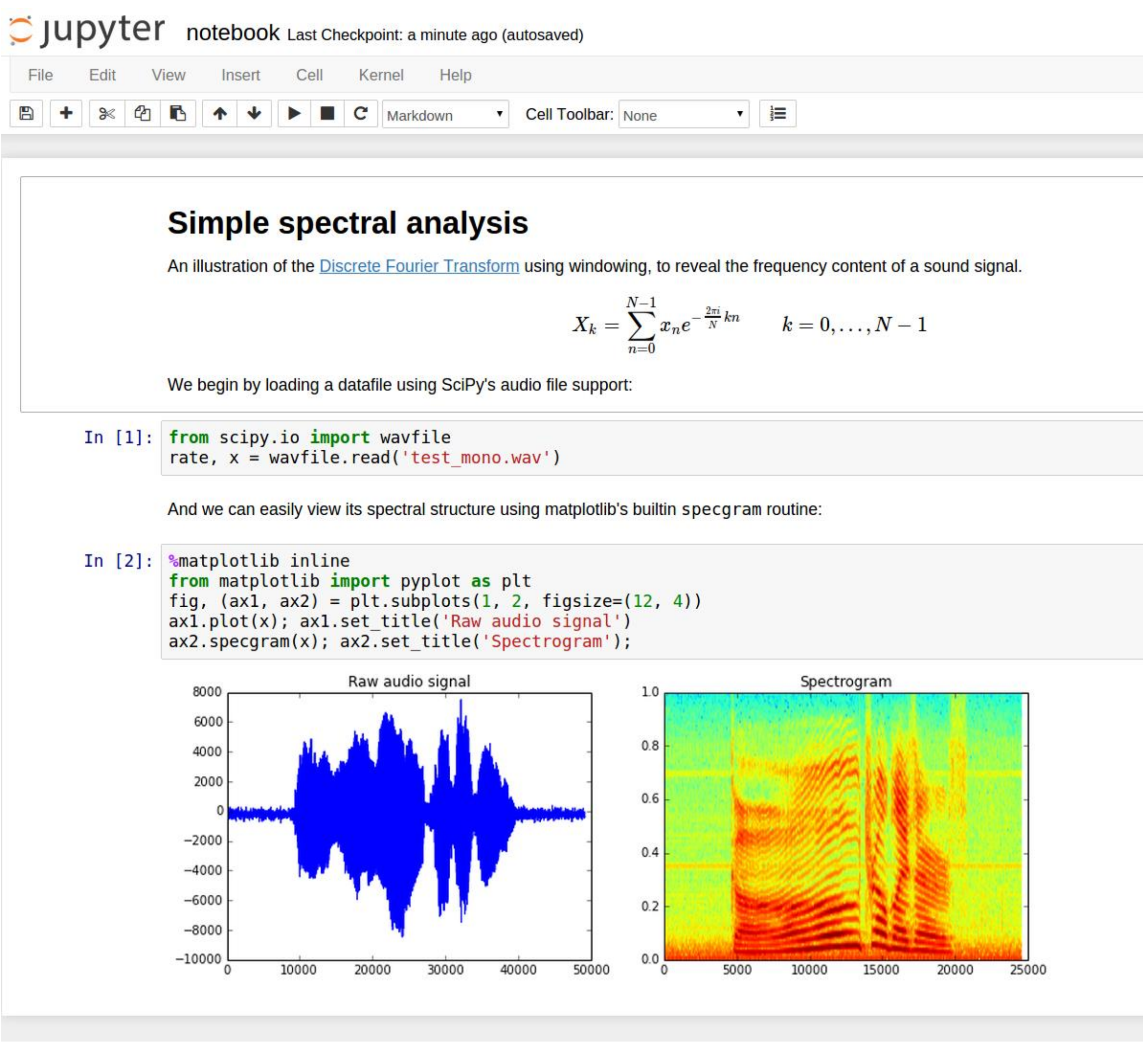
THE JUPYTER NOTEBOOK

Joe Futrelle, October 2018

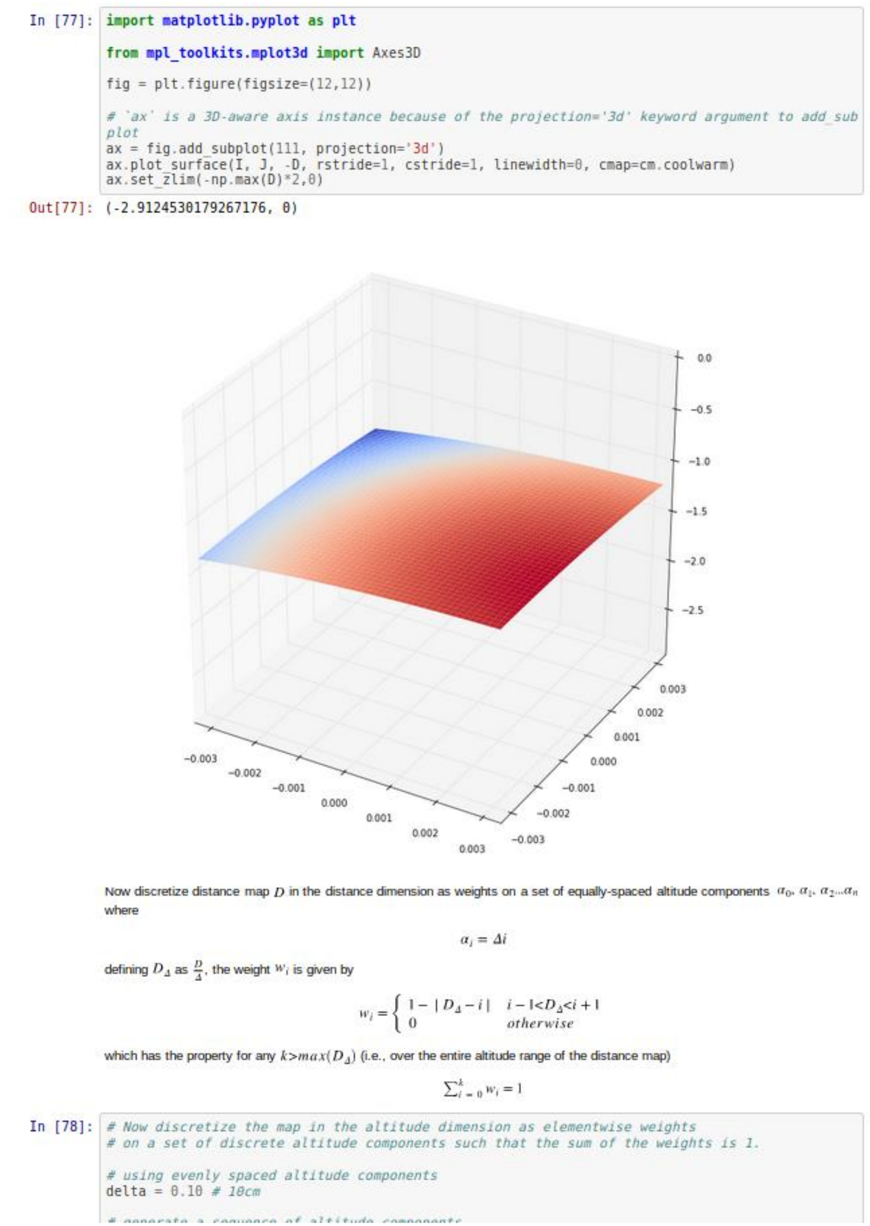
What is the Jupyter notebook?

- Open-source browser-based tool
  - Developing code
  - Visualizing results
  - Documenting code
  - Sharing code on the web
- Inspired by Mathematica, MATLAB, and RStudio
- Formerly IPython notebook
  - But supports many languages



Why should you care?

- Free (no license fee)
- Prototype rapidly with integrated interactive visualization
- Document and share code
  - Similar to R vignettes
- Allow others to easily run and modify your code
- Lots and lots of integrated tools and libraries
  - Rapidly growing list



In [77]:
```
import matplotlib.pyplot as plt

from mpl_toolkits.mplot3d import Axes3D

fig = plt.figure(figsize=(12,12))

# `ax` is a 3D-aware axis instance because of the projection='3d' keyword argument to add_sub
plot
ax = fig.add_subplot(111, projection='3d')
ax.plot_surface(I, J, -D, rstride=1, cstride=1, linewidth=0, cmap=cm.coolwarm)
ax.set_zlim(-np.max(D)*2,0)
```

Out[77]: (-2.9124530179267176, 0)

