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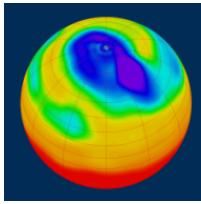

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Creating NetCDF files with Python

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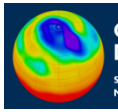

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We are using netCDF4-python!

There are many options for working with NetCDF files in Python. In this example we have chosen to highlight the use of the **netCDF4-python** module.

The **netCDF4-python** module is useful because:

- It implements the basic "classic" model as well as more advanced features.
- It provides a simple interface to the NetCDF structure.
- It has been used as the underlying NetCDF I/O layer for many more advanced packages.

Creating/Opening a netCDF file

To create a netCDF file from python, you simply call the `Dataset()` constructor. This is also the method used to open an existing netCDF file.

If the file is open for write access (`w`, `r+` or `a`), you may write any type of data including new dimensions, groups, variables and attributes.

Working with “classic” NetCDF

The `netCDF4` module can read and write files in any netCDF format. When creating a new file, the format may be specified using the `format` keyword in the `Dataset` constructor. The default format is `NETCDF4`.

This tutorial will focus exclusively on the NetCDF-”classic” data model using: `NETCDF4_CLASSIC`

Creating a NetCDF file

Open a new NetCDF file in “write” ('w') mode:

```
>>> from netCDF4 import Dataset
>>> dataset = Dataset('data/test.nc', 'w',
            format='NETCDF4_CLASSIC')

>>> print dataset.file_format
NETCDF4_CLASSIC
```

Create dimensions

Define a set of dimensions used for your variables:

```
level = dataset.createDimension('level', 10)
lat = dataset.createDimension('lat', 73)
lon = dataset.createDimension('lon', 144)
time = dataset.createDimension('time', None)
```

And you can query dimensions with:

```
>>> print len(lon)
144
>>> print time.isunlimited() # is special!
True
```

Dimensions

All of the `Dimension` instances are stored in a python dictionary. This allows you to access each dimension by its name using dictionary key access:

```
print 'Lon dimension:', dataset.dimensions['lon']

for dimname in dataset.dimensions.keys():
    dim = dataset.dimensions[dimname]
    print dimname, len(dim), dim.isunlimited()
```

```
Lon dimension: <type 'netCDF4.Dimension'>: name = 'lon', size = 144
level 10 False
time 0 True
lat 73 False
lon 144 False
```

Variables

NetCDF **variables** behave much like python multi-dimensional arrays in `numpy`. However, unlike numpy arrays, netCDF4 variables can be appended to along the 'unlimited' dimension (a.k.a. the "record dimension").

To create a netCDF variable, use:

```
Dataset.createVariable(<var_id>, <type>,
                       <dimensions>)
```

This method has two mandatory arguments: the variable ID (a Python string) and the variable datatype. Additionally a tuple of dimensions can be provided.

Creating a variable

```
import numpy as np

# Create coordinate variables for 4-dimensions

times = dataset.createVariable('time', np.float64, ('time',))
levels = dataset.createVariable('level', np.int32, ('level',))
latitudes = dataset.createVariable('latitude', np.float32,
 ('lat',))
longitudes = dataset.createVariable('longitude', np.float32,
 ('lon',))

# Create the actual 4-d variable
temp = dataset.createVariable('temp', np.float32,
 ('time','level','lat','lon'))
```

Accessing variables

All of the variables in the `Dataset` are stored in a Python dictionary, in the same way as the dimensions:

```
>>> print 'temp variable:', dataset.variables['temp']

>>> for varname in dataset.variables.keys():
...     var = dataset.variables[varname]
...     print varname, var.dtype, var.dimensions, var.shape

temp variable: <type 'netCDF4.Variable'> float32 temp(time, level,
lat, lon) unlimited dimensions: time
current shape = (0, 10, 73, 144)
time float64 (u'time',) (0,)
level int32 (u'level',) (10,)
latitude float32 (u'lat',) (73,)
longitude float32 (u'lon',) (144,)
temp float32 (u'time', u'level', u'lat', u'lon') (0, 10, 73, 144)
```

Attributes (global)

Global attributes are set by assigning values to `Dataset` instance variables. Attributes can be strings, numbers or sequences. Returning to our example:

```
import time

# Global Attributes
dataset.description = 'bogus example script'
dataset.history = 'Created ' + time.ctime(time.time())
dataset.source = 'netCDF4 python module tutorial'
```

Attributes (variable)

