MODIS to VIIRS Transition for Air Quality Applications

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October 22, 2020, Online Training

Course Structure and Materials

- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://appliedsciences.nasa.gov/join-mission/training/english/modis-viirs-transition-air-quality-applications
  - Q&A following each lecture and/or by email at:
    - pawan.gupta@nasa.gov or
    - melanie.cook@nasa.gov

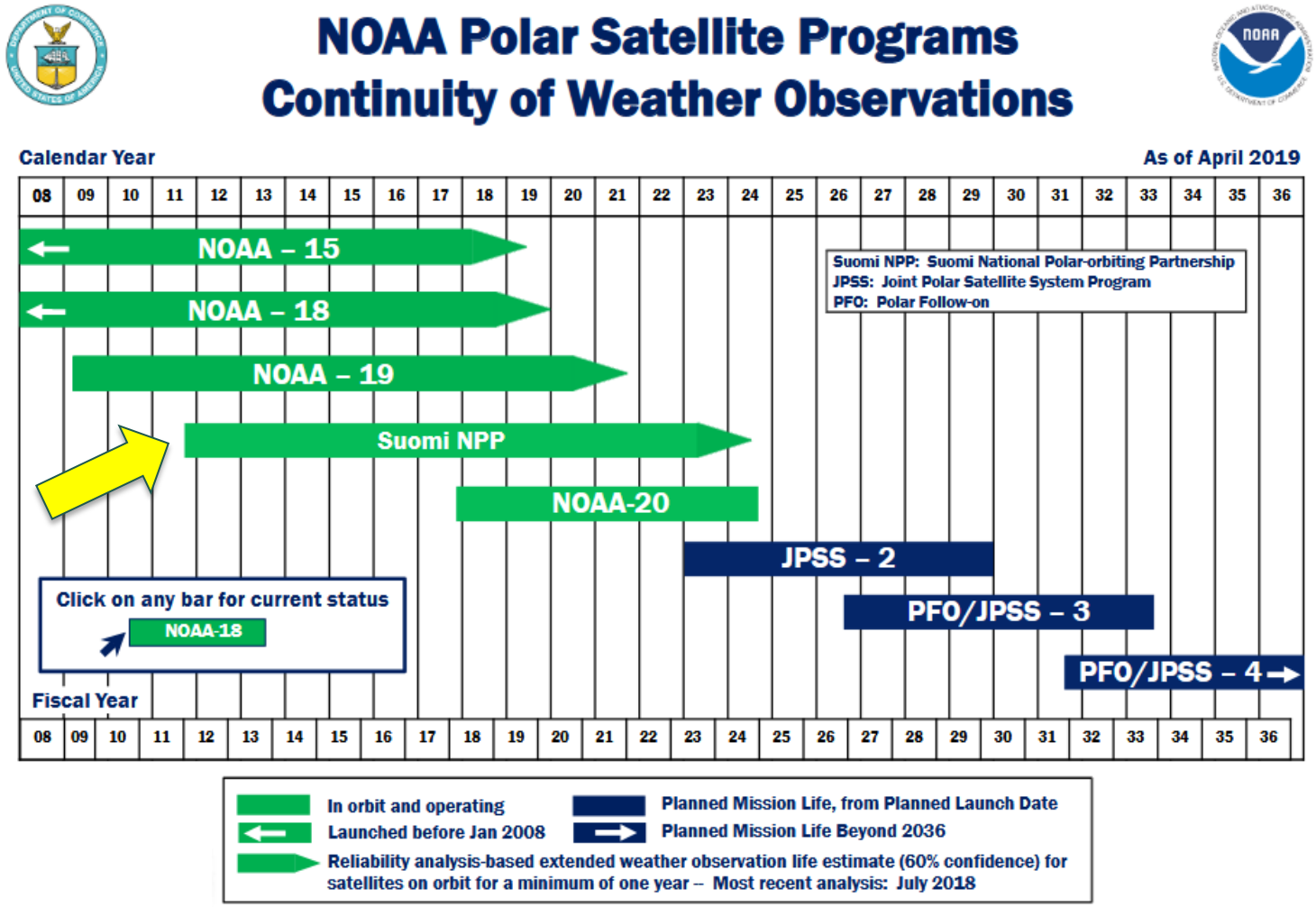
Learning Objectives

By the end of this training, participants will:

- Access NASA VIIRS aerosol products through Earthdata
- Describe the differences between the MODIS and VIIRS instruments and aerosol optical depth (AOD) products
- Understand how VIIRS aerosol optical depth observations can be used for air quality applications

Satellites and Sensors

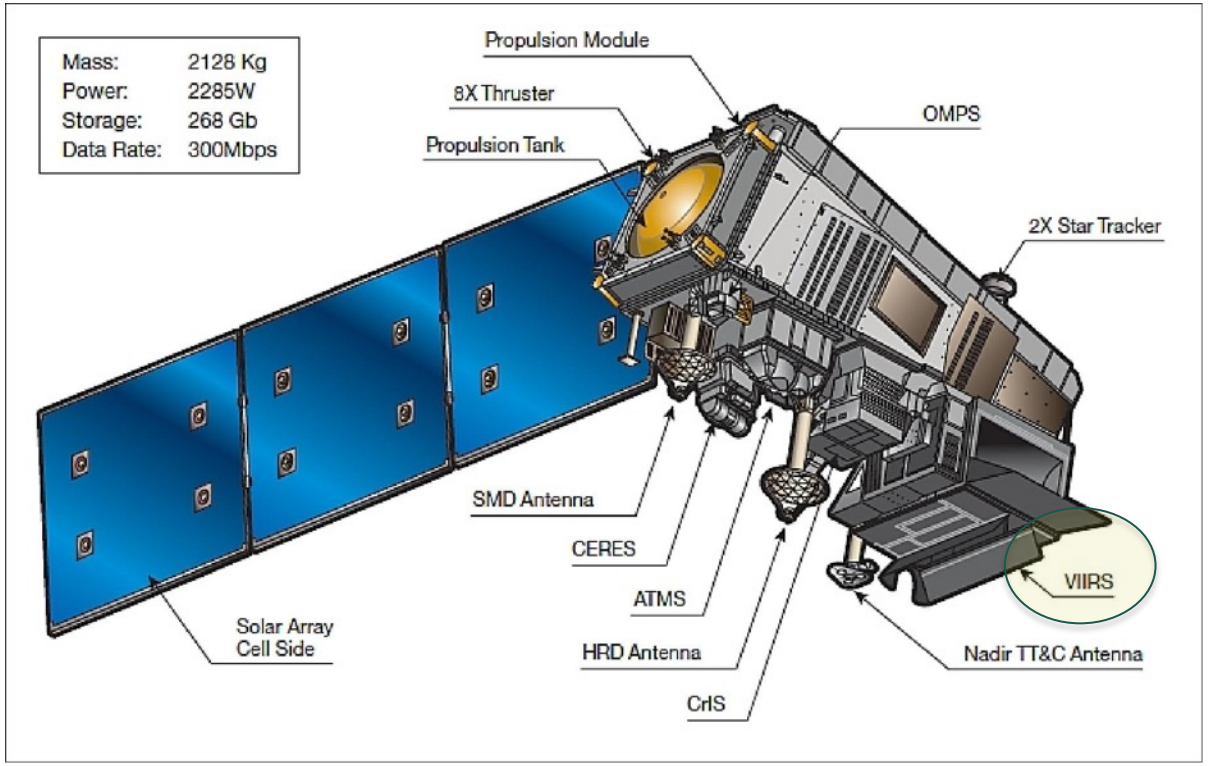
NOAA Series of Satellites – Historical Perspective



https://www.nesdis.noaa.gov/sites/default/files/asset/document/POES_Flyout_April_2019_Signature.pdf

S-NPP Satellite

- Named after Verner E. Suomi, a meteorologist at the University of Wisconsin, who is recognized widely as "the father of satellite meteorology."
- **Sensors**
  - **VIIRS** (Visible/Infrared Imager and Radiometer Suite) – Land, Atmosphere, Ocean
  - **CrIS** (Cross-Track Infrared Sounder)- Water Vapor, Pressure
  - **OMPS** (Ozone Mapping and Profiler Suite) - Ozone
  - **ATMS** (Advanced Technology Microwave Sounder) – Moisture and Temperature
  - **CERES** (Clouds and the Earth's Radiant Energy System) – Energy Budget

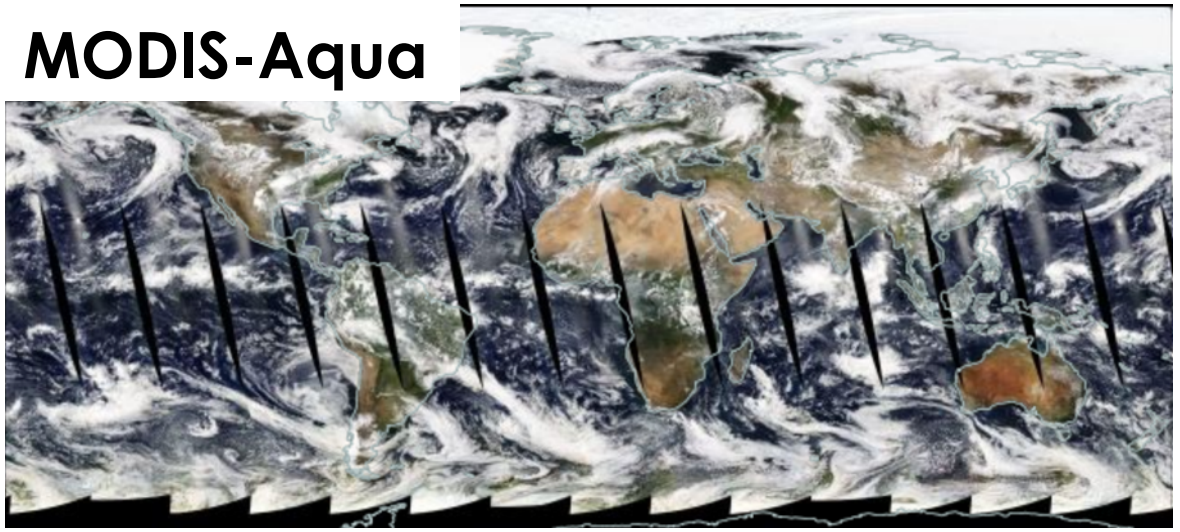


https://directory.eoportal.org/web/eoportal/satellite-missions/s/suomi-npp

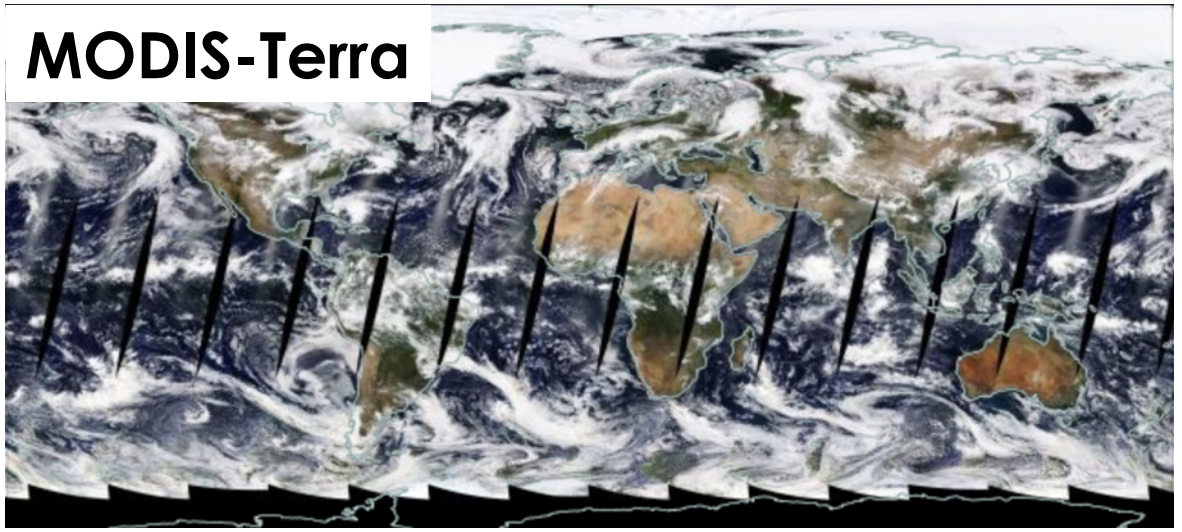
Moderate Resolution Imaging Spectroradiometer (MODIS)

