Atmospheric Applications of Remote Sensing: Understanding & Visualizing Data

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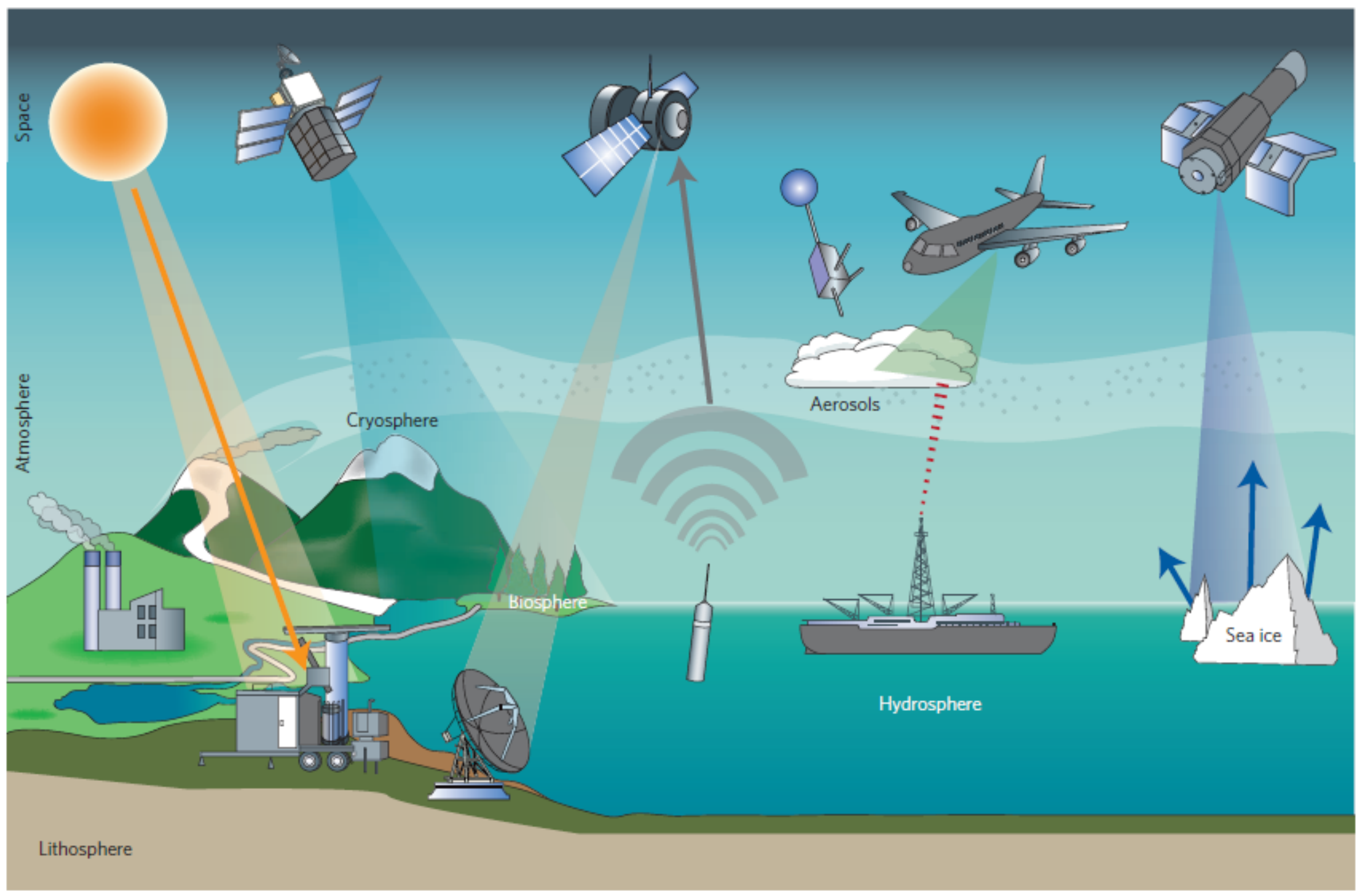

Space
Atmosphere
Cryosphere
Aerosols
Biosphere
Sea ice
Hydrosphere
Lithosphere

Agenda

- Application of Satellite Remote Sensing in understanding our atmosphere.
- Understanding climate change
- Surface air quality
- Understanding Satellite Data – The HDF format
- An application example (Terra/MODIS) –
  - Accessing data set and visualizing wind speed over ocean

Role of SRS in Understanding Atmosphere

- Today's main concern about our atmosphere – Climate Change
- Jun Yang et al. discuss the role of satellite remote sensing in climate change studies –
  - The authors highlight some key discoveries not detected by climate models and conventional observations.
  - For example – the spatial pattern of sea-level rise and the cooling effects of increased stratospheric aerosols.
  - An increase in the sea surface temperature (SST) has been observed in all ocean basins since the 1970s, with an average estimated increase of 0.28˚Cfrom 1984 to 2006.
  - Snow-Cover Extent (SCE), being an important indicator of global warming, has reduced by 0.8 million km^2 per decade over Northern Hemisphere.
  - Measuring *surface elevation changes* from satellite altimetry data collected by satellites such as ICESat-2, CryoSat-2 or by *measuring ice-mass changes* using GRACE satellite data has shown mass losses of Antarctic and Greenland ice-sheets.