Now discretize distance map D in the distance dimension as weights on a set of equally-spaced altitude components $\alpha_0, \alpha_1, \alpha_2 ... \alpha_n$ where

$$\alpha_i = \Delta i$$

defining D_Δ as $\frac{D}{\Delta}$, the weight w_i is given by

$$w_i = \begin{cases} 1 - |D_\Delta - i| & i-1 < D_\Delta < i+1 \\ 0 & otherwise \end{cases}$$

which has the property for any $k > max(D_\Delta)$ (i.e., over the entire altitude range of the distance map)

$$\sum_{i=0}^{k} w_i = 1$$

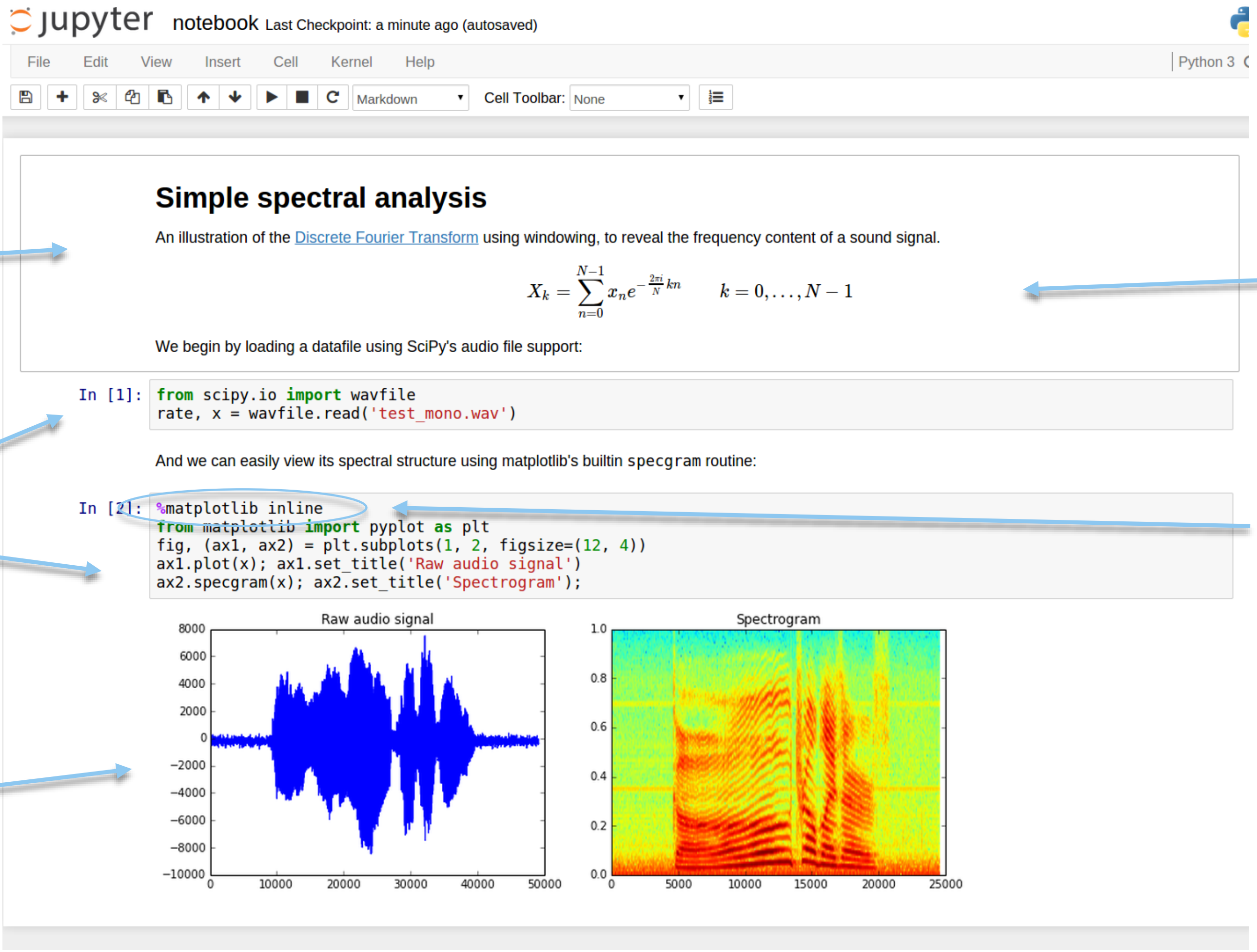
In [78]:
```
# Now discretize the map in the altitude dimension as elementwise weights
# on a set of discrete altitude components such that the sum of the weights is 1.

# using evenly spaced altitude components
delta = 0.10 # 10cm
```

