# Python_tutorial_netcdf

September 10, 2018

```
In [1]: %matplotlib inline
```

Reading Scientific Datasets in Python Todd Spindler IMSG at NCEP/EMC Verification Post Processing Product Generation Branch Learn scientific data visualization in three easy* lessons!; * and many more perhaps not-quite-so-easy lessons...

***Just an FYI before we begin***

- This entire presentation was created using Python 3 and Jupyter Notebooks
- All three example notebooks and the data sets are available from our web site:
  - http://polar.ncep.noaa.gov/ngmmf_python
- Feel free to download them and play with the notebooks

Three commonly used binary dataset formats in use at EMC are (in no particular order):

- **NetCDF** (Network Common Data Format)
- **GRIB** (GRIdded Binary or General Regularly-distributed Information in Binary form)
- **BUFR** (Binary Universal Form for the Representation of meteorological data)

### 0.0.1 Example 1: Reading a NetCDF data set

NetCDF can be read with any of the following libraries: - **netCDF4-python**

- **xarray**
- **PyNIO**

In this example we'll use xarray to read a Global RTOFS NetCDF dataset, plot a parameter (SST), and select a subregion.

The xarray library can be installed via pip, conda (or whatever package manager comes with your Python installation), or distutils (python setup.py).

- Begin by importing the required libraries.

```
In [2]: import matplotlib.pyplot as plt     # standard graphics library
        import xarray
        import cartopy.crs as ccrs          # cartographic coordinate reference system
        import cartopy.feature as cfeature # features such as land, borders, coastlines
```

- Open the file as an xarray Dataset and display the metadata.

```
In [3]: dataset = xarray.open_dataset('rtofs_glo_2ds_n000_daily_prog.nc',decode_times=True)
```

- `decode_times=True` will automatically decode the datetime values from NetCDF convention to Python datetime objects
- Note that this reads a local data set, but you can replace the filename with the URL of the corresponding NOMADS OpenDAP data set and continue without further changes.

```
In [4]: dataset
```

```
Out[4]: <xarray.Dataset>
        Dimensions:        (Layer: 1, MT: 1, X: 4500, Y: 3298)
        Coordinates:
          * MT             (MT) datetime64[ns] 2018-08-26
            Date           (MT) float64 ...
          * Layer          (Layer) int32 1
          * Y              (Y) int32 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 ...
          * X              (X) int32 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 ...
            Latitude       (Y, X) float32 ...
            Longitude      (Y, X) float32 ...
        Data variables:
            u_velocity     (MT, Layer, Y, X) float32 ...
            v_velocity     (MT, Layer, Y, X) float32 ...
            sst            (MT, Y, X) float32 ...
            sss            (MT, Y, X) float32 ...
            layer_density  (MT, Layer, Y, X) float32 ...
        Attributes:
            Conventions:  CF-1.0
            title:        HYCOM ATLb2.00
            institution:  National Centers for Environmental Prediction
            source:       HYCOM archive file
            experiment:   09.2
            history:      archv2ncdf2d
```

- There's an extra Date field. Since it's not needed, here's how to get rid of it.

```
In [5]: dataset = dataset.drop('Date')
```

- You can also use the python delete command: `del dataset['Date']`
- There's a quirk in the Global RTOFS datasets -- the bottom row of the longitude field is unused by the model and is filled with junk data.
- I'll use array subsetting to get rid of it, and save just the SST parameter to a separate DataArray.

```
In [6]: sst = dataset.sst[0,0:-1,:]    # this can be shortened to [0,:-1,]
```

