ESCI 386 – Scientific Programming, Analysis and Visualization with Python

Lesson 13 - 2D Plots

Contour Plots

- Contour plots are created using the `contour()` pyplot function or axes method.

- The only required argument is a 2-D array of values, z.
  - `plt.contour(z)`

Basic Contour Example

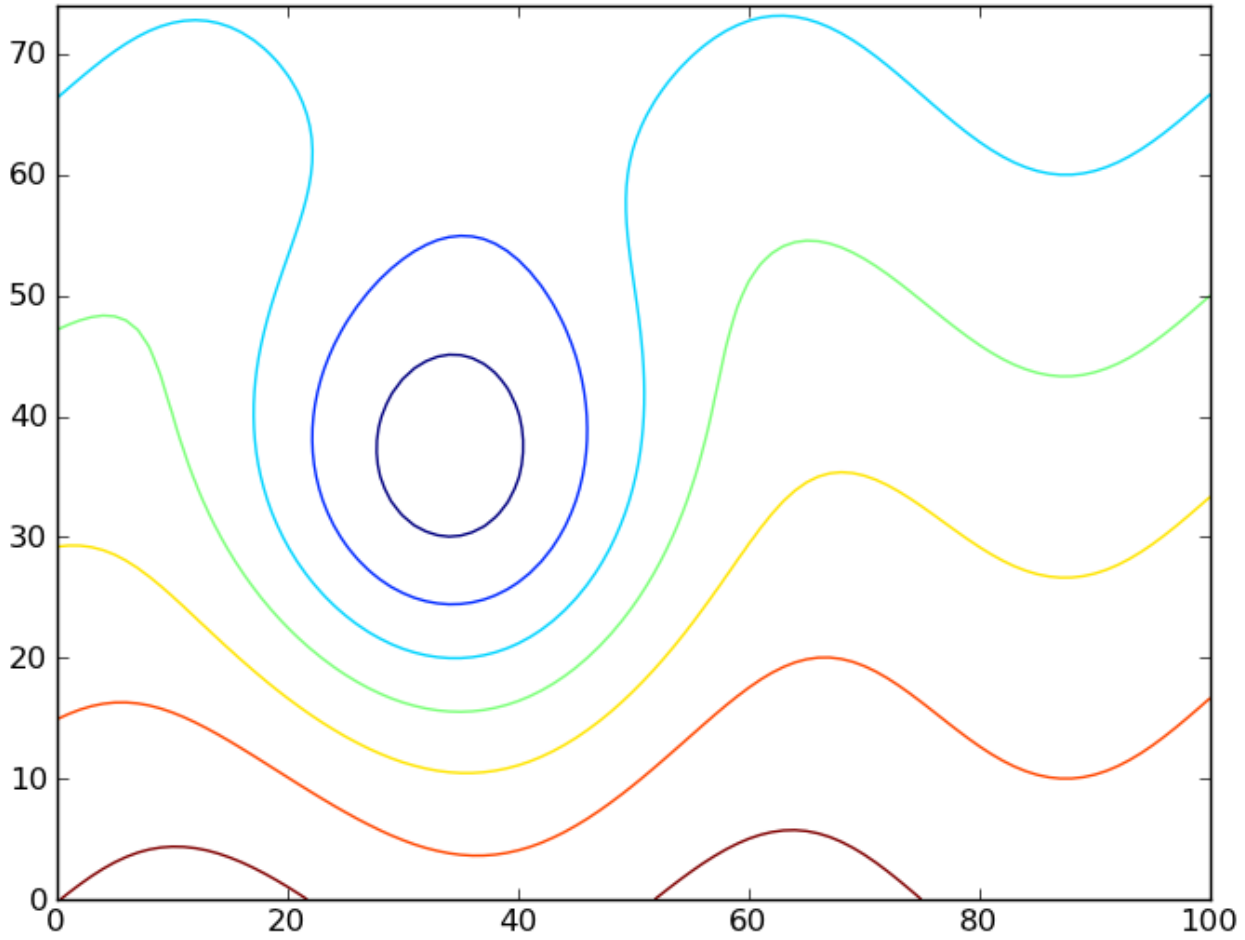
```
import matplotlib.pyplot as plt
import numpy as np

z = np.load('heights.npy')
plt.contour(np.transpose(z))

plt.show()
```

- Note: We used `transpose(z)` because NumPy stores arrays in [row, column] format whereas this data set assumes [column, row]
  - Keep this in mind if your plots display as rotated.

- 'heights.npy' is in the '\\cyclone2\shared\ESCI 386' directory.

File: contour-basic.py

Basic Contour Result



Contour Plots

- Optional arrays x and y can specify the locations of the *z* values.
  - `plt.contour(`x`,`y`,`z`)`

- The arrays x and y must also be 2-D arrays of the same shape as z, or must be 1-D arrays where x has the same length as the first dimension of z and y has the same length as the second dimension of z.
  - Including the arrays x and y allows irregularly spaced data to be contoured.