- 2000 – Present
- Spatial Resolution:
  - 250 m, 500 m, 1 km
- Platforms:
  - Terra (morning overpass time)
  - Aqua (afternoon overpass time)
- Temporal Resolution:
  - Daily, 8-day, 16-day, monthly, yearly
- Spectral Coverage:
  - 36 Bands (major bands include red, blue, IR, NIR, MIR)
- Provide measurements of land, water, and atmosphere

MODIS-Aqua



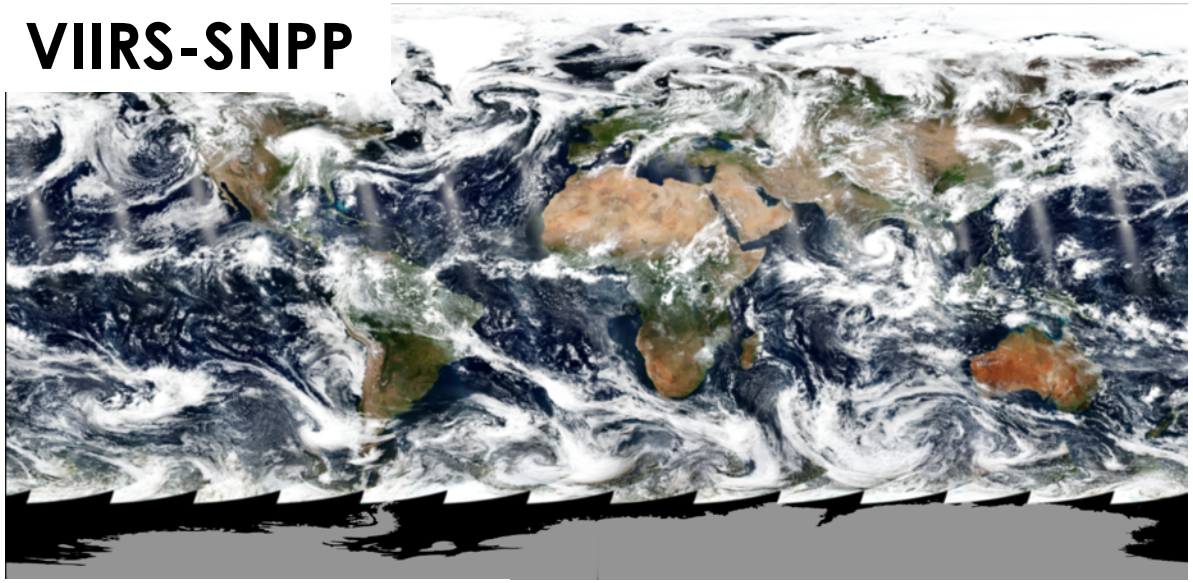
MODIS-Terra



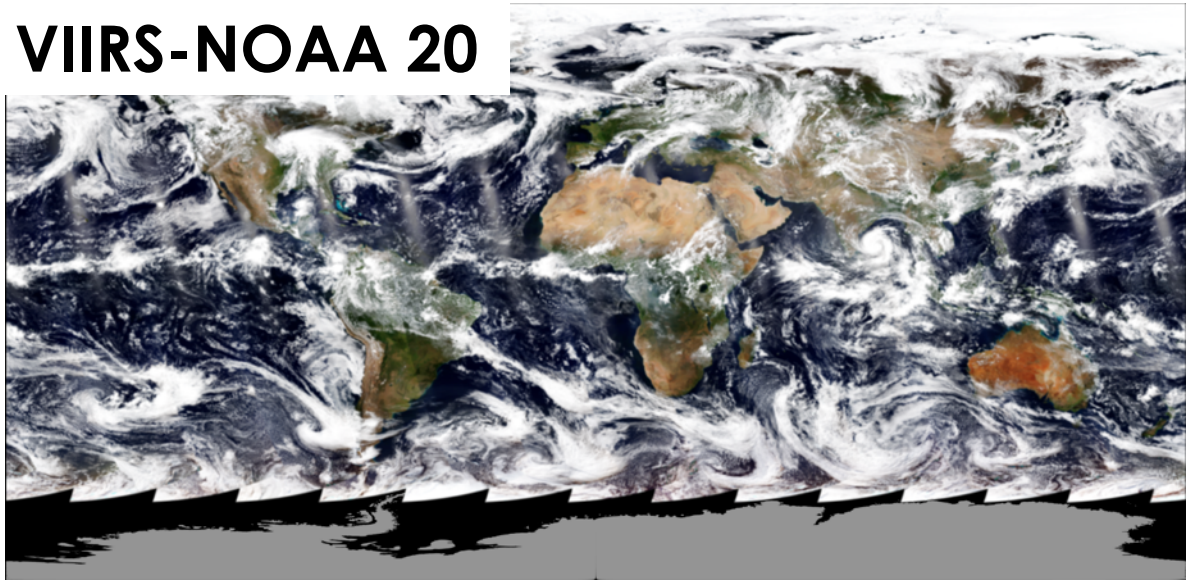
Visible Infrared Imaging Radiometer Suite (VIIRS)

- 2011 – Present
- Spatial Resolution:
  - 375 m, 750 m
- Platforms:
  - SNPP, NOAA20 (JPSS1) - Current
  - JPSS2, JPSS3 - Future
- Temporal Resolution:
  - Daily, 8-day, 16-day, monthly, yearly
- Spectral Coverage:
  - 22 bands (major bands include red, blue, IR, NIR, MIR)
- Provide measurements of land, water, and atmosphere

VIIRS-SNPP



VIIRS-NOAA 20



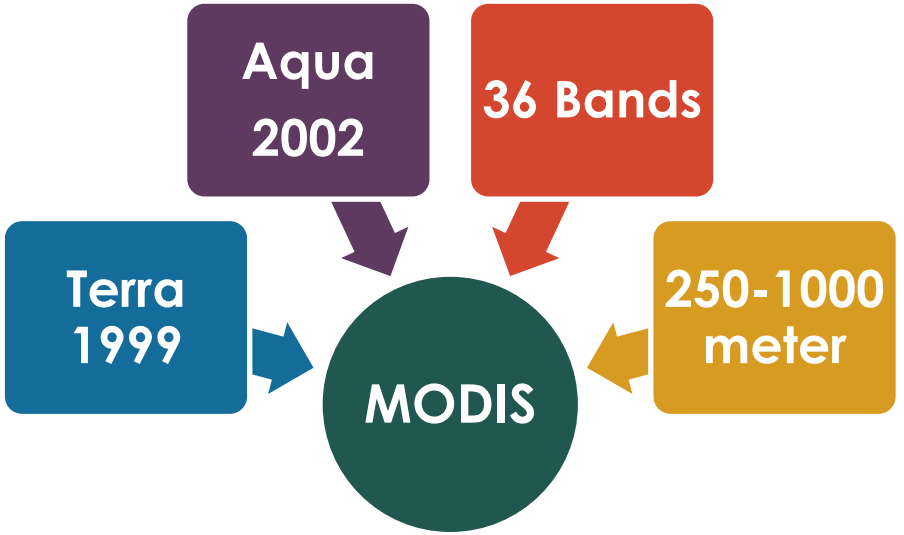
MODIS vs. VIIRS

MODIS vs. VIIRS – Historical Perspective

- S-NPP serves at the bridge between NASA EOS and JPSS satellites.
- JPSS previously called NPOESS
- JPSS is developed by NASA for NOAA

MODIS - Moderate Resolution Imaging Spectroradiometer
VIIRS – Visible Infrared Imaging Radiometer Suite
NPOESS - National Polar-orbiting Operational Environmental Satellite System
S-NPP - Suomi National Polar-orbiting Partnership
JPSS - Joint Polar Satellite System (NOAA 20)
EOS - Earth Observing System