Surface Air Quality

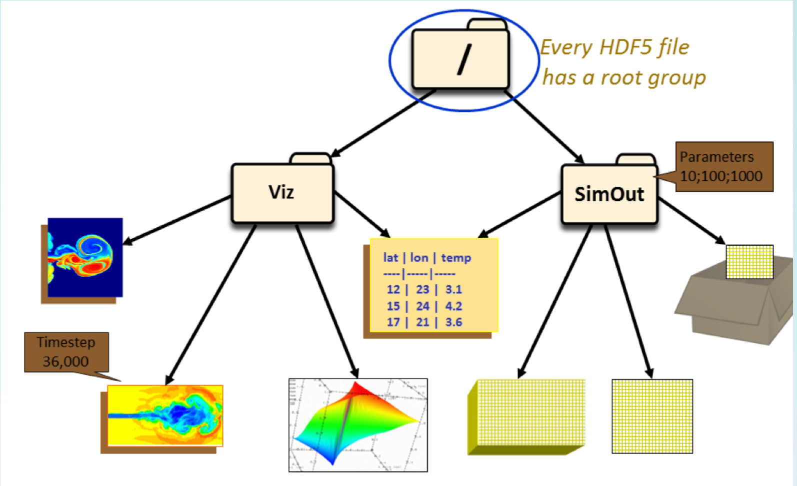
- Randall V. Martin discusses the capabilities of satellite remote sensing in making global observations of wide range of pollutant species comprising surface air quality such as aerosols, tropospheric O_3, NO_2, CO, HCHO, and SO_2.
- Landsat satellites complemented with ground-based monitors determine the population exposure to air pollution. Fraser et al. in 1984 used GOES satellite observations to conduct first retrieval of aerosol optical depth over land and *applied it to examine a haze event over the eastern United States*.
- Trace Gas Remote Sensing and Aerosol Remote Sensing use solar backscatter and thermal infrared emission to measure small aerosol optical thickness as a function of atmospheric reflectance due to molecular scattering.
- Remote Sensing instruments like Cloud-Aerosol Transport System (CATS) and CALIPSO (Cloud-Aerosol Lidar Infrared Pathfinder Spaceborne Observations) uses multi-wavelength lidar to provide vertical profiles measurements of atmospheric aerosols and clouds.

Understanding Satellite Data - HDF

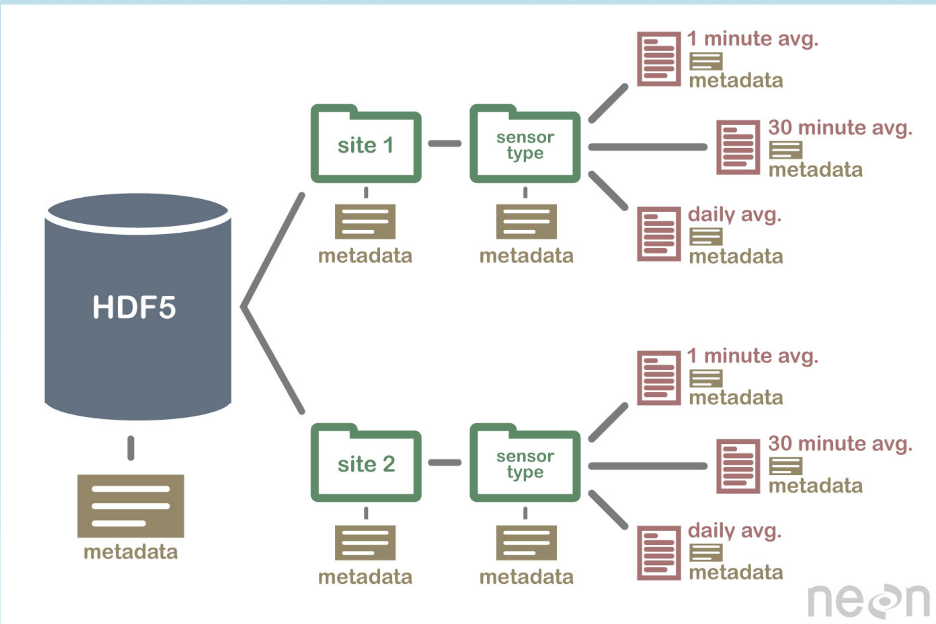
- HDF – Hierarchical Data Format is a self-describing multi-object file format for sharing scientific data in a distributed environment.
- For each data object in an HDF file, there are predefined tags that identify such information as the type of data, the amount of data, its dimensions, and its location in the file.
- The self-describing capability of HDF files makes it possible to fully understand the structure and contents of a file just from the information stored in the file itself.
- HDF is a platform independent file format. It can be used on many different computers, regardless of the operating system that machine is running.
- The latest HDF format is HDF5 which adheres to the HDF5 file format specification, which specifies the bit-level organization of an HDF5 file on storage media.