Contour Plots

- A fourth argument that can be included is the number of contour levels to draw.
  - `plt.contour(x,y,z,7)` would draw seven evenly spaced contour levels.

- The contour levels can also be specified with the `levels` keyword, which will be set to a list or arrayof contour values to be drawn.

Contour Line Colors and Widths

- The colors of the contour lines can be specified with the `colors` keyword, which can be either a single color, or a list of colors, one for each line.
  - If colors is set to `'black'` and no `linestyles` are set, then negative contours will be drawn with dashes lines while positive contours will be solid.
  - To make all contours solid and black just set `colors = 'black'` and `linestyles = 'solid'`.

- The `linestyles` and `linewidths` keywords control the line plotting styles and sizes.

Contour Labels

- Labels are controlled by creating a `ContourSet` object when calling the contour function/method
  - `cs = plt.contour(z)`

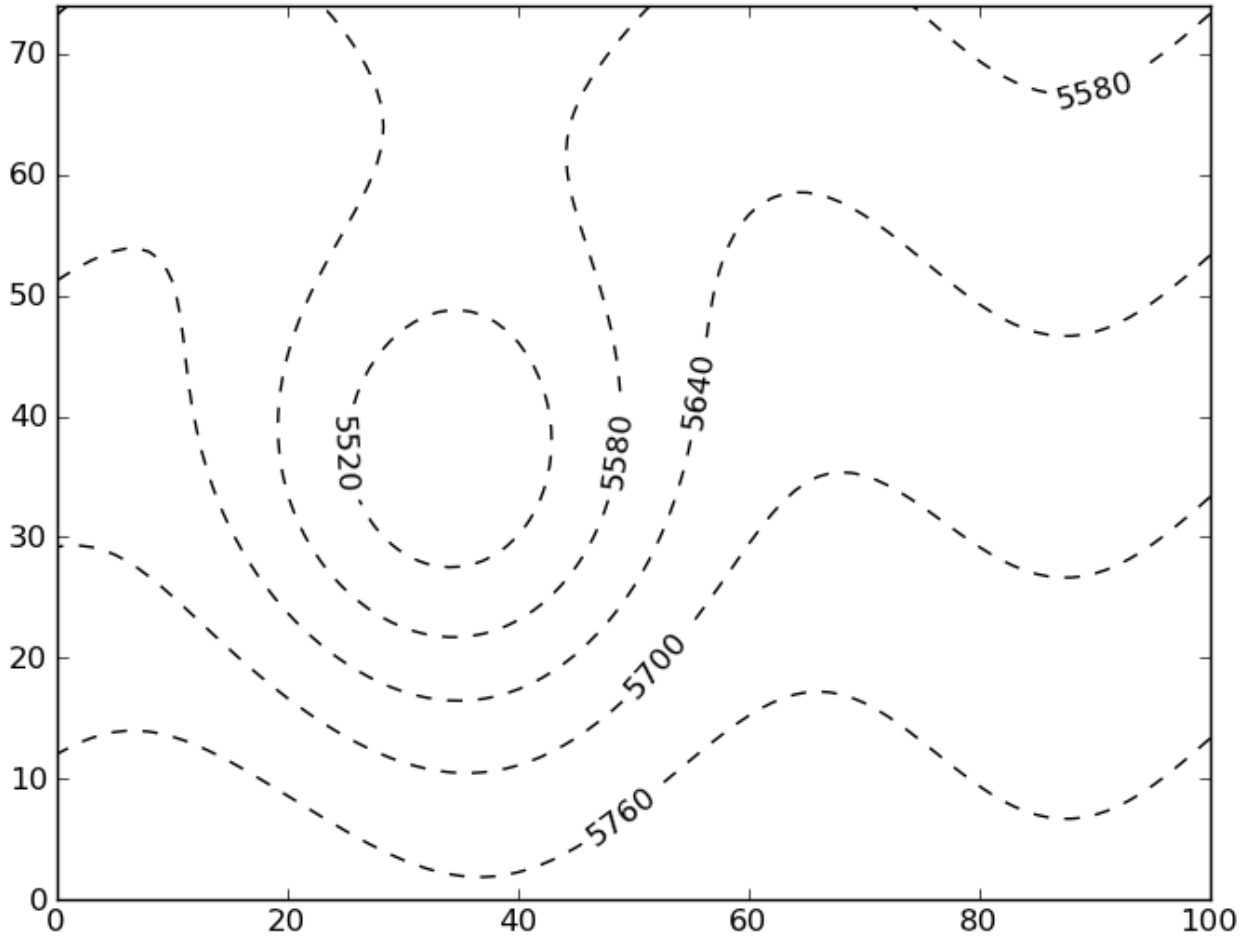
  and then using the `pyplot.clabels()` function or `axes.clabels()` method which allows label positions and formats to be specified.