Notebook model: cells, markdown, and magic

Notebook is divided into cells

Code is in code cells

Visualizations are inline



HTML documentation is in markdown cells

Magics extend notebook functionality

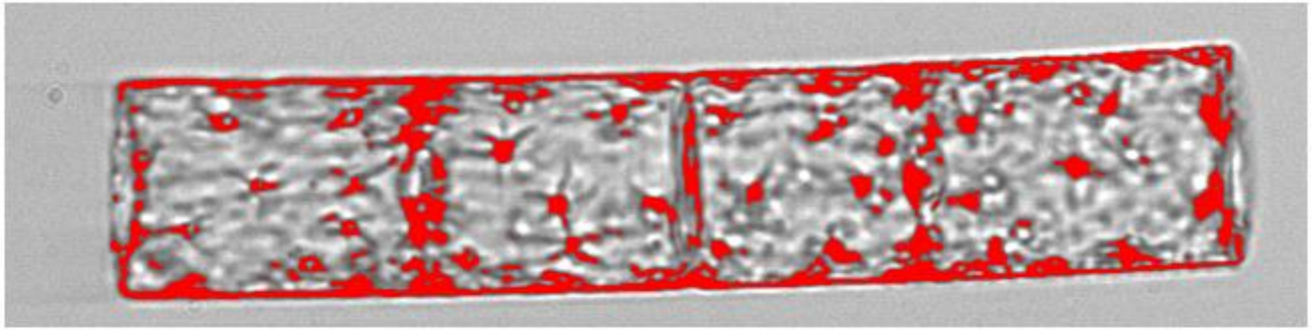
Notebook model: code cells

Code cell

In [21]:
```
from scipy.cluster.vq import kmeans2

# step 4: estimate dark areas using kmeans
samples = roi.reshape((roi.size, 1))
(means, _) = kmeans2(samples,k=2)
thresh = np.mean(means)
dark = roi < (thresh * 0.65)

show_masked(rgb,dark)
```

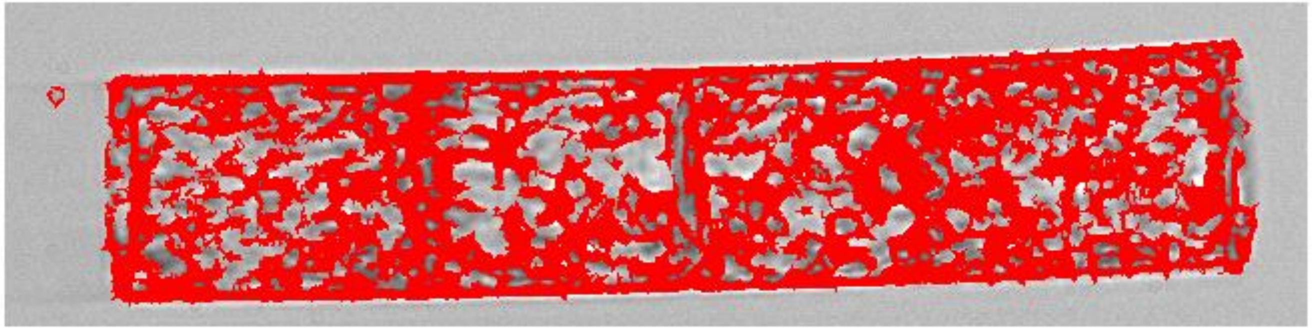
Output of code cell

Out[21]:



In [22]:
```
dark_blob = blob + dark
show_masked(rgb,dark_blob)
```

Out[22]:



Cells can be run individually (e.g., repeatedly) and in any order

Cells share all variables

Notebook model: markdown cells

Simple alternative to HTML

```
### Plot cruise track using [cartopy](https://scitools.org.uk/cartopy/docs/latest/)

* Using 10m coastlines
* Using [`stock_img`](https://scitools.org.uk/cartopy/docs/latest/matplotlib
/geoaxes.html?highlight=stock_img#cartopy.mpl.geoaxes.GeoAxes.stock_img) until I can find a
better base map
```