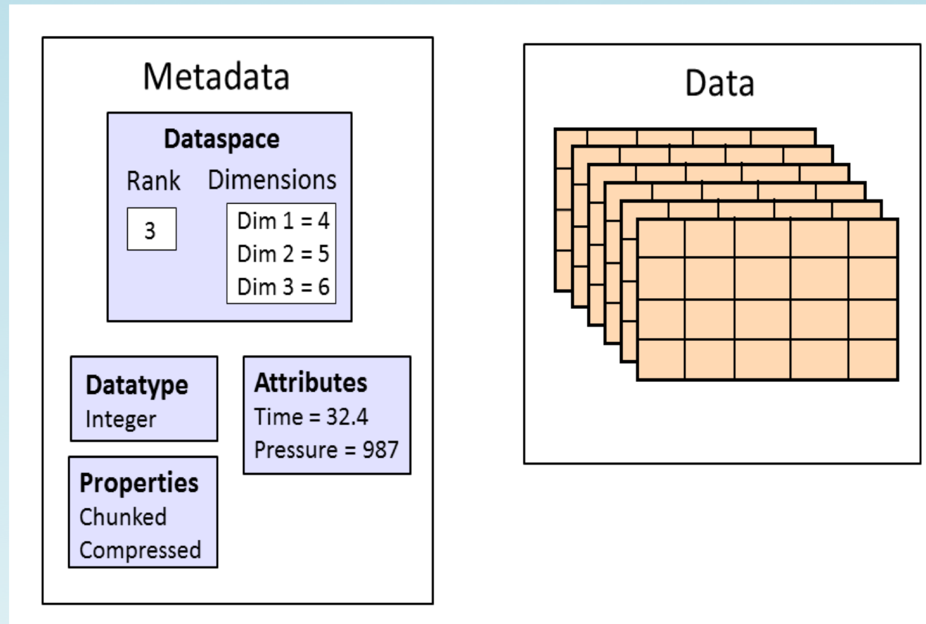
HDF Data Model

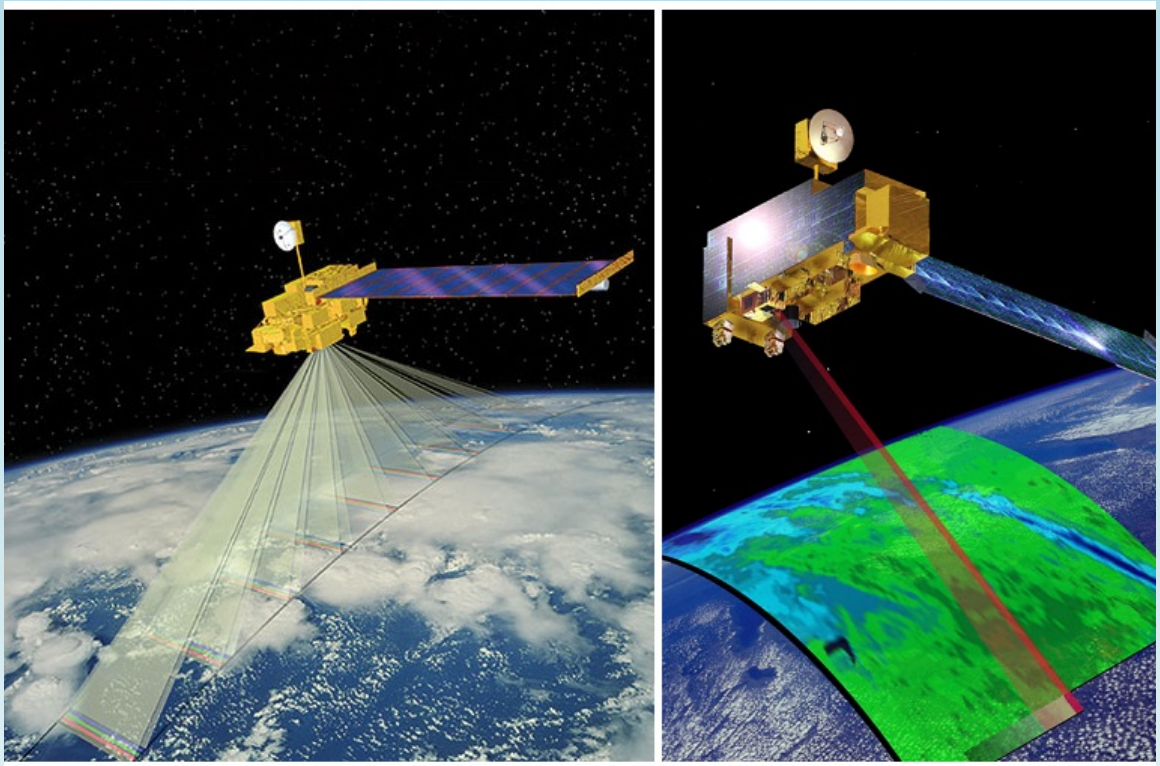
- The two primary objects in the HDF5 Data Model are *groups* and *datasets*.
- Variety of other objects in the HDF5 Data Model that support groups and datasets, includes *datatypes, dataspaces, properties* and *attributes*.
- Every HDF5 file contains a ***root*** group that can contain other groups or be linked to objects in other files.
- Datasets - HDF5 datasets organize and contain the "raw" data values. A dataset consists of metadata that describes the data, in addition to the data itself.
- Datatypes, dataspaces, properties and (optional) attributes are HDF5 objects that describe a dataset. The datatype describes the individual data elements.