Contour Label Example

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

z = np.load('heights.npy')

cs = plt.contour(np.transpose(z),levels = range(5400,6000,60),
                 colors = 'black', linestyles = 'dashed')
plt.clabel(cs, fmt = '%.0f', inline = True)

plt.show()
```

File: contour-label.py

Contour Label Result



Keywords for `clabel()`

Keyword	Purpose	Values
fmt	Controls formatting of labels	Standard Python format specifiiers (preceded by '%'
`fontsize`	Controls font size of labels	Point value for font.
`colors`	Controls colors of labels	Any valid `matplotlib` color. Can be a single color or a list of different colors.
`inline`	Controls whether labels mask or block contour line	`True	False`
`inline_spacing`	Controls blank space on either side of inline labels.	Number of pixels to leave blank.
`manual`	Allows manual placement of contours using mouse clicks.	`True	False`
`rightside_up`	Controls whether labels can be placed upside down.	`True	False`
`capsize`	Controls size of error bar caps	Floating point. Default is 3.
`align`	Controls alignment of bars with axis labels	`'edge'` or `'center'`
`orientation`	Controls orientation of bars	`'vertical'` or `'horizontal'`
`log`	Sets log axis	`False` or `True`

Contour Exercise

- Play around with plotting the contours from the example. Try:
  - specifying different level
  - specifying fixed spacing of contour interval
  - manual placement of contours

Filled Contour Plots

- Filled contours are created using `contourf()` in place of `contour()`.

- `contourf()` does not draw the contour lines.
  - If you want both filled contours with contour lines you have to use both `contourf()` and `contour()`.

Adding a Colorbar

- A color bar can be added to the filled contour plot using either the `pyplot.colorbar()` function or the `figure.colorbar()` method.
  - There is no axes method for a color bar.

- If using the `pyplot.colorbar()` function the colorbar will be automatically be applied to the current image or contour set, and so specifying a ContourSet `cs` is optional.

- If using the figure.colorbar() method you must specify the ContourSet to which the colorbar will be applied.