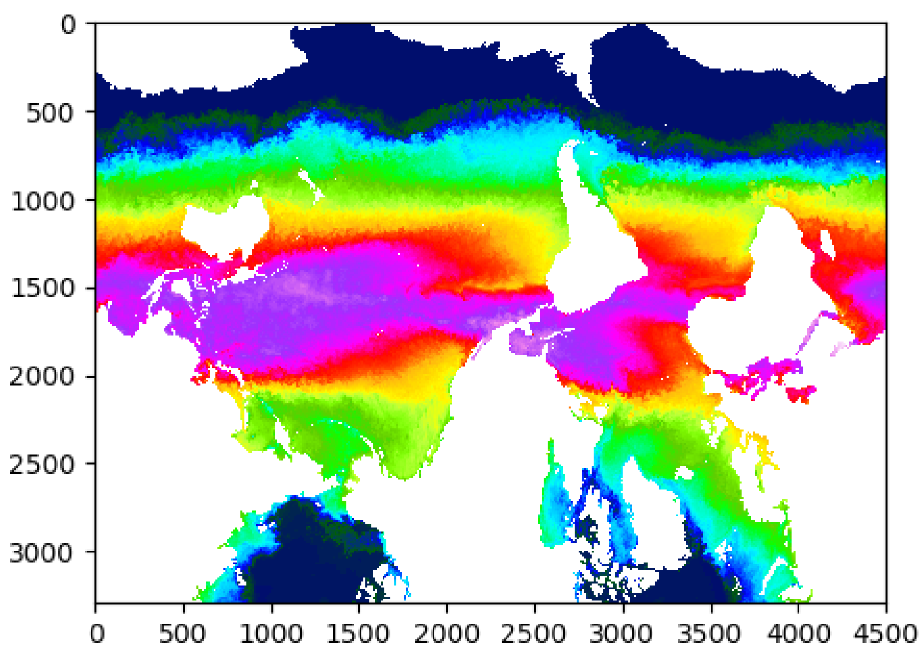
- Note that subsetting an xarray parameter will also subset the associated coordinates at the same time.

In [7]:
```
sst
```

Out[7]:
```
<xarray.DataArray 'sst' (Y: 3297, X: 4500)>
[14836500 values with dtype=float32]
Coordinates:
    MT         datetime64[ns] 2018-08-26
  * Y          (Y) int32 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 ...
  * X          (X) int32 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 ...
    Latitude   (Y, X) float32 ...
    Longitude  (Y, X) float32 ...
Attributes:
    standard_name:  sea_surface_temperature
    units:          degC
    valid_range:    [-2.1907086 34.93205  ]
    long_name:       sea surf. temp.   [09.2H]
```

- For a quick look at the raw data array, use matplotlib's `imshow` function to display the SST parameter as an image.

In [8]:
```
plt.figure(dpi=100)          # open a new figure window and set the resolution
plt.imshow(sst,cmap='gist_ncar');
```




- This is how the model data is stored in the array. The Latitude array is similarly upside down.

- Also note that the longitude values are a bit odd.

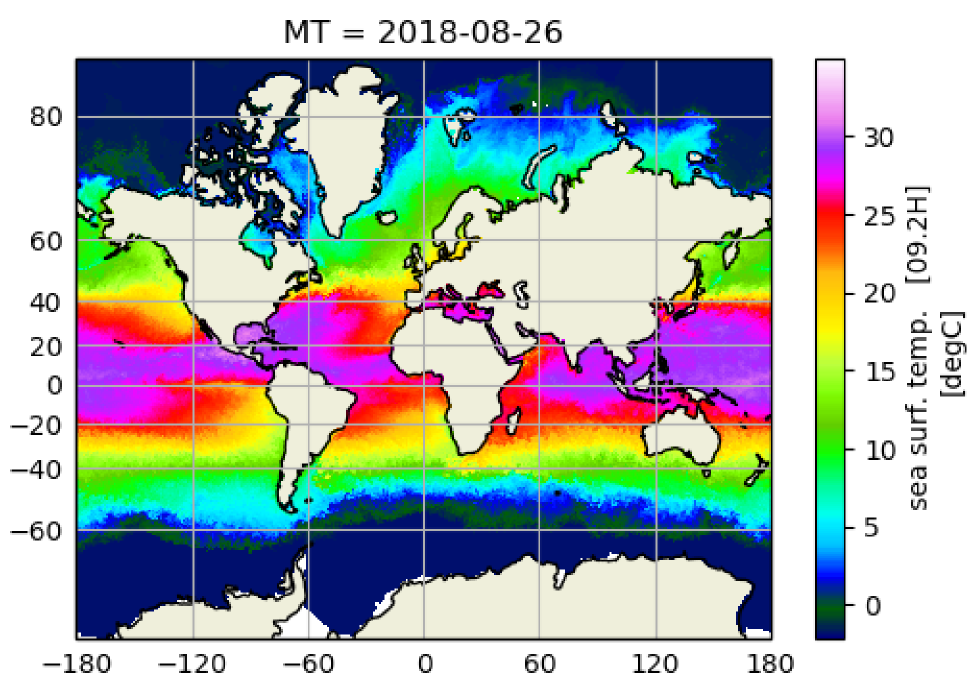
```
In [9]: print(sst.Longitude.min().data, sst.Longitude.max().data)
```

```
74.1199951171875 434.1199951171875
```