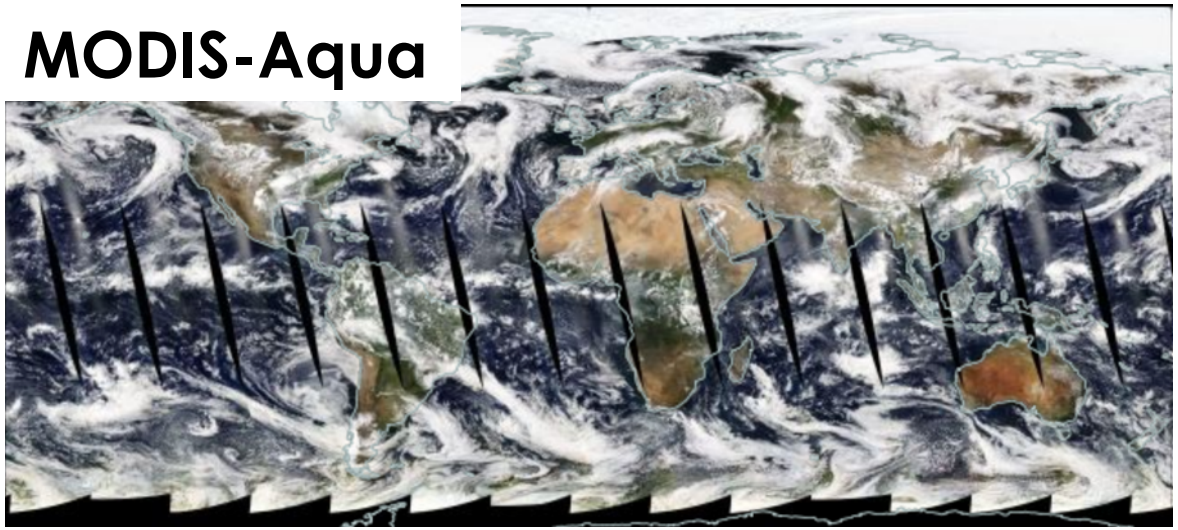
NASA EOS Missions



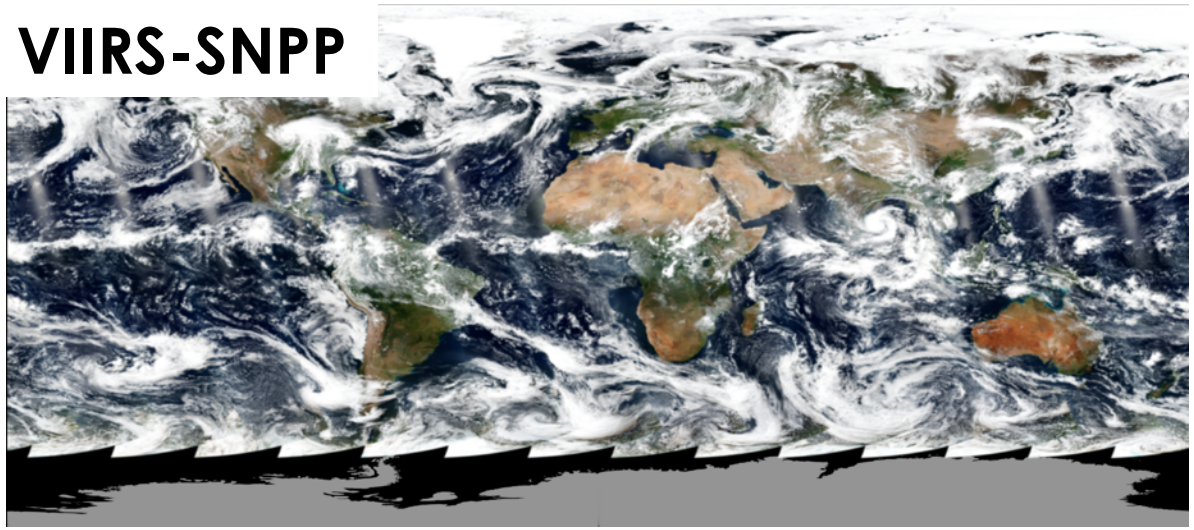
NASA-NOAA Joint Mission

MODIS vs. VIIRS - Coverage

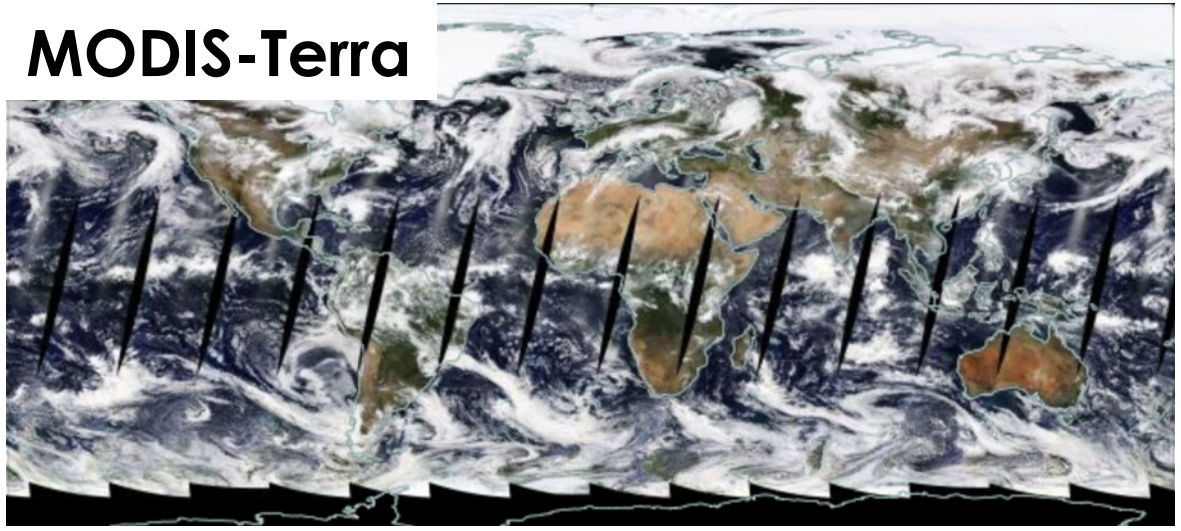
MODIS-Aqua



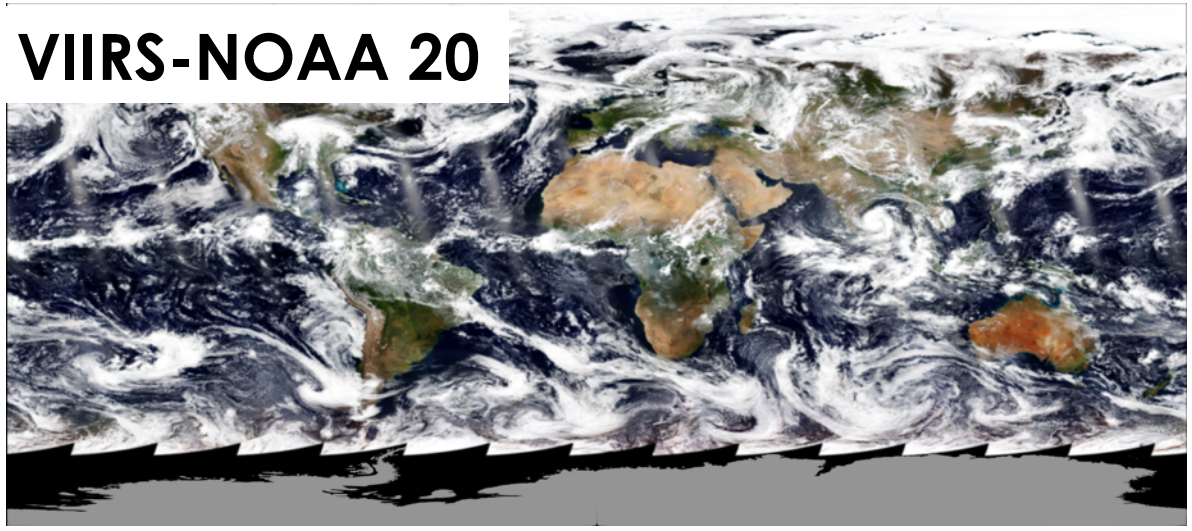
VIIRS-SNPP



MODIS-Terra



VIIRS-NOAA 20



Visible Infrared Imaging Radiometer (VIIRS)

A multi-wavelength imager like MODIS with similar wavelength bands

	MODIS	VIIRS-SNPP	VIIRS-N20
Orbit Altitude	690 km	824 km	824
Equator Crossing Time	13:30 LT	13:30 LT	12:40 LT
Swath	2,330 km	3,060 km	3,060 km
Pixel Nadir	0.5 km	0.75 km	0.75 km
Pixel Edge	2 km	1.5 km	1.5 km
Spectral Coverage	0.405 to 14.385 µm	0.412 to 12.1 µm	0.412 to 12.1 µm
Spectral Bands	36	22	22

True Color Images

True Color Image (or RGB)

A MODIS "true color image" uses visible wavelength bands 1, 4, 3.

R = 0.66 µm

G = 0.55 µm

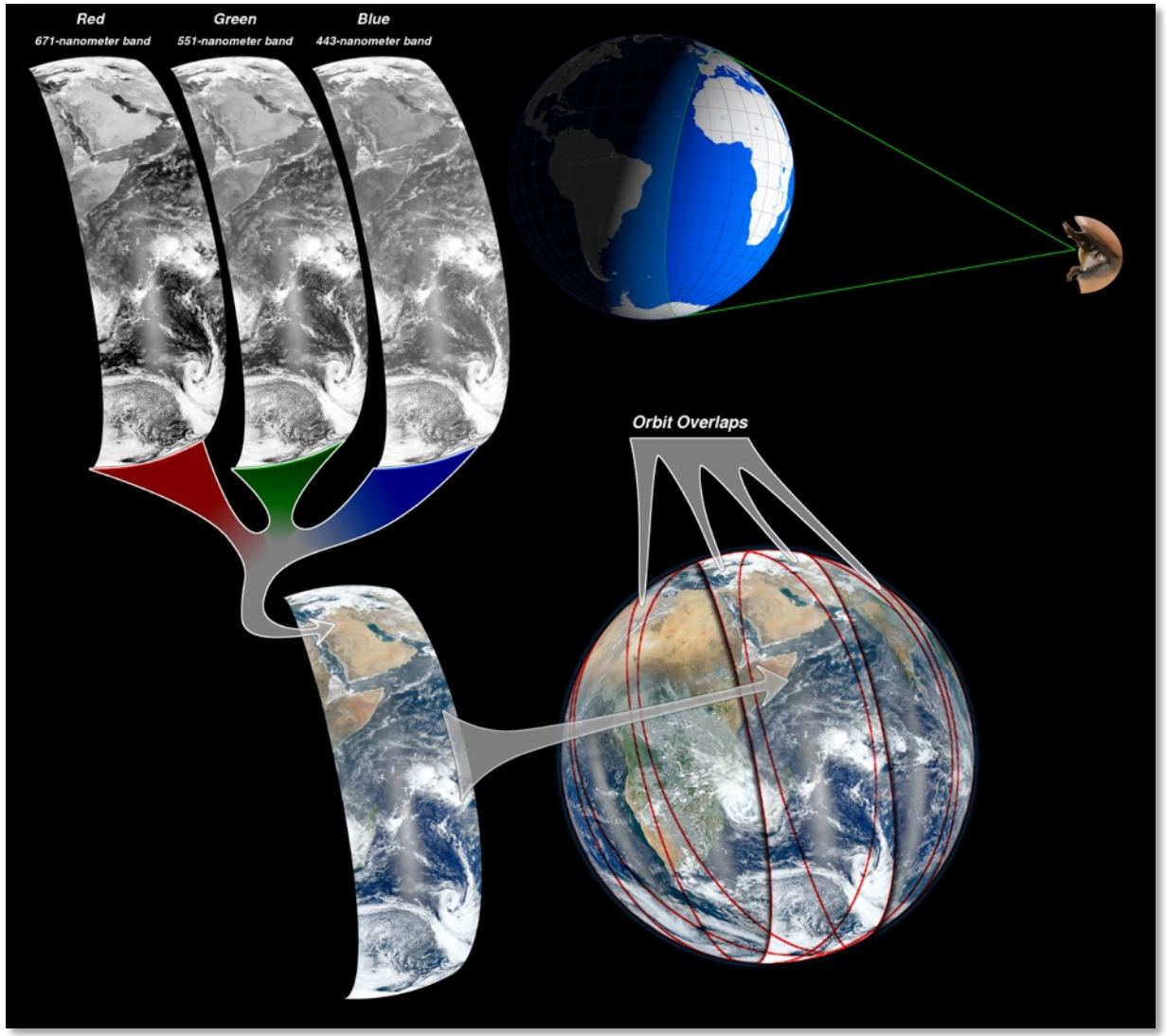
B = 0.47 µm

A VIIRS "true color image" uses visible wavelength bands I1, M4, M3.