- The orientation of the color bar is controlled using the orientation keyword, which takes the values ‘vertical’ or ‘horizontal’.

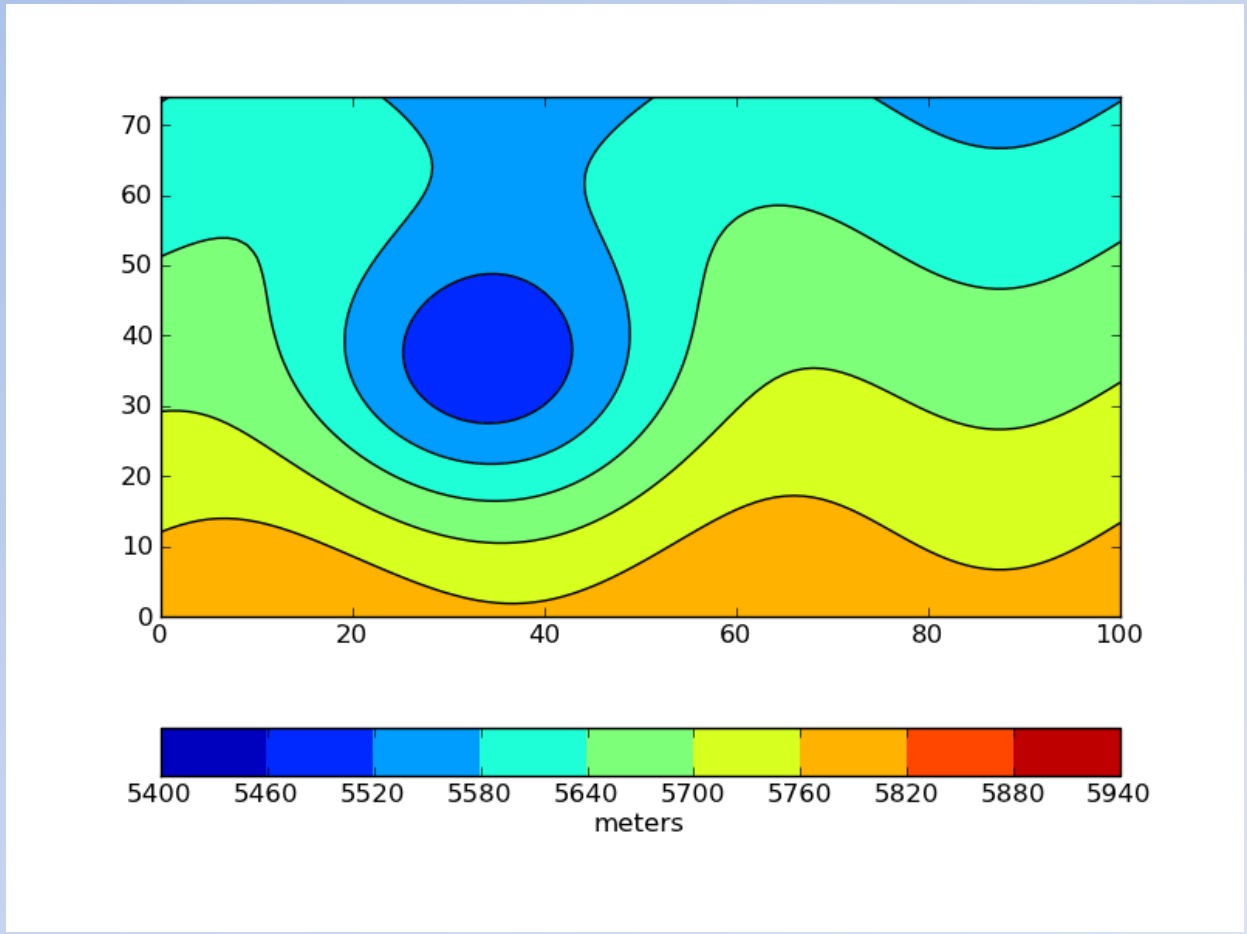
Adding a Colorbar

- The colorbar can be labeled by creating a colorbar instance and then using the `set_label()` method, e.g.:
  - `cb = plt.colorbar(cs)`
  - `cb.set_label('meters')`

- There are several other keywords for controlling details of the color bar, including whether it has square or pointy ends, etc. Consult the online documentation for details.

Filled Contour Exercise

- Create the figure shown.



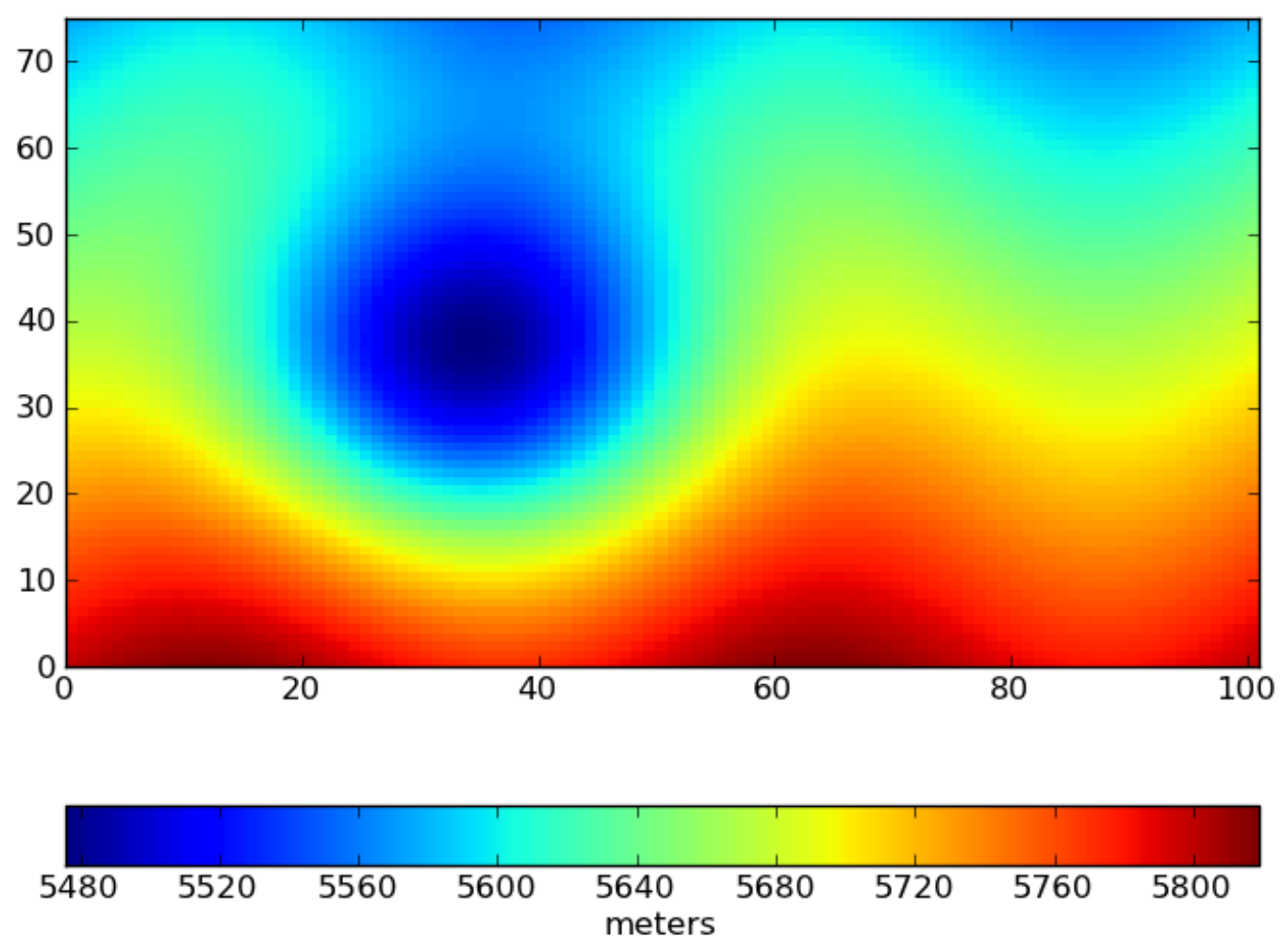
pcolor() Plots

- pcolor stands for pseudocolor
- pcolor plots are often better looking than filled contour plots, but they take longer to create
- They are created using the pcolor() pyplot function or axes method.
- colormaps are created the same way they are using contourf()

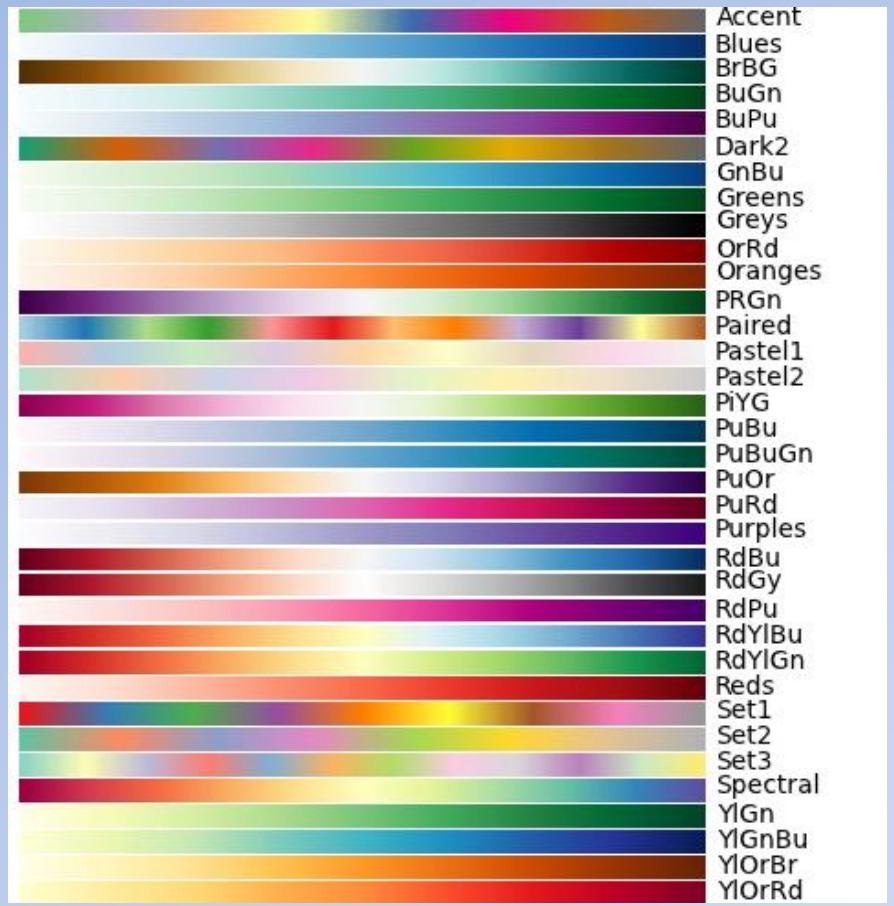
pcolor() Example

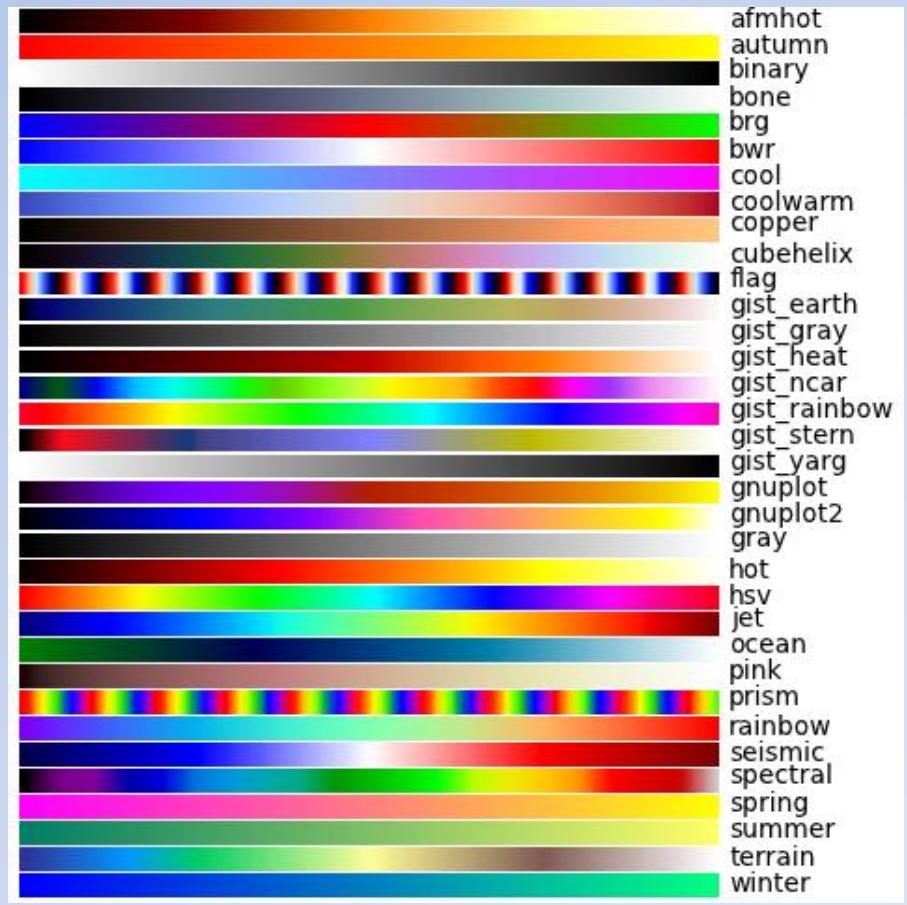
```
import matplotlib.pyplot as plt
import numpy as np

