
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
fig=plt.figure()
axes3d=fig.gca(projection='3d')
```

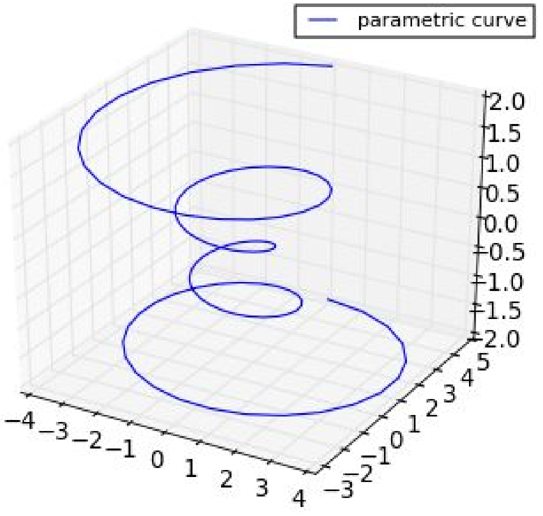
- From this instance, choose between :

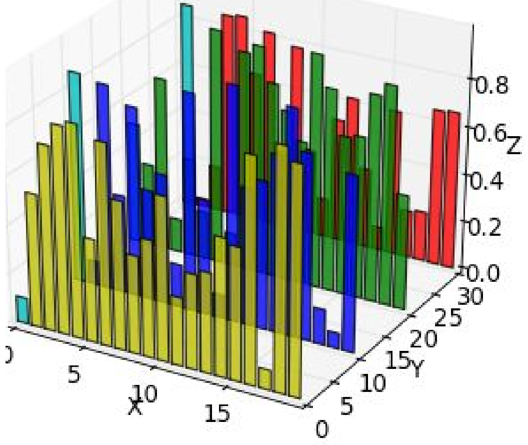
```
bar3D, contour3D, plot3D, plot_surface,
  plot_wireframe, scatter3D, text2D, text3D,
```

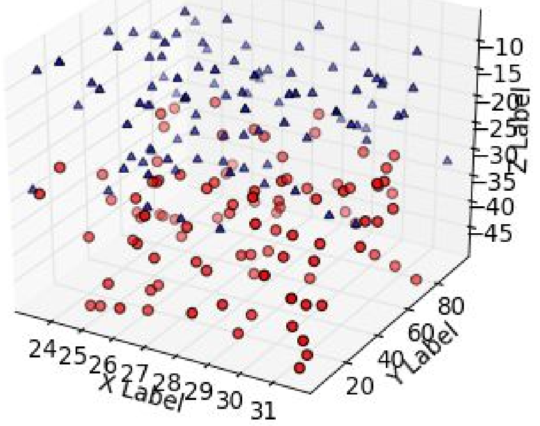
mplot3d Toolkit : input

- Each plotting function uses 3 arrays as an input
- The shape of these arrays depend on the plot
- For 3D line plots, bar plots, scatter plots, X,Y,Z are 1D array

lentgh = number of points to be plotted

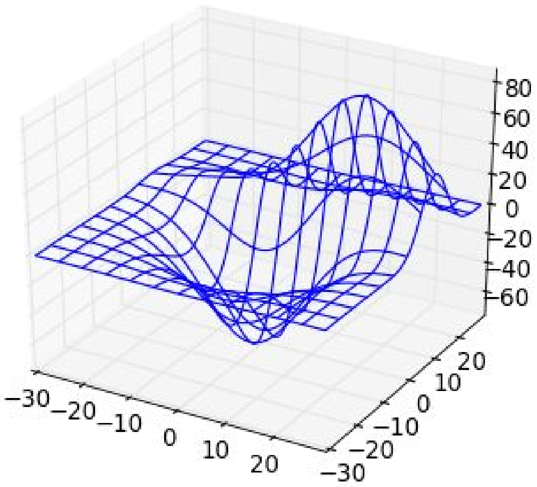


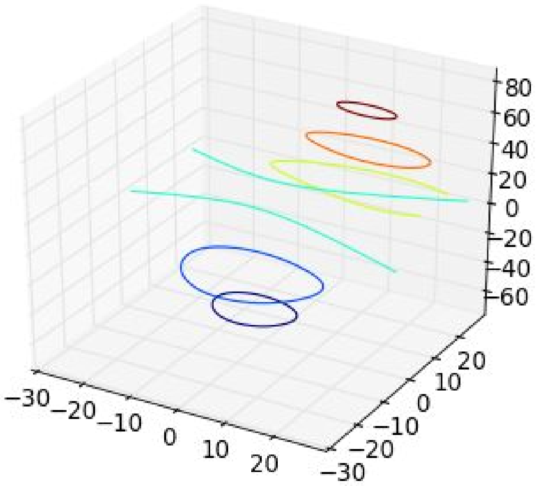




mplot3d Toolkit : input

- For wireframe plots, surface plots, X, Y are 2D coordinates matrices, Z is a 2D array containing the values





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Matplotlib :

- is the python package to keep in mind when it comes to plotting
- tries to mimic matlab
- is tightly coupled to numpy and other top python libraries
- is integrated in ipython, pythonxy and other IDE
- Can help you to migrate from Matlab to python :

http://www.projet-plume.org/files/PRaybaut.pdf