R = 0.640 µm

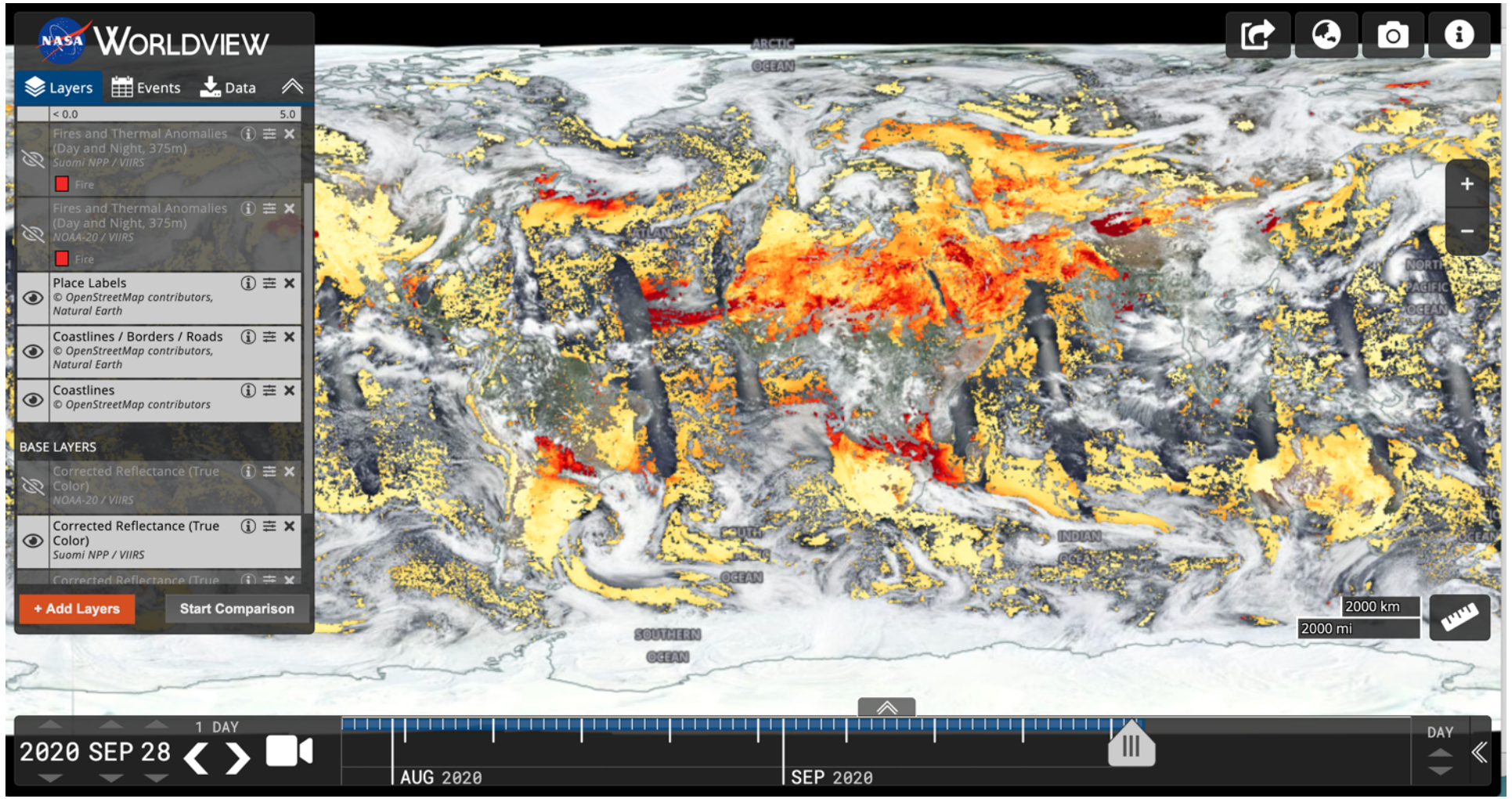
G = 0.555 µm

B = 0.488 µm



NASA Data Visualization – Level 1 & 2 – Near Real Time

https://worldview.earthdata.nasa.gov/



Air Quality-Relevant Observations

Data Products Relevant to Air Quality

	MODIS (T & A)	VIIRS-SNPP	VIIRS-N20
Aerosol Optical Depth	✓	✓	✓
Smoke Detection	✗	✓	✓
Dust Detection	✗	✓	✓
Fire Detection	✓	✓	✓
True Color Image	✓	✓	✓

NASA Aerosol Data

Aerosol Data - NASA Products

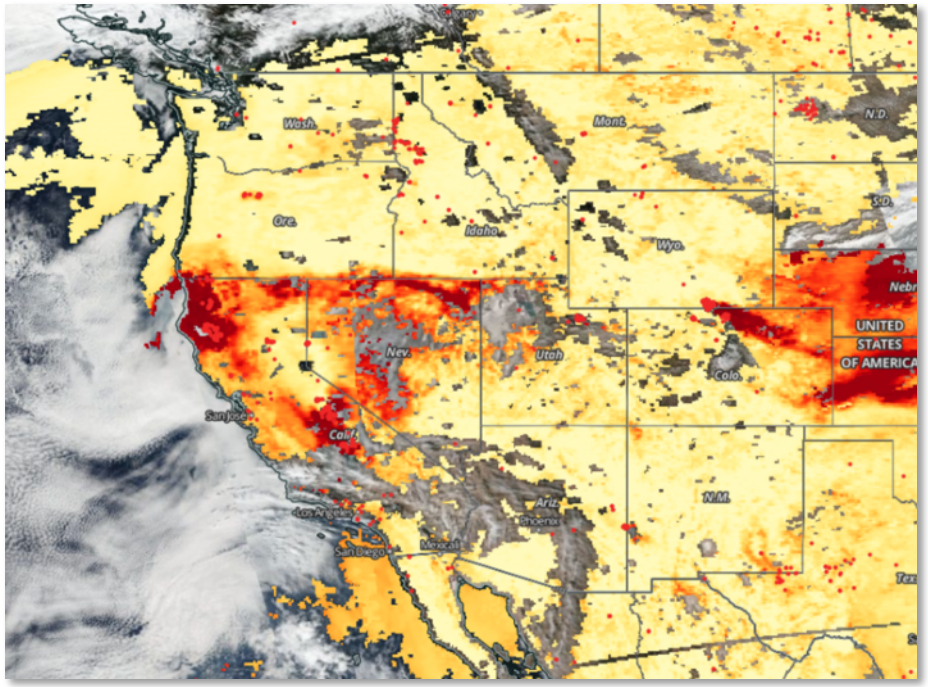
	MODIS (T & A)	VIIRS-SNPP	VIIRS-NOAA20
Data	AOD	AOD	x
Spatial Resolution	1, 3, 10 km	6 km	x
Global Coverage	1-2 days	Daily	Daily
Algorithm	DT, DB, MAIAC	DB, DT	X
Data Availability	2000 (2003) - current	2012- current	2017-current
Data Format	HDF	NetCDF	x

DT = Dark Target DB = Deep Blue
MAIAC = Multi-Angle Implementation of Atmospheric Correction

SNPP VIIRS – NASA Products

- Deep Blue (DB)
  - Spatial resolutions: 6 km (Level 2), 1 deg. (Level 3)
  - Products: AOD, Angstrom Exponent, Aerosol Type
  - Short name: AERDB_L2
  - https://deepblue.gsfc.nasa.gov/
- Dark Target (DT)
  - Spatial resolutions: 6 km (Level 2), 1 deg. (Level 3)
  - Products: AOD
  - Short name: AERDT_L2_VIIRS_SNPP
  - https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/products/AERDT_L2_VIIRS_SNPP/

October 05, 2020

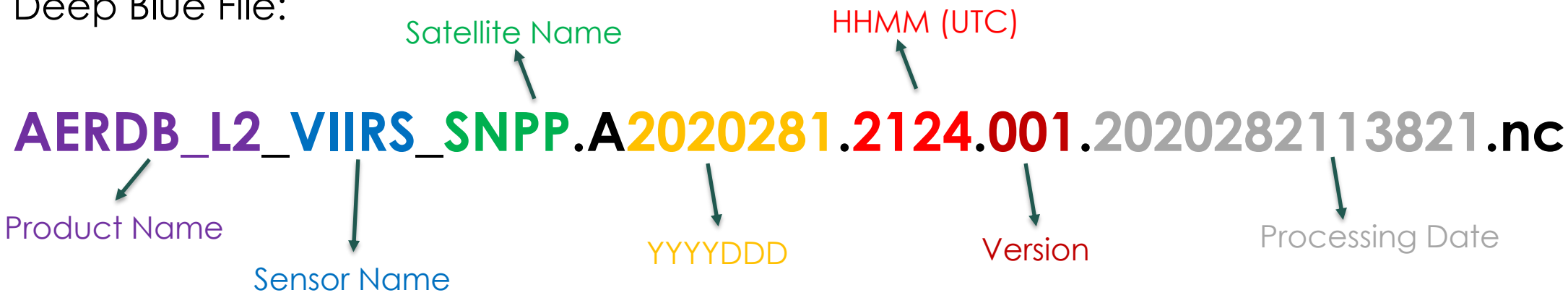


https://go.nasa.gov/2GzTOye

File Names

- Deep Blue and Dark Target data sets comes in two different files.

Deep Blue File:



AERDB_D3_VIIRS_SNPP.A2020251.001.2020255000324.nc
AERDB_M3_VIIRS_SNPP.A2020214.001.2020252000719.nc

- Dark Target File
  - AERDT_L2_VIIRS_SNPP.A2020251.2042.001.2020252071112.nc

VIIRS DB Aerosols

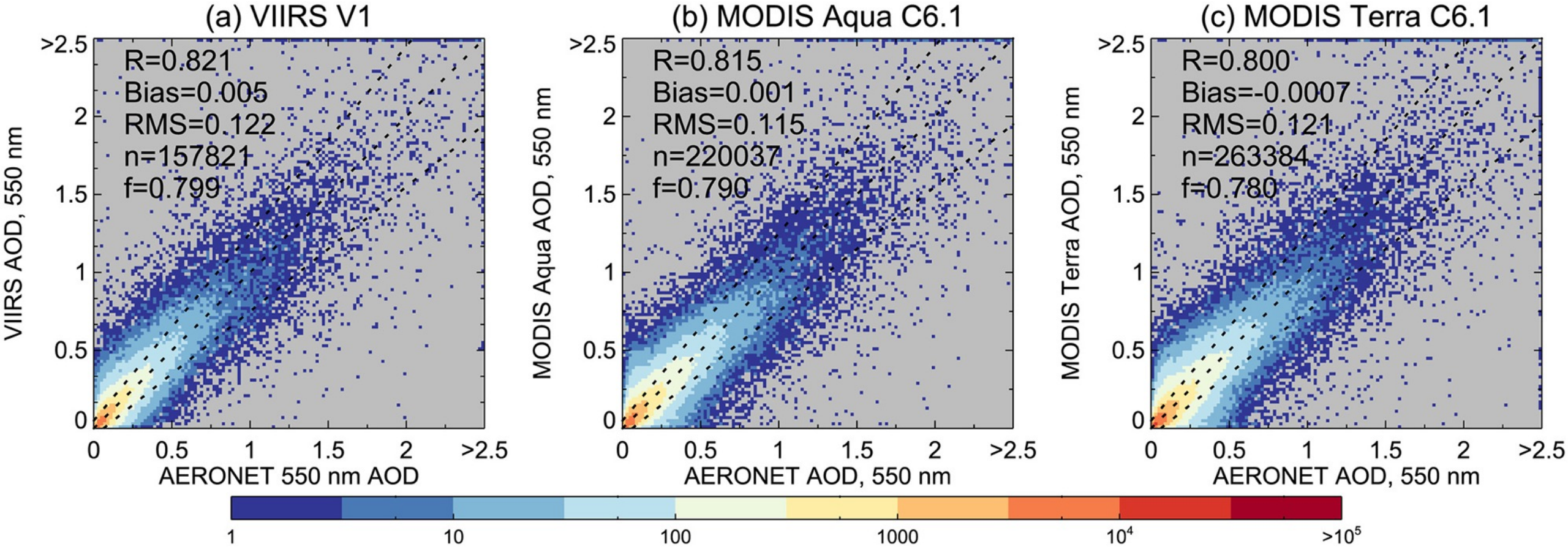
https://deepblue.gsfc.nasa.gov/data#data-viirs

- Level 2
  - 6-minute file
  - 6x6 km nadir resolution
- Level 3
  - Daily
  - Monthly
  - 1x1 degree
- NetCDF4

SDS name	Description
L2 files (AERDB_L2)	
Latitude	Central latitude of the retrieval pixel, degrees North.
Longitude	Central longitude of the retrieval pixel, degrees East.
Aerosol_Optical_Thickness_550_Land	The AOD at 550 nm over land.
Aerosol_Optical_Thickness_550_Land_Best_Estimate	As above, except only populated for those retrieval pixels passing quality assurance tests. This is the SDS that is it anticipated the majority of data users will use.
Aerosol_Optical_Thickness_550_Ocean	The AOD at 550 nm over ocean
Aerosol_Optical_Thickness_550_Ocean_Best_Estimate	As above, except only populated for those retrieval pixels passing quality assurance tests. This is the SDS that is it anticipated the majority of data users will use.
Aerosol_Optical_Thickness_550_Land_Ocean	The combined AOD at 550 nm, from the Deep Blue algorithm over land, and the SOAR algorithm over water.
Aerosol_Optical_Thickness_550_Land_Ocean_Best_Estimate	As above, except only populated for those retrieval pixels passing quality assurance tests. This is the SDS that is it anticipated the majority of data users will use.