z = np.load('heights.npy')
nx, ny = np.shape(z)

cs = plt.pcolor(np.transpose(z))
cb = plt.colorbar(cs, orientation = 'horizontal')
cb.set_label('meters')
plt.xlim(0,nx)
plt.ylim(0,ny)
plt.show()
```

pcolor() results



Available Color Maps





The colormaps can be reversed by appending the name with '_r'.

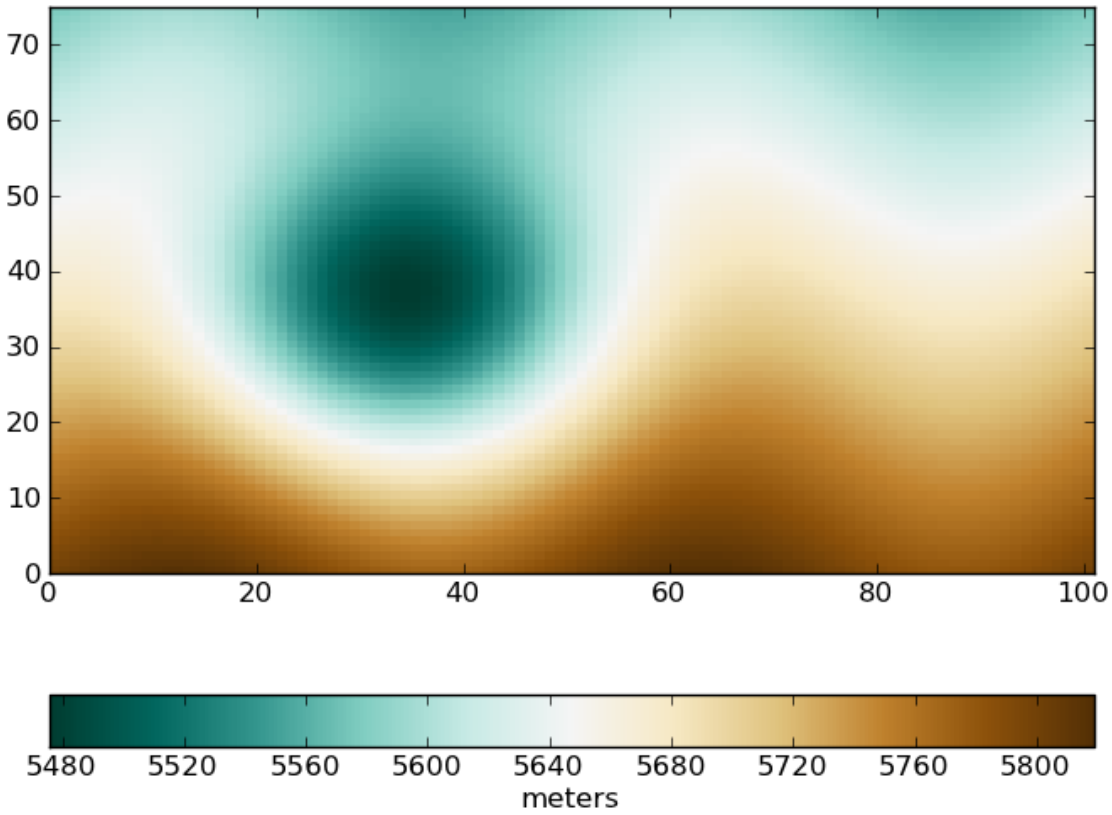
Selecting Different Color Maps

- To change the color map, you must first import matplotlib.cm
- Then, you can use the get_cmap() function and pass in the name of the color map you want.
- In the call to contour (), contourf (), or pcolor() you pass the name of the color map using the cmap keyword.

Changing Color Map Example

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

z = np.load('heights.npy')
nx, ny = np.shape(z)
cmap = cm.get_cmap('BrBG_r')
cs = plt.pcolor(np.transpose(z), cmap = cmap)
cb = plt.colorbar(cs, orientation = 'horizontal')
cb.set_label('meters')
plt.xlim(0,nx)
plt.ylim(0,ny)
plt.show()
```

New Color Map Results



Plotting Wind Barbs

- Wind barbs are plotted using the `barbs()` function/method.
- `barbs(`*x*`,`*y*`,`*u*`,`*v*`)` takes four arrays as arguments:
  - *x* is the x-coordinates of the barbs
  - *y* is the y-coordinates of the barbs
  - *u* is the u-component of velocity
  - *v* is the v-coordinate of velocity
- The barb positions do not have to be uniformly spaced.
- To get color-coded barbs based on speed, a fifth array containing the speeds at each position can be included.