HDF File Structure







Understanding & Visualizing Data – A Study

Terra/MODIS Aerosol
Dataset Title: MODIS/Terra Aerosol 5-Min L2 Swath 3km

Dataset Release Date: 2017-10-20

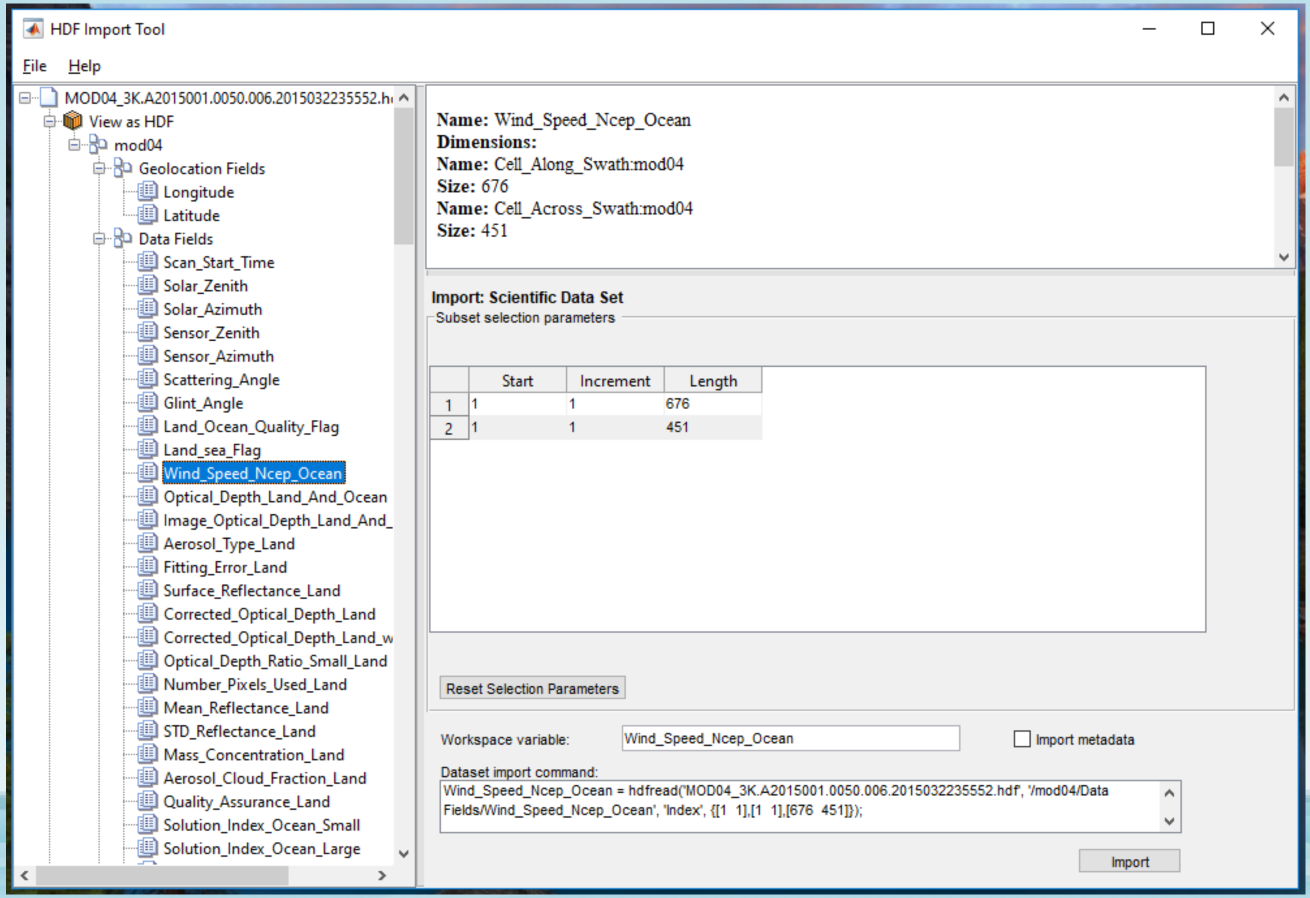
Dataset Release Place: MODAPS at NASA/GSFC