Validation

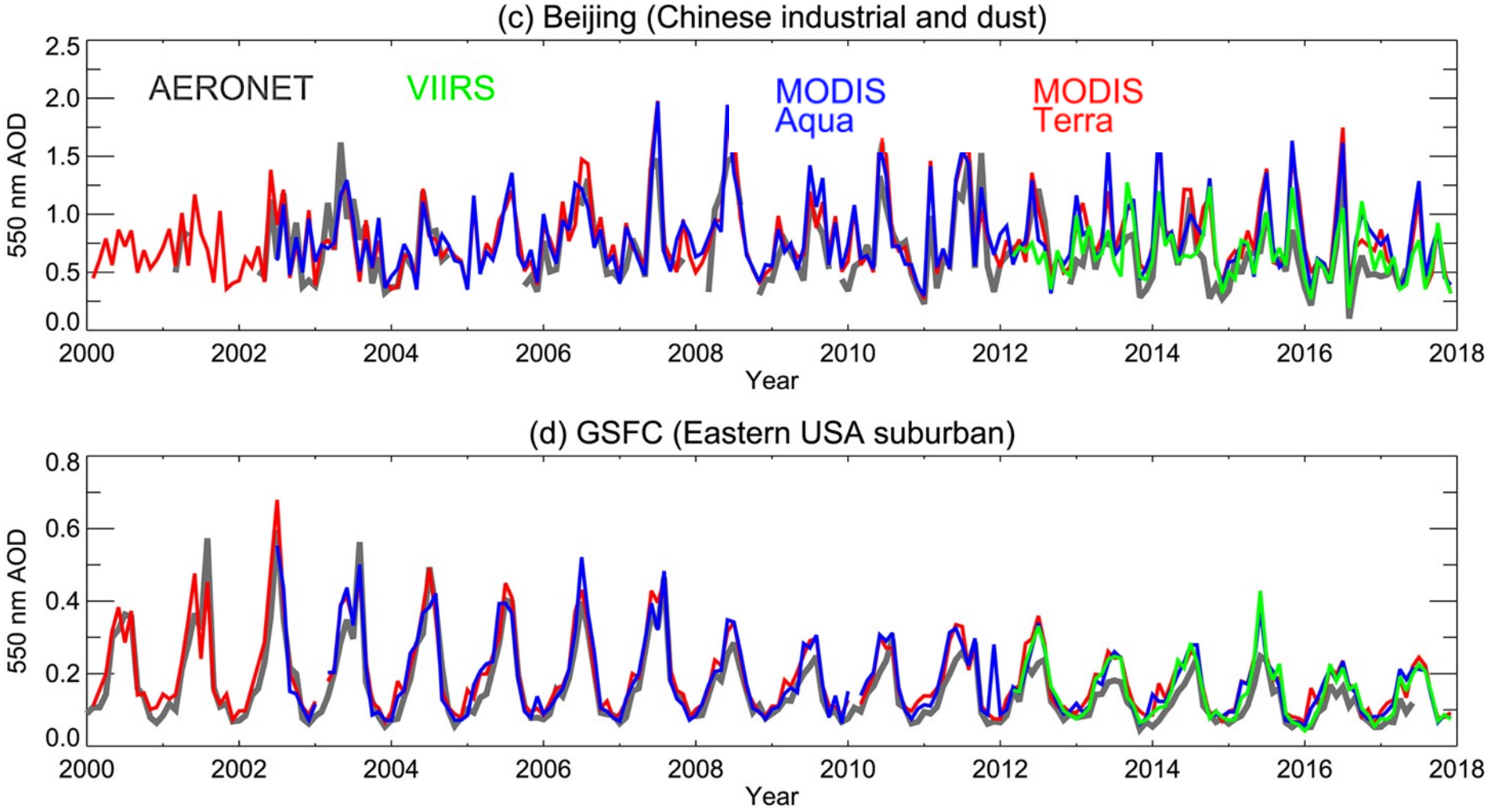
https://doi.org/10.1029/2018JD029688



Hsu et al., 2019

Validation – Temporal Consistency

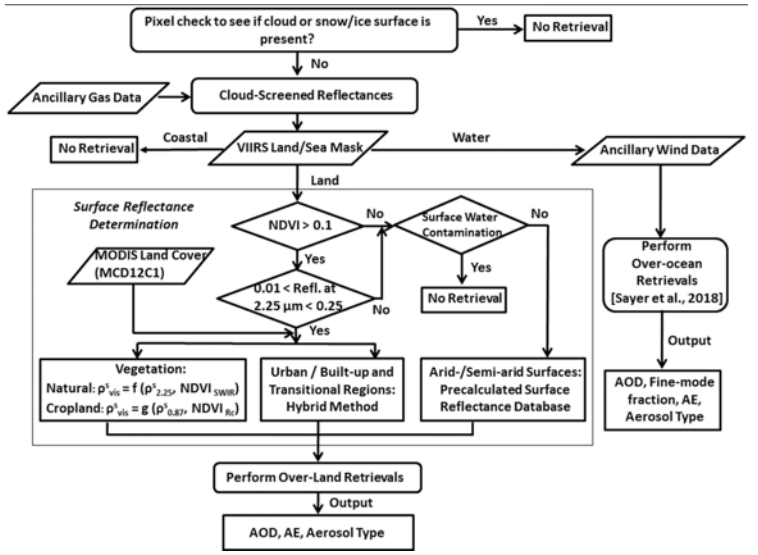
https://doi.org/10.1029/2018JD029688

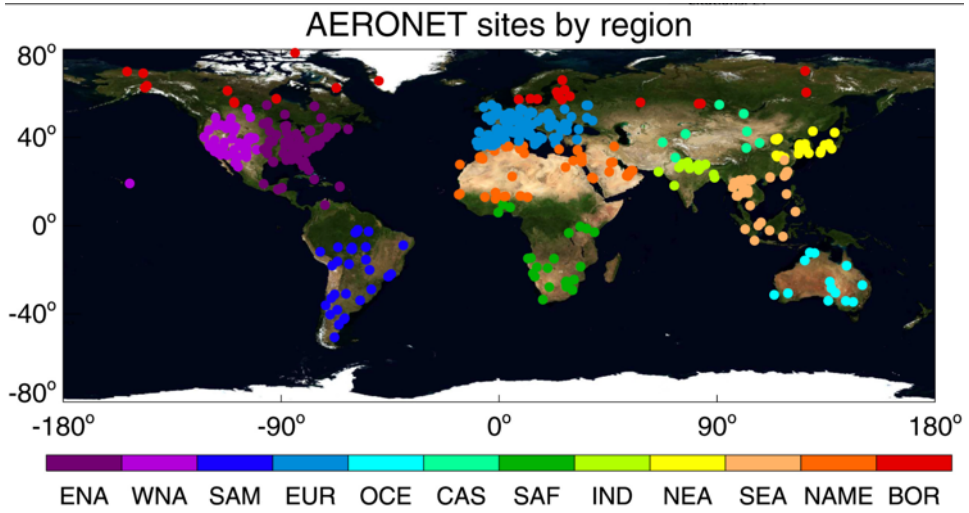


Hsu et al., 2019

VIIRS Deep Blue Aerosol Reference

- **Hsu, N. C.**, **J. Lee**, **A. M. Sayer**, et al. 2019. "VIIRS Deep Blue Aerosol Products Over Land: Extending the EOS Long-Term Aerosol Data Records." *Journal of Geophysical Research: Atmospheres* **124** (**7**): 4026-4053 [10.1029/2018jd029688]
- **Sayer, A. M.**, **N. C. Hsu**, **J. Lee**, **W. V. Kim**, and S. T. Dutcher. 2019. "Validation, Stability, and Consistency of MODIS Collection 6.1 and VIIRS Version 1 Deep Blue Aerosol Data Over Land." *Journal of Geophysical Research: Atmospheres* **124** (**8**): 4658-4688 [10.1029/2018jd029598]