barb() Example

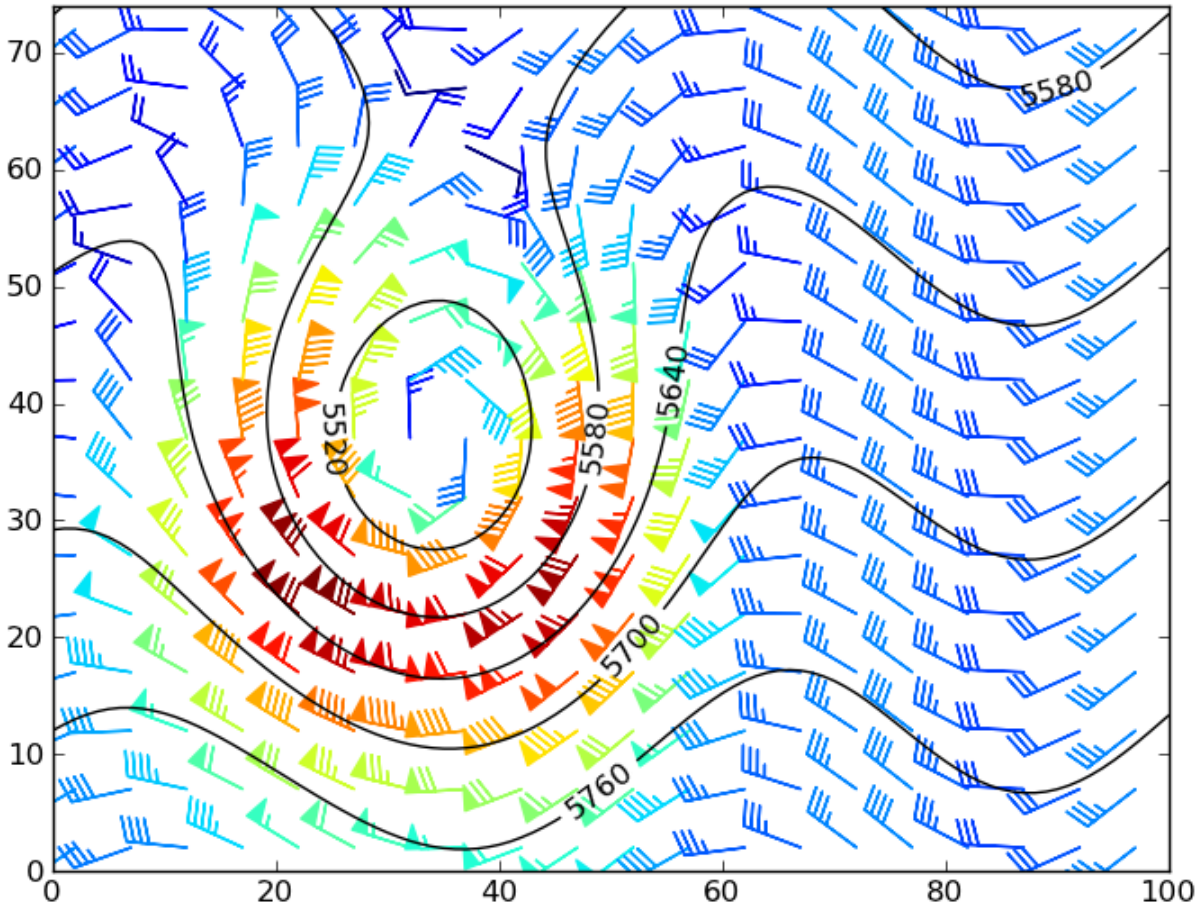
```
import numpy as np
import matplotlib.pyplot as plt
h = np.transpose(np.load('heights.npy'))
V = np.load('uandv.npz')
x = np.transpose(V['x'])
y = np.transpose(V['y'])
u = np.transpose(V['u'])
v = np.transpose(V['v'])
cs = plt.contour(h, levels = range(5400,6000,60), colors = 'black')
plt.clabel(cs, fmt = '%.0f', inline = True)

speed = np.sqrt(u**2+v**2)
plt.barbs(x,y,u,v,speed)

plt.show()
```