Data – Origin & other details

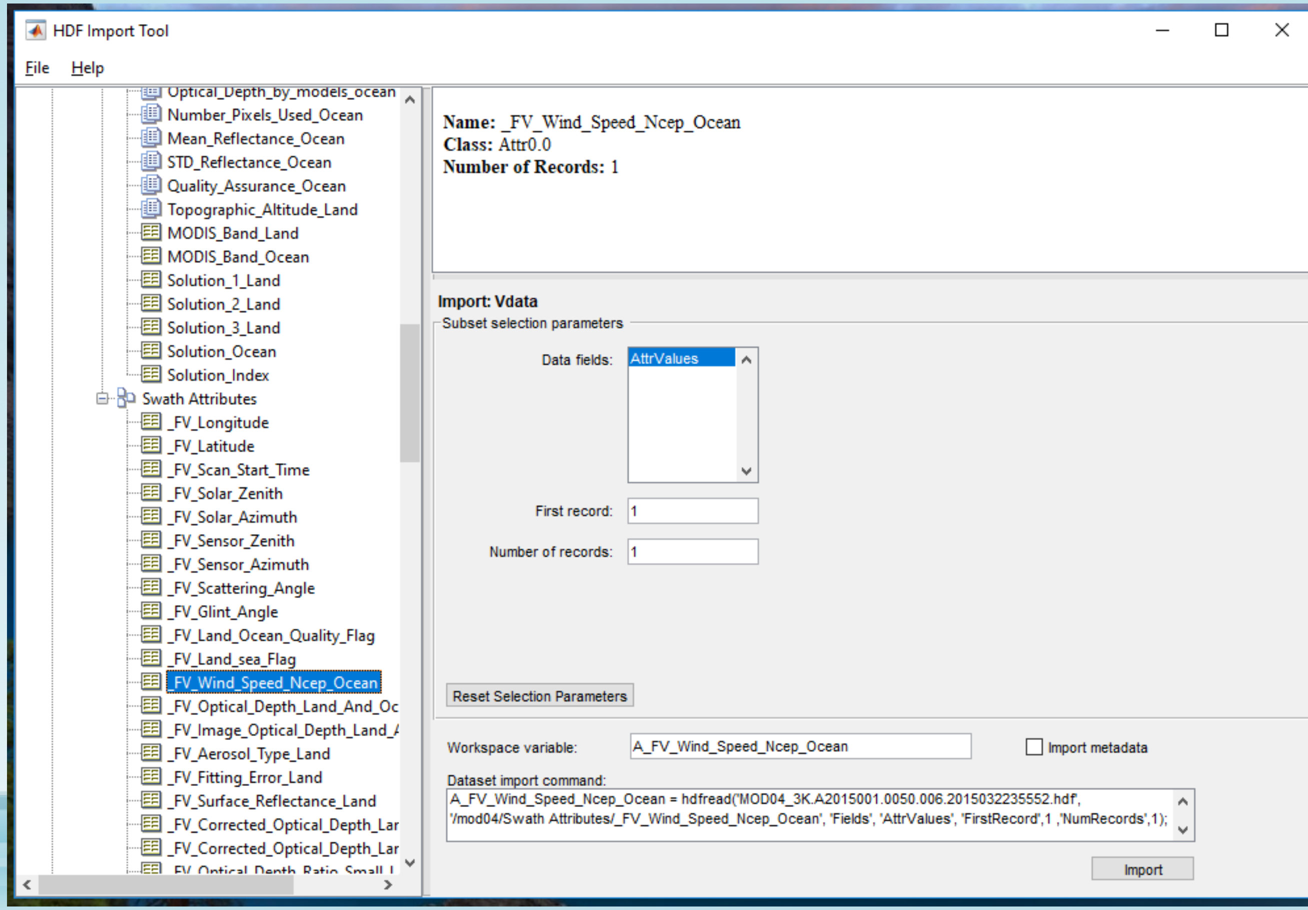
- MODIS data from Terra satellite acquired from NASA's **Level 1 and Atmosphere Archive and Distribution System (LAADS) DAAC (Distributed Active Archive Center)**
- LAADS DAAC provides access to MODIS Level 1 data (geolocation, L1A, and radiance L1B) and Atmosphere (Level 2 and 3) data products.
- Data Set Short Name: MOD04_3K
- Data Set Long Name: MODIS/Terra Aerosol 5Min L2 Swath 3km
- The MODIS level-2 atmospheric aerosol product provides retrieved ambient aerosol optical properties, quality assurance, and other parameters, globally over ocean and land.