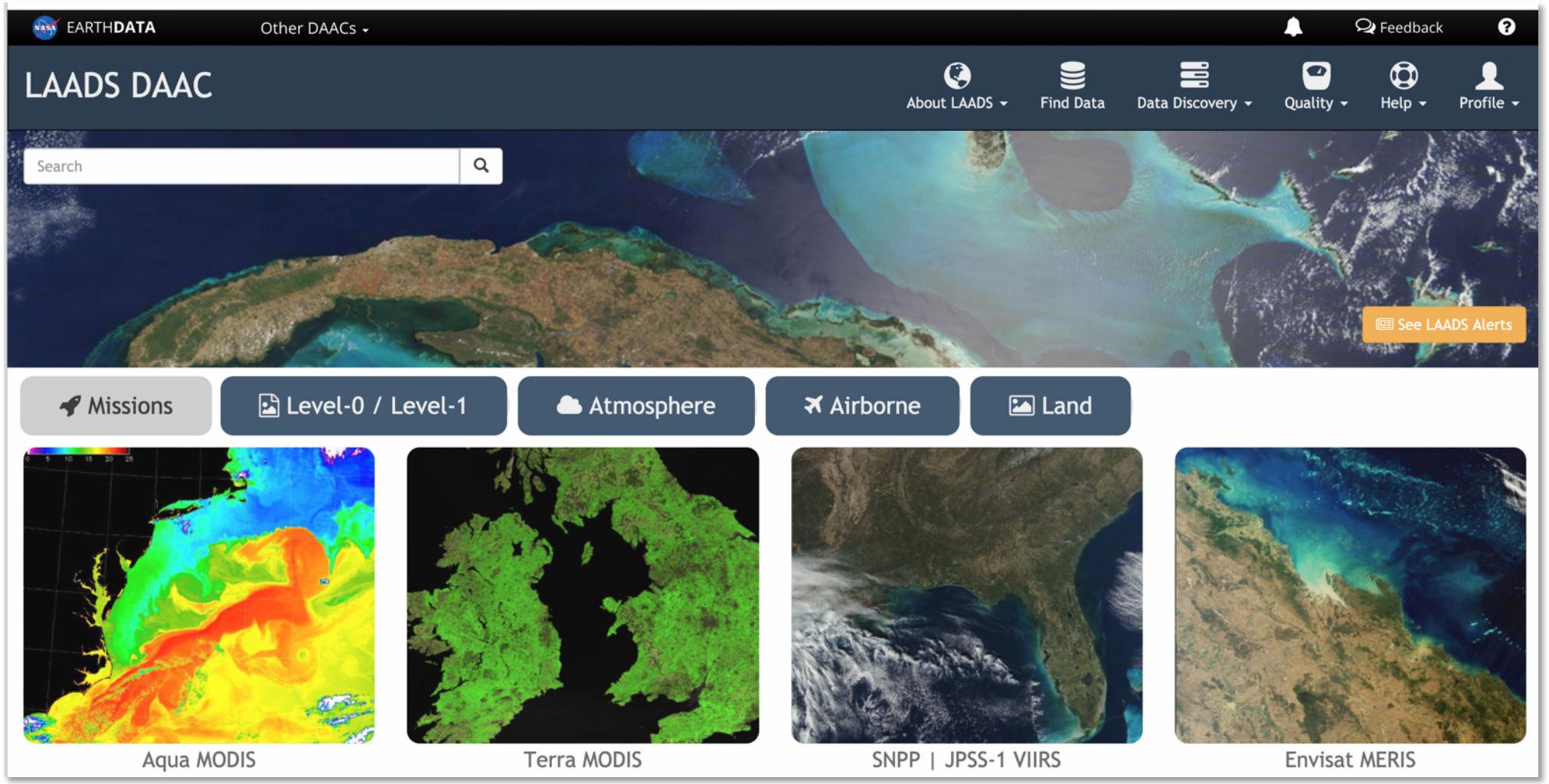




How to Access the Data

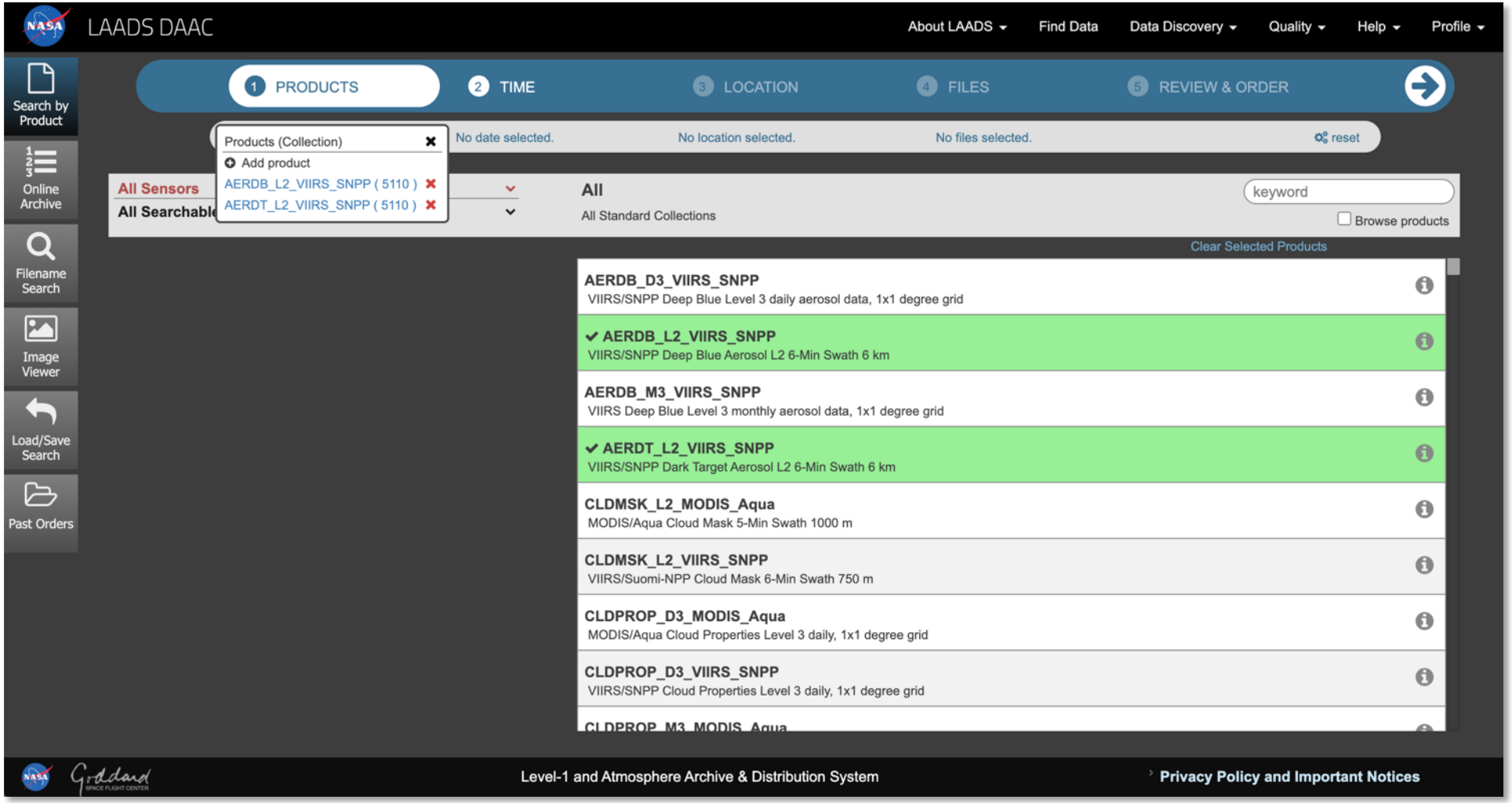
NASA Aerosol Data Download – Level 1, 2, 3 - Historical

https://ladsweb.modaps.eosdis.nasa.gov/



NASA Aerosol Data Download

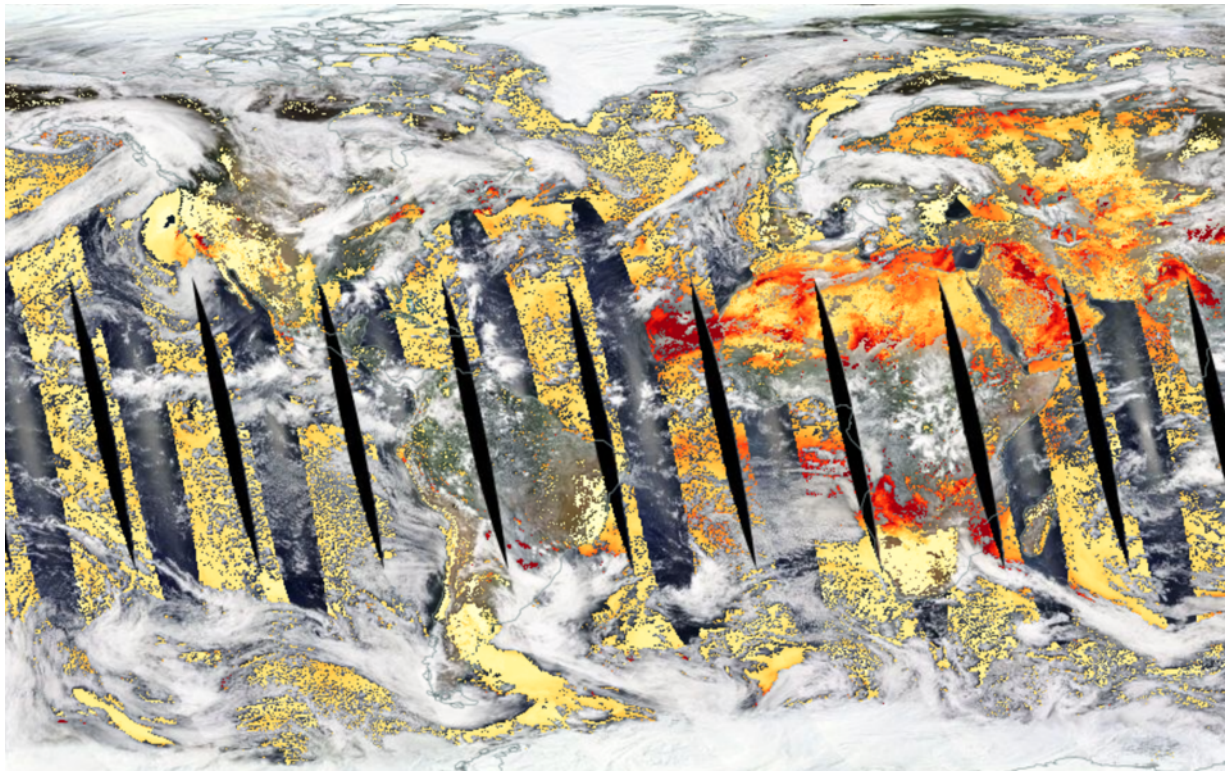
https://ladsweb.modaps.eosdis.nasa.gov/



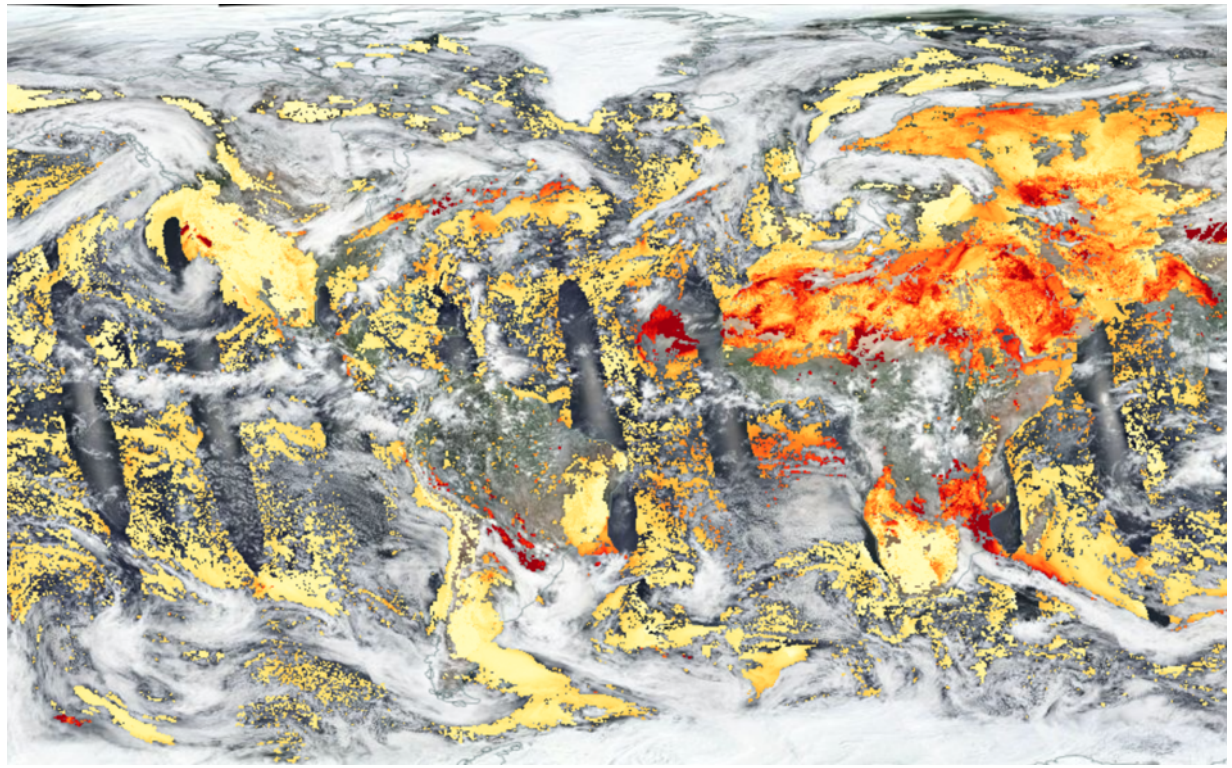
AOD Example

MODIS vs. VIIRS – September 27, 2020

https://go.nasa.gov/3nlrOyz

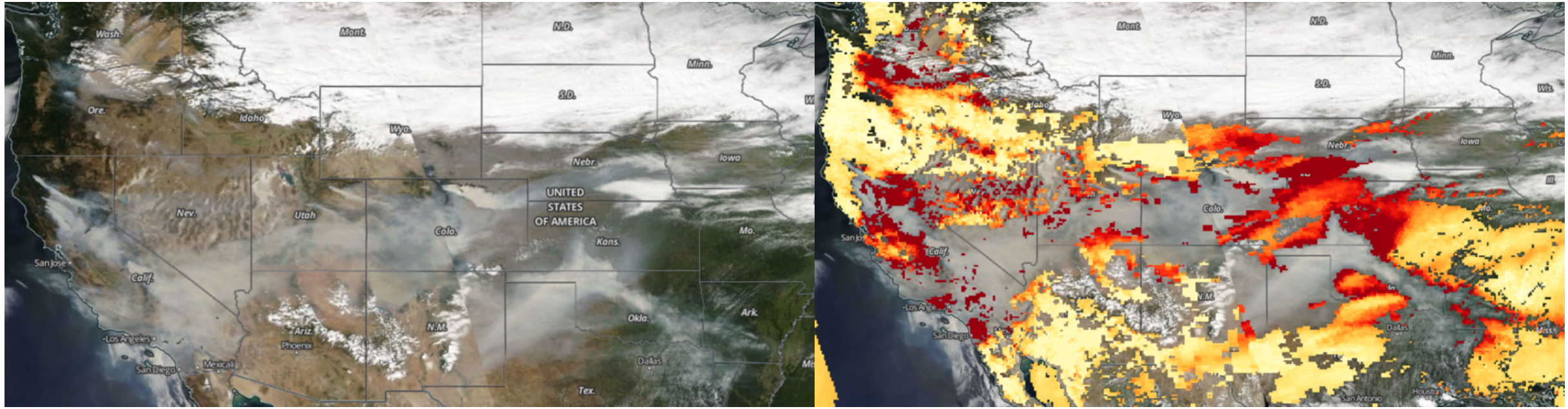


MODIS-Aqua (DB)