Variable attributes are set by assigning values to `Variable` instance variables:

```
# Variable Attributes
latitudes.units = 'degree_north'
longitudes.units = 'degree_east'
levels.units = 'hPa'
temp.units = 'K'

times.units = 'hours since 0001-01-01 00:00:00'
times.calendar = 'gregorian'
```

Accessing attributes

Attributes are accessed as attributes of their relevant instances:

```
>>> print dataset.description
bogus example script

>>> print dataset.history
Created Mon Mar 17 01:12:31 2014
```

Writing data

Now that you have a netCDF `Variable` instance, how do you put data into it? You can just treat it like an array and assign data to a slice.

```
>>> lats = np.arange(-90,91,2.5)
>>> lons = np.arange(-180,180,2.5)
>>> latitudes[:] = lats
>>> longitudes[:] = lons
>>> print 'latitudes =\n', latitudes[:]
latitudes =
[-90.   -87.5 -85.     -82.5 -80.     -77.5 -75.     -72.5 -70.
...
-60.    -57.5 -55.     -52.5 -50.     -47.5 -45.     -42.5 -40
...
```

Growing data along unlimited dimension (1)

Unlike NumPy's array objects, netCDF `Variable` objects that have an unlimited dimension will grow along that dimension if you assign data outside the currently defined range of indices.

```
>>> print 'temp shape before adding data = ', temp.shape

temp shape before adding data = (0, 10, 73, 144)
```

Growing data along unlimited dimension (2)

```
>>> from numpy.random import uniform
>>> nlats = len(dataset.dimensions['lat'])
>>> nlons = len(dataset.dimensions['lon'])
>>> temp[0:5,:,:,:] = uniform(size=(5,10,nlats,nlons))
>>> print 'temp shape after adding data = ', temp.shape

temp shape after adding data = (5, 10, 73, 144)
temp shape before adding data = (0, 10, 73, 144)
```

NOTE: **numpy.random.uniform**(size = X) returns values from a uniform distribution in a numpy array with dimensions expressed in a tuple X.

Defining date/times correctly (1)

Time coordinate values pose a special challenge to netCDF users. Most metadata standards (such as CF and COARDS) specify that time should be measure relative to a fixed date using a certain calendar, with units specified like `"hours since YY:MM:DD hh-mm-ss"`.

These units can be awkward to deal with, without a utility to convert the values to and from calendar dates. The functions `num2date()` and `date2num()` are provided with this package to do just that. Here's an example of how they can be used…

Defining date/times correctly (2)

```
>>> # Fill in times.
>>> from datetime import datetime, timedelta
>>> from netCDF4 import num2date, date2num
>>> dates = []

>>> for n in range(temp.shape[0]):
...     dates.append(datetime(2001, 3, 1) + n *
                          timedelta(hours=12))

>>> times[:] = date2num(dates, units = times.units,
                          calendar = times.calendar)
>>> print 'time values (in units %s): ' % times.units +
                          '\n', times[:]

time values (in units hours since 0001-01-01
00:00:00.0): [ 17533104. 17533116. 17533128. 17533140.
17533152.]
```

Defining date/times correctly (3)

```
>>> dates = num2date(times[:], units=times.units,
              calendar=times.calendar)
>>> print 'dates corresponding to time values:\n', dates

dates corresponding to time values:
  [datetime.datetime(2001, 3, 1, 0, 0)
   datetime.datetime(2001, 3, 1, 12, 0)
   datetime.datetime(2001, 3, 2, 0, 0)
   datetime.datetime(2001, 3, 2, 12, 0)
   datetime.datetime(2001, 3, 3, 0, 0)]
```

`num2date()` converts numeric values of time in the specified `units` and `calendar` to `datetime` objects, and **`date2num()`** does the reverse.

Finally, let's write the file

Simply…

```
>>> dataset.close()
# and the file is written!
```

I wonder what it looks like

```
netcdf test {
dimensions:
    level = 10 ;
    time = UNLIMITED ; // (5 currently)
    lat = 73 ;
    lon = 144 ;

variables:
    double time(time) ;
        time:units = "hours since 0001-01-01 00:00:00.0" ;
        time:calendar = "gregorian" ;
    int level(level) ;
        level:units = "hPa" ;
    float latitude(lat) ;
        latitude:units = "degrees north" ;
    float longitude(lon) ;
        longitude:units = "degrees east" ;
    float temp(time, level, lat, lon) ;
        temp:units = "K" ;

// global attributes:
    :description = "bogus example script" ;
    :history = "Created Mon Mar 17 01:12:31 2014" ;
    :source = "netCDF4 python module tutorial" ;
}
```

Further reading

Python-netCDF4:

http://netcdf4-python.googlecode.com/svn/trunk/docs/netCDF4-module.html