MOD04_3K	**View as HDF**
Class: SWATH	mod04
Geolocation Fields	Longitude, Latitude
Data Fields	Wind_Speed_Ncep_Ocean

HDF Data Import using MATLAB



Swath Attribute



HDF5 example – CATS data

- To demonstrate how HDF5 data looks, we used CATS data which is available for Level 1 & 2 in HDF5 format.

```
FILE_NAME_CATS='CATS-ISS_L1B_D-M7.2-V2-08.2017-10-29T21-15-38T21-48-21UTC.hdf5';
SWATH_NAME_CATS='cats_d';
DATAFIELD_NAME_CATS = 'Cats_Iss_Lib_Data';
%h5disp(FILE_NAME)
%h5disp(FILE_NAME,'/channel_1064')
h5disp(FILE_NAME_CATS,'/channel_1064/FFOV/Total_Attenuated_Backscatter1064_Fore_FOV')
data_cats = h5read(FILE_NAME_CATS,'/channel_1064/FFOV/Total_Attenuated_Backscatter1064_Fore_FOV'
lat_cats = h5read(FILE_NAME_CATS,'/ancillary_data/MET/MET_Data_Latitude')
long_cats = h5read(FILE_NAME_CATS,'/ancillary_data/MET/MET_Data_Longitude')
```

Command Window

```
>> FILE_NAME_CATS='CATS-ISS_L1B_D-M7.2-V2-08.2017-10-29T21-15-38T21-48-21UTC.hdf5';
SWATH_NAME_CATS='cats_d';
DATAFIELD_NAME_CATS = 'Cats_Iss_Lib_Data';
%h5disp(FILE_NAME)
%h5disp(FILE_NAME,'/channel_1064')
h5disp(FILE_NAME_CATS,'/channel_1064/FFOV/Total_Attenuated_Backscatter1064_Fore_FOV')
HDF5 CATS-ISS_L1B_D-M7.2-V2-08.2017-10-29T21-15-38T21-48-21UTC.hdf5
Dataset 'Total_Attenuated_Backscatter1064_Fore_FOV'
    Size:  533x39257
    MaxSize:  533x39257
    Datatype:   H5T_IEEE_F32LE (single)
    ChunkSize:  250x19628
    Filters:  deflate(5)
    FillValue:  0.000000
fx >>
```