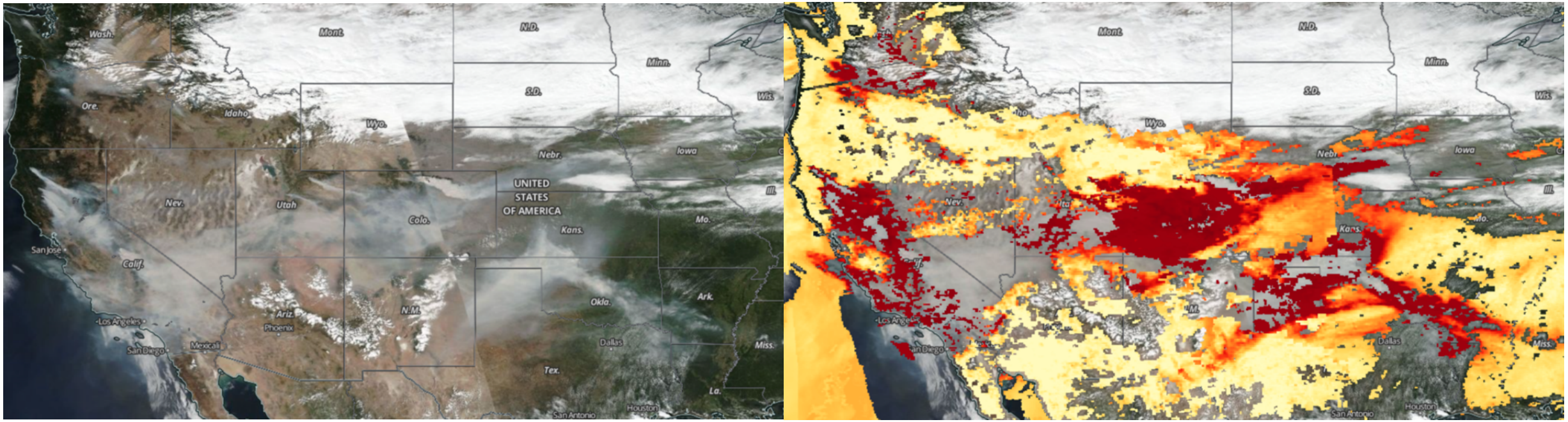


VIIRS-SNPP (DB)

Application – MODIS- Aqua (Sep 7th, 2020)



Application – VIIRS-SNPP (Sep 7th, 2020)



NOAA Aerosol Data

Aerosol Data - NOAA Products

	MODIS (T & A)	VIIRS-SNPP	VIIRS-N20
Data	X	AOD Smoke, Dust Mask	AOD Smoke, Dust Mask
Spatial Resolution	X	750m, 6 km	750m, 6 km
Global Coverage	X	Daily	Daily
Algorithm	X	NOAA	NOAA
Data Availability	X	2012- current	2017-current

Aerosol Data - NOAA Products

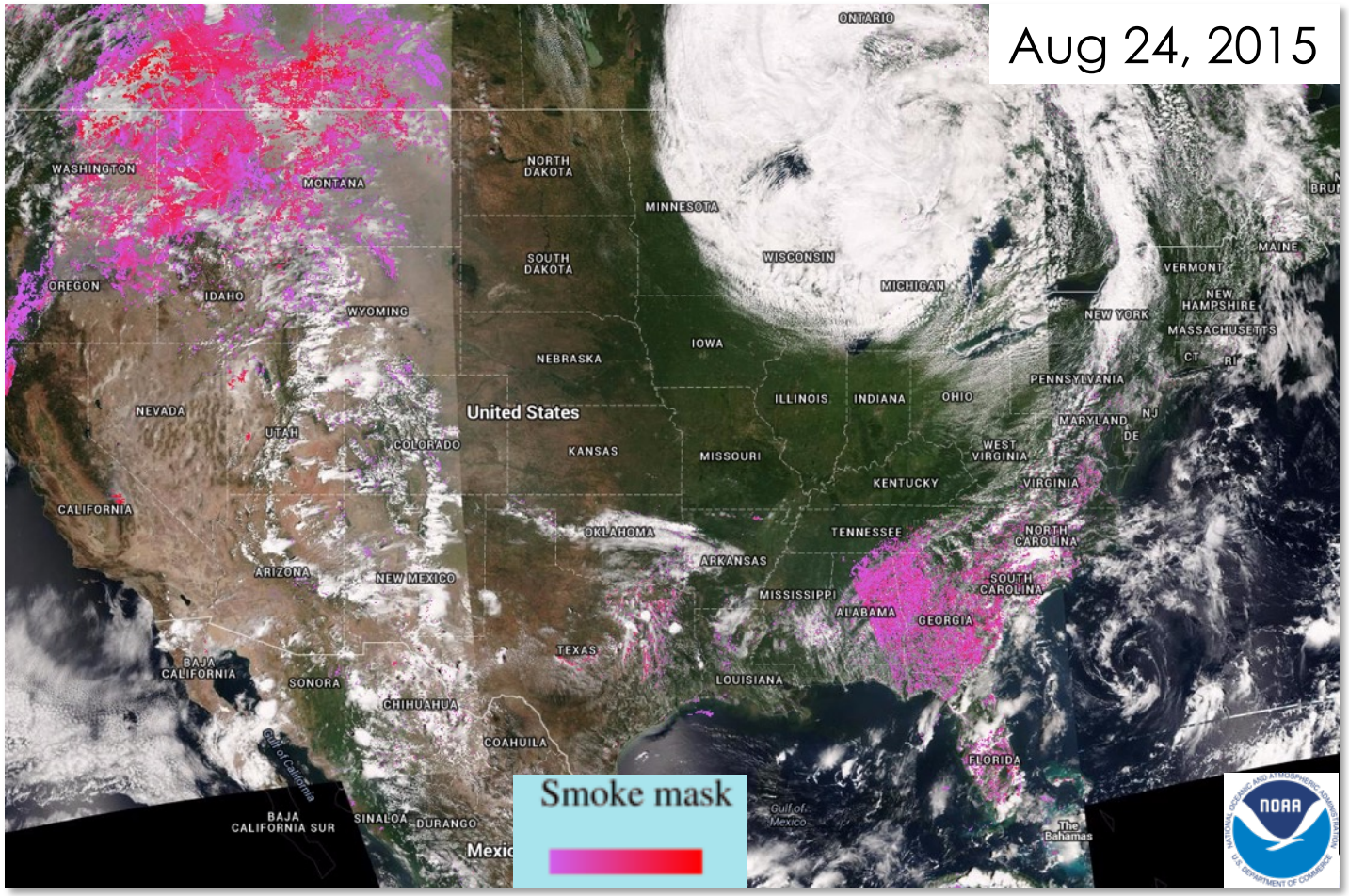
Filenames

NOAA has two aerosol products (datasets):

- Aerosol Optical Depth
  - JRR-AOD_v2r3_**j01**_s202009280811382_e202009280813027_c202009280832280.nc
  - JRR-AOD_v2r3_**npp**_s202009280709032_e202009280710274_c202009280749220.nc

- Aerosol Detection Product (ADP)
  - JRR-ADP_v2r1_npp_s201911010742162_e201911010743404_c201911010834210.nc
  - 6 Type Flags: (1-presence; 0-absence) *1. Volcanic ash flag 2. Dust flag 3. Smoke flag 4. Nuc (none/unknown/clear) 5. Cloud* flag 6. *Snow/ice flag*
  - Dust/Smoke Aerosol Index Value
  - Quality Flags (low, medium, and high confidence for each type)

VIIRS Smoke Mask - NOAA

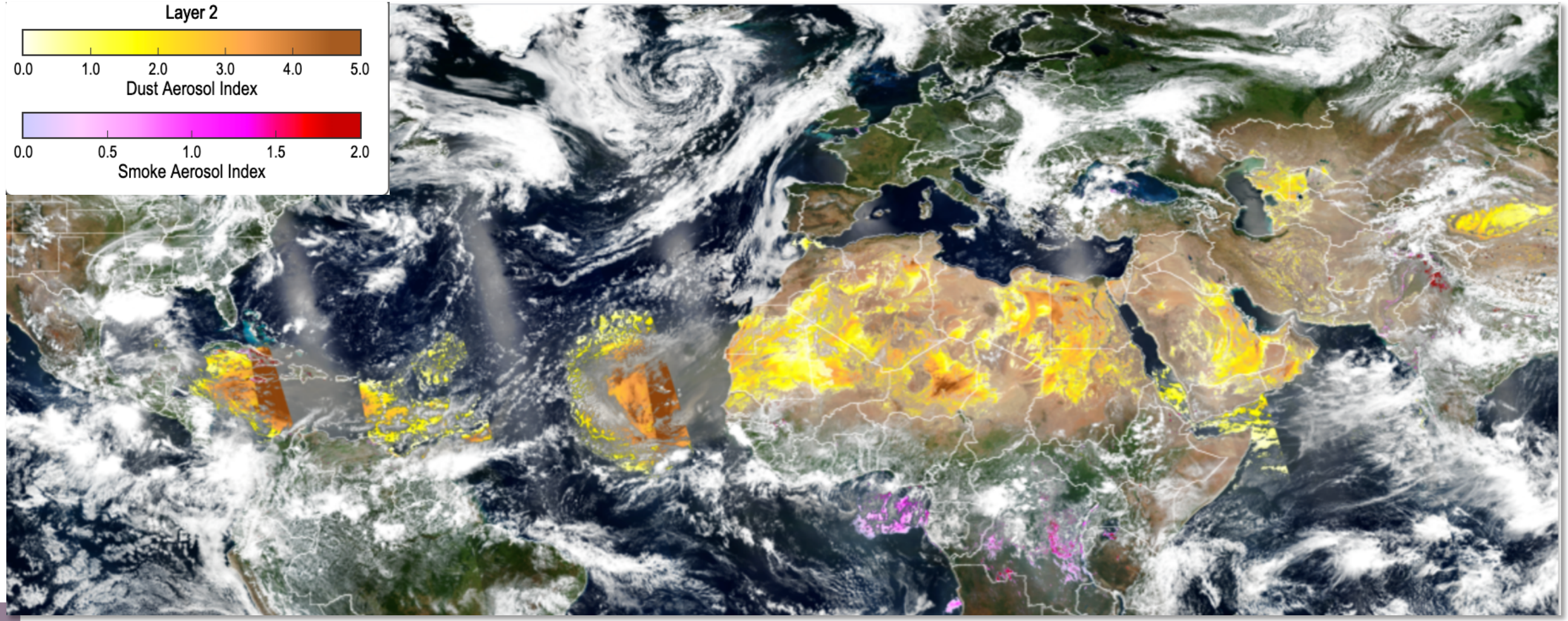


- Smoke Mask: Qualitative indicator of smoke
- Derived using spectral and spatial threshold tests based on VIIRS measurements in visible and IR
- **Useful for identifying local and transported smoke plumes**
- Colored shades of pink
- Light Pink: Thin Smoke
- Bright Pink/Magenta: Thick Smoke