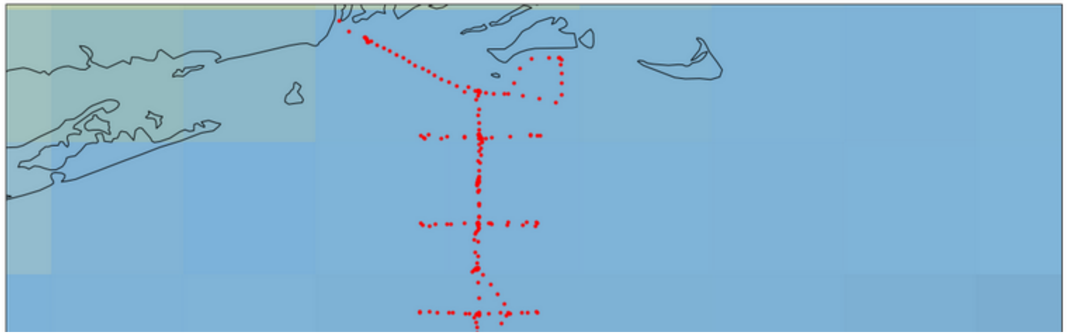
Generates HTML

Plot cruise track using cartopy

- Using 10m coastlines
- Using `stock_img` until I can find a better base map

In [8]:

```
%matplotlib inline
import matplotlib.pyplot as plt

import cartopy.crs as ccrs

fig = plt.figure(figsize=(20, 10))
ax = fig.add_subplot(1, 1, 1, projection=ccrs.PlateCarree())

ax.coastlines(resolution='10m')
r = 2
ax.set_extent([wh_lon-r, wh_lon+r, wh_lat-r, wh_lat], ccrs.PlateCarree())

ax.scatter(lons, lats, color='red', s=9, transform=ccrs.Geodetic())

ax.stock_img()
None
```



Notebook model: fancier markdown example

Inline equations in markdown cell

```
Since $L_{s} = u\overrightarrow{L_{i}}$ we only need solve for $u$

$$u = \frac{
-\alpha (am -lb)
}{
-i (bn - mc) + j (an - lc) + f (am - lb)
}$$

So distance to substrate for a given $\begin{bmatrix}i & j\end{bmatrix}$ and $\alpha$ is
$||u\overrightarrow{L_{i}}||$ or

$$\left \| {
\frac{
-\alpha (am -lb)
}{
-i (bn - mc) + j (an - lc) + f (am - lb)
} \begin{bmatrix}
i\\j\\-f
\end{bmatrix}
} \right \|$$
```

Rendering

Since $L_{s} = u\overrightarrow{L_{i}}$ we only need solve for u

$$u = \frac{-\alpha (am -lb)}{-i (bn - mc) + j (an - lc) + f (am - lb)}$$

So distance to substrate for a given $\begin{bmatrix}i & j\end{bmatrix}$ and α is $||u\overrightarrow{L_{i}}||$ or

$$\left \| {\frac{-\alpha (am -lb)}{-i (bn - mc) + j (an - lc) + f (am - lb)} \begin{bmatrix}i\\j\\-f\end{bmatrix}} \right \|$$

Notebook model: magic (“%” and “%%”)

Line magic

Cell magic

```
In [1]: %load_ext Cython

In [2]: def python_fib(n):
            a, b = 1, 1
            for _ in range(n):
                a, b = a + b, a
            return a

        %timeit python_fib(75)

        19.1 µs ± 534 ns per loop (mean ± std. dev. of 7 runs, 10000 loops each)

In [3]: %%cython

        def cython_fib(int n):
            cdef long a, b
            cdef int i
            a, b = 1, 1
            for i in range(n):
                a, b = a + b, a
            return a

In [4]: %timeit cython_fib(75)

        340 ns ± 5.47 ns per loop (mean ± std. dev. of 7 runs, 1000000 loops each)
```

Live demos: wish me luck!

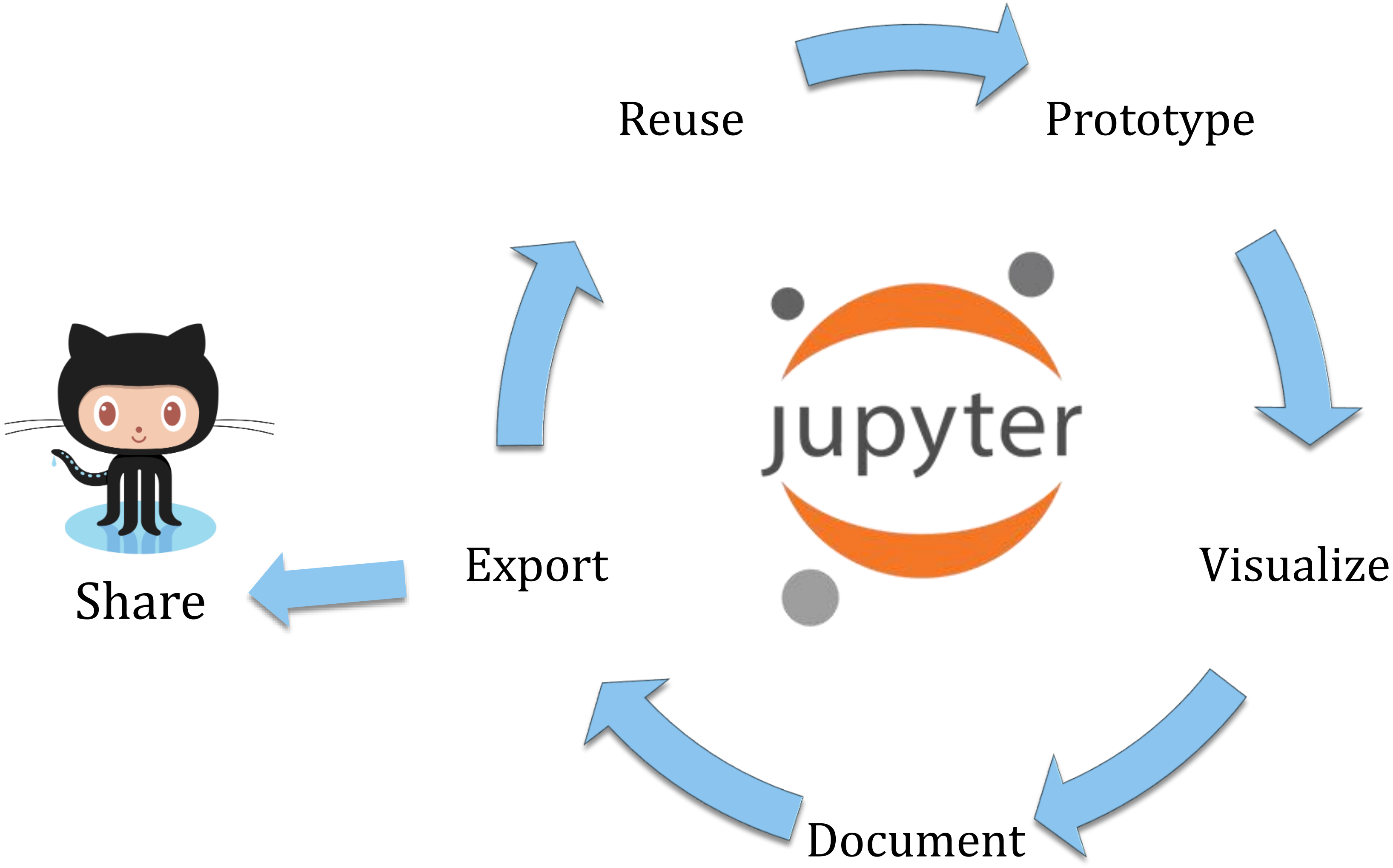
Sharing notebooks

- Upload to GitHub and GitHub will render them
  - e.g., https://gist.github.com/joefutrelle/9898646
- Use nbviewer.jupyter.org for similar functionality
  - e.g., https://nbviewer.jupyter.org/gist/joefutrelle/9898646
- Embed in blogs and discussion forums
- Share .ipynb files
  - Simple JSON text format
  - Includes output such as plots, etc.
- Hosting services for notebooks: not out there yet
  - But you can run your own multi-user JupyterHub
  - Integration with HPC through Pangeo

Caveats: things that Jupyter isn't good at (yet)

- No built-in way to manage dependencies
  - But integrated external tools like Anaconda help a lot
- Hard to version control notebooks
  - .ipynb files are JSON, not ordinary plain text files with lines of code
  - Snapshotting works
- No built-in automated testing
  - But ordinary defensive coding works
- Code editing lacks many features found in IDEs (yet)
- Notebook model has some issues
  - Out of order code execution can be confusing

My Jupyter workflow



Bottom line

- Jupyter is an emerging and popular open-source project in the data science community
- It's very good for exploratory data analysis and development of interactive visualizations
- It's good for prototyping new capabilities or libraries
- It's great for sharing code on the web
- New features are being added all the time
- It's fun!