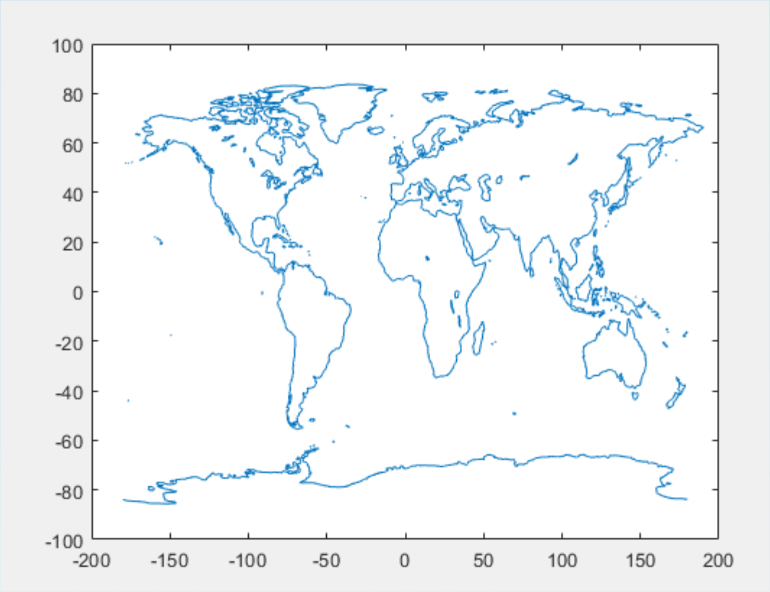
Fetching & Reading swath data

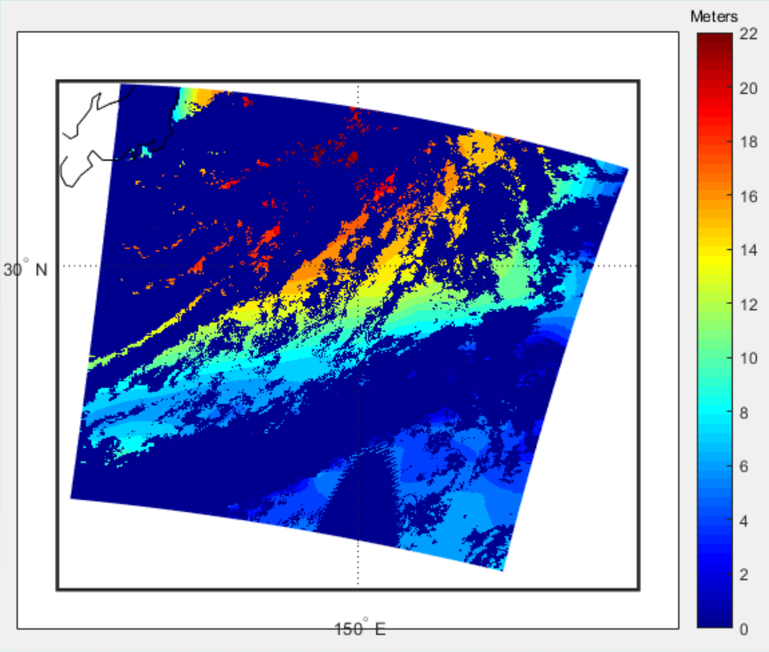
- For visualizing data, we need to map the region for which the data was collected.
- So, using the swath attribute data in the file, we extract the longitude & latitude data values.
- This is used to scale the corresponding data plot (Wind speed over ocean here) over the total coast map (provided by MATLAB Mapping toolbox).

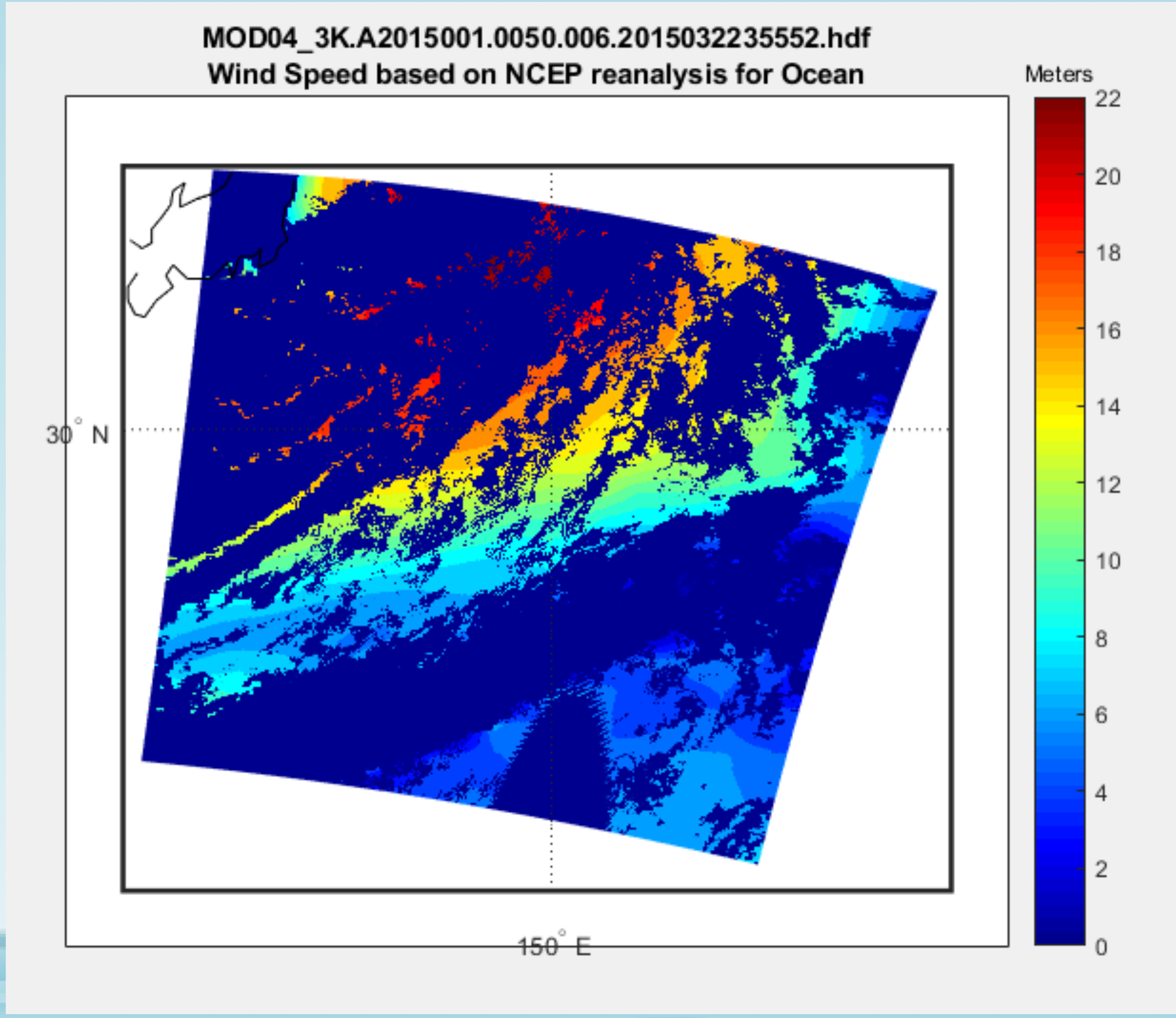
```
FILE_NAME='MOD04_3K.A2015001.0050.006.2015032235552.hdf';
SWATH_NAME='mod04';
DATAFIELD_NAME = 'Wind_Speed_Ncep_Ocean';
file_id = hdfsw('open', FILE_NAME, 'rdonly');
swath_id = hdfsw('attach', file_id, SWATH_NAME);
[data, status] = hdfsw('readfield', swath_id, DATAFIELD_NAME, [], [], []);

% Read lat and lon.
[lon, status] = hdfsw('readfield', swath_id, 'Longitude', [], [], []);
[lat, status] = hdfsw('readfield', swath_id, 'Latitude', [], [], []);
```