Side Courtesy of Shobha Kondragunta

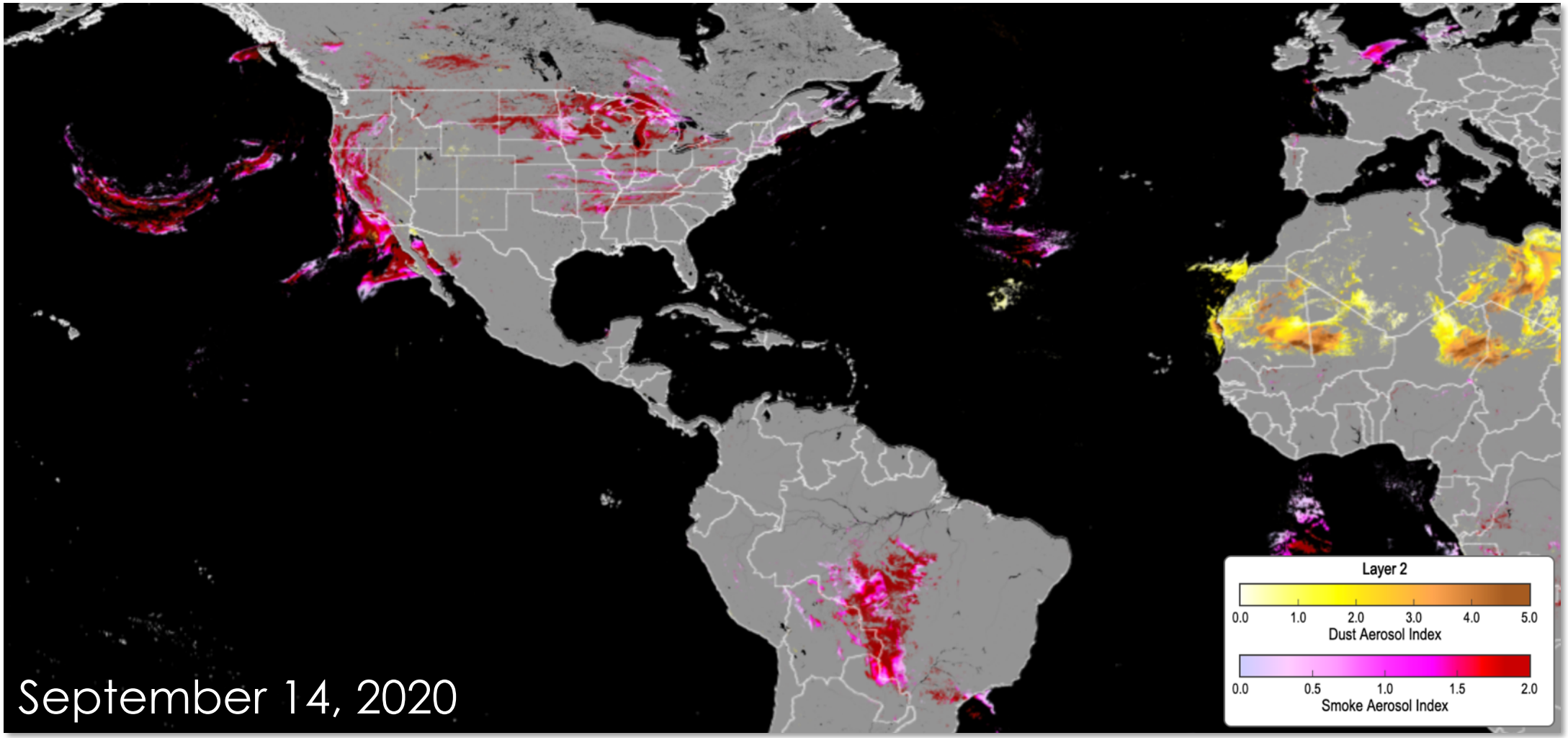
Dust Mask – Saharan Dust Transport of Summer 2020

https://www.star.nesdis.noaa.gov/jpss/mapper



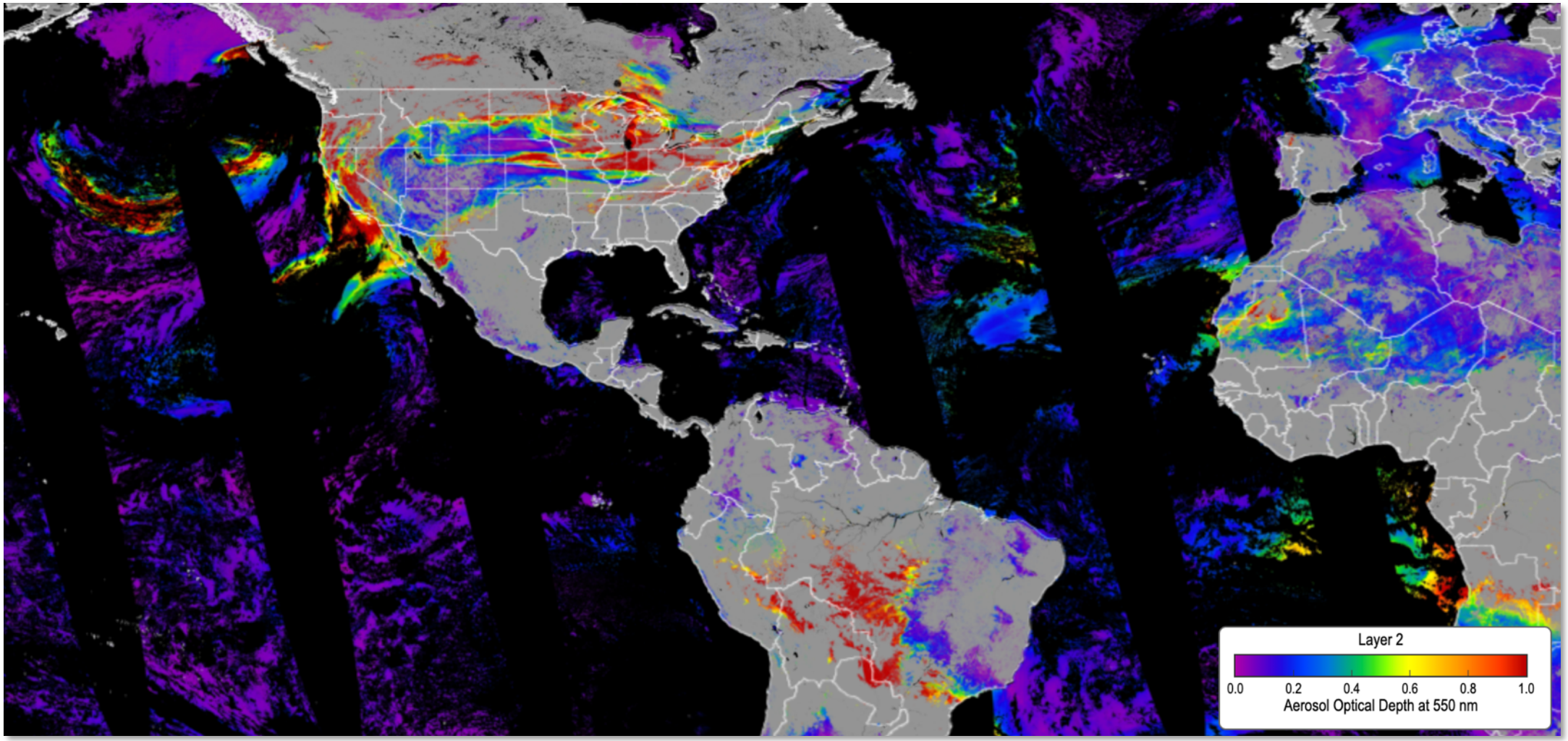
Smoke from Western US Fires – Smoke Mask

https://www.star.nesdis.noaa.gov/jpss/mapper

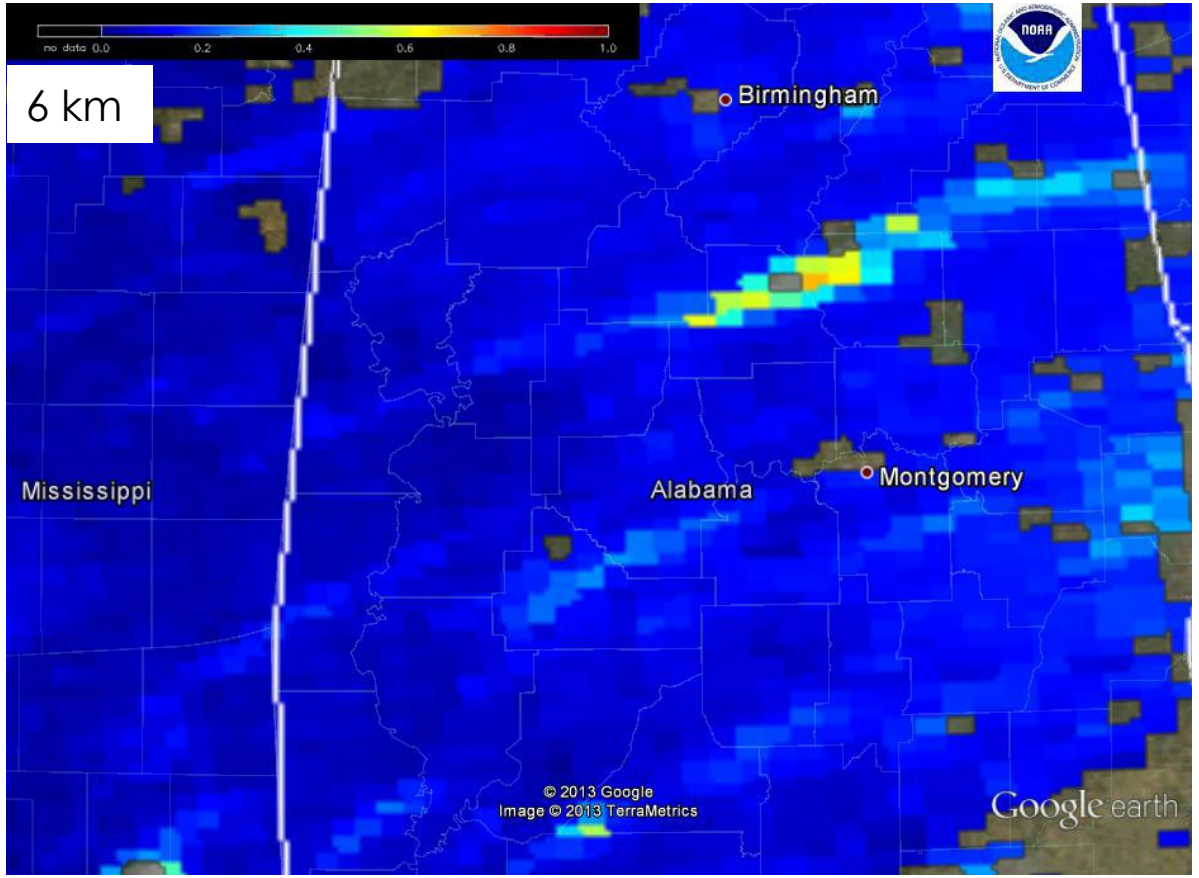