Loads wind data

Plots wind barbs

File: windbarb.py

`barb()` Results

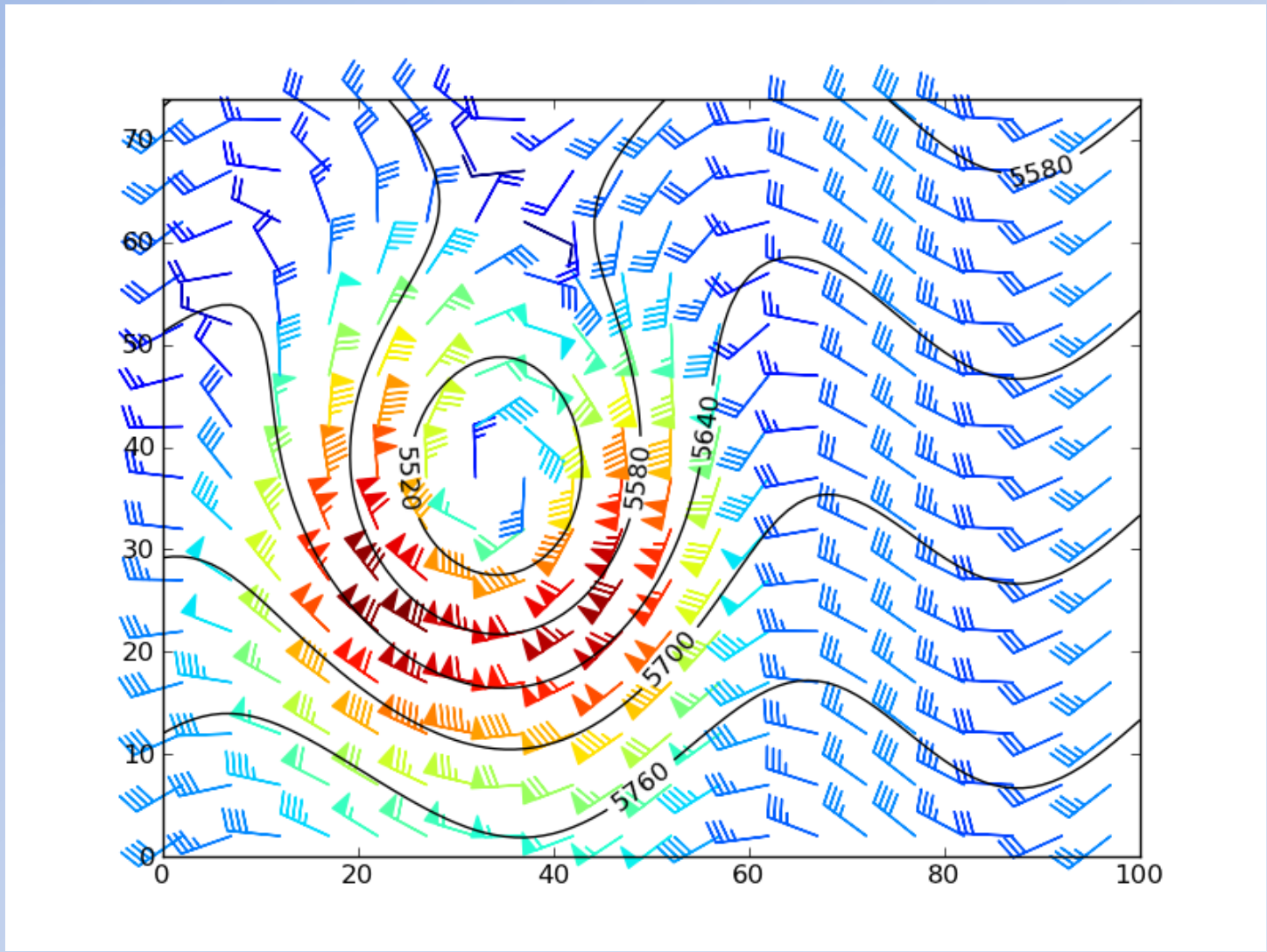


Keeping Barbs from Being Clipped at Edges of Plot

- To prevent barbs at edges from being clipped, first create a BoundingBox instance and then use `set_clip_box(None)`

```
bb = plt.barbs(x,y,u,v,speed)
bb.set_clip_box(None)
```

`barbs()` Results (no clipping)



Southern Hemisphere

- The barbs can be flipped to the opposite side (for the Southern Hemisphere) by setting the `flip_barb` keyword to `True`.

Plotting Vectors

- To plot vectors instead of wind barbs use the `quiver()` function/method.

- Usage of `quiver()` is very similar in use to `barbs()`.

Streamlines

- Newer versions of matplotlib can plot streamlines.
  - Our version currently cannot.

Creating 2-D arrays of x and y values from 1-D arrays.

- Often we need 2-D arrays of x and y coordinate values.
- We can create them from 1-D arrays of x and y using the numpy meshgrid() function.

```
>>> x
array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
>>> y
array([-3, -2, -1,  0,  1,  2,  3])
>>> x2,y2 = np.meshgrid(x,y)
>>> x2
array([[0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4, 5, 6, 7, 8, 9],
       [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]])
```

```
>>> y2
array([[-3, -3, -3, -3, -3, -3, -3, -3, -3, -3],
       [-2, -2, -2, -2, -2, -2, -2, -2, -2, -2],
       [-1, -1, -1, -1, -1, -1, -1, -1, -1, -1],
       [ 0,  0,  0,  0,  0,  0,  0,  0,  0,  0],
       [ 1,  1,  1,  1,  1,  1,  1,  1,  1,  1],
       [ 2,  2,  2,  2,  2,  2,  2,  2,  2,  2],
       [ 3,  3,  3,  3,  3,  3,  3,  3,  3,  3]])
```