Overlaying data over coast map

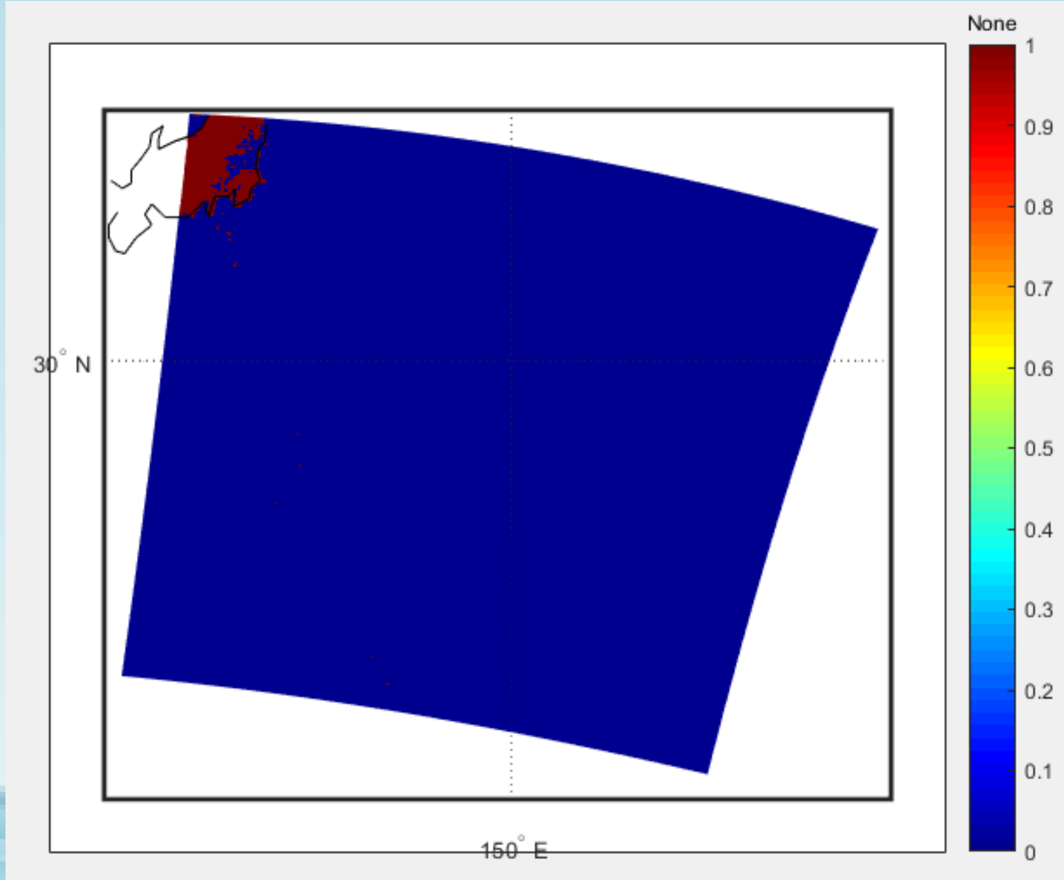






MOD04_3K.A2015001.0050.006.2015032235552.hdf
Wind Speed based on NCEP reanalysis for Ocean
Meters
22
20
18
16
14
12
10
8
6
4
2
0
30° N
150° E

Aerosol Cloud Fraction Land



References

- **Level 1 and Atmosphere Archive and Distribution System (LAADS) DAAC**
- **HDF-EOS TOOLS AND INFORMATION CENTER**
- HDF Group
- Neon Data Skills – Remote Sensing