- In fact, the whole model grid is pretty weird. It's called a tripolar grid.
- Now set up the figure and plot the sst field in a Mercator projection, using Cartopy to handle the projection details and letting xarray decide how to plot the data. The default for 2-D plotting is `pcolormesh()`.
- Xarray is very smart and will try to use a diverging (bicolor) colormap if the data values straddle zero.
- You override this by specifying the colormap with `cmap=` and the `vmin=, vmax=` values for your data.

```
In [10]: plt.figure(dpi=100)
         ax=plt.axes(projection=ccrs.Mercator())
         ax.add_feature(cfeature.LAND)          # fill in the land areas
         ax.coastlines()                        # use the default low-resolution coastline
         gl=ax.gridlines(draw_labels=True)      # default is to label all axes.
         gl.xlabels_top=False                   # turn off two of them.
         gl.ylabels_right=False

         sst.plot(x='Longitude',y='Latitude',
                  cmap='gist_ncar',vmin=sst.min(),vmax=sst.max(),
                  transform=ccrs.PlateCarree());
```



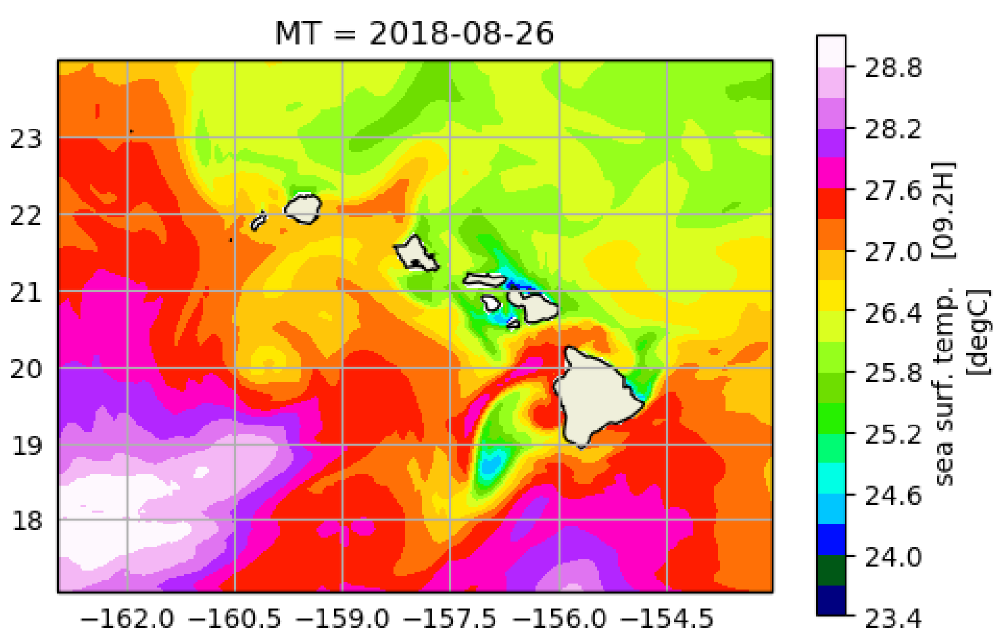
- Now let's concentrate on the waters around Hawaii (lat: 17 to 24, lon: -163 to -153)
- RTOFS longitudes are defined as 74-430, so we need to convert the -163 and -153 values by computing modulo 360.
- Use the `object.where()` method with the lat/lon limits.

```
In [11]: hawaii = sst.where((sst.Longitude>=-163%360) & (sst.Longitude<=-153%360) &
                            (sst.Latitude>=17) & (sst.Latitude<=24), drop=True)
```

- Note the `drop=True` option, which instructs the `.where()` method to subset the data. Otherwise it will retain the full array size and simply mask out the unwanted data.
- As before, let's plot the SST in a Mercator projection, but use a high-resolution coastline.
- Since the water around Hawaii is warm I don't have to specify the colormap limits.

```
In [12]: plt.figure(dpi=100)
         ax=plt.axes(projection=ccrs.Mercator())
         ax.add_feature(cfeature.LAND)
         ax.add_feature(cfeature.GSHHSFeature()) # use a high-resolution GSHHS coastline
         gl=ax.gridlines(draw_labels=True)
         gl.xlabels_top=False
         gl.ylabels_right=False

         hawaii.plot.contourf(x='Longitude',y='Latitude',levels=20,
                              cmap='gist_ncar',add_colorbar=True,
                              transform=ccrs.PlateCarree());
```



## 0.1 Next Example -- Reading a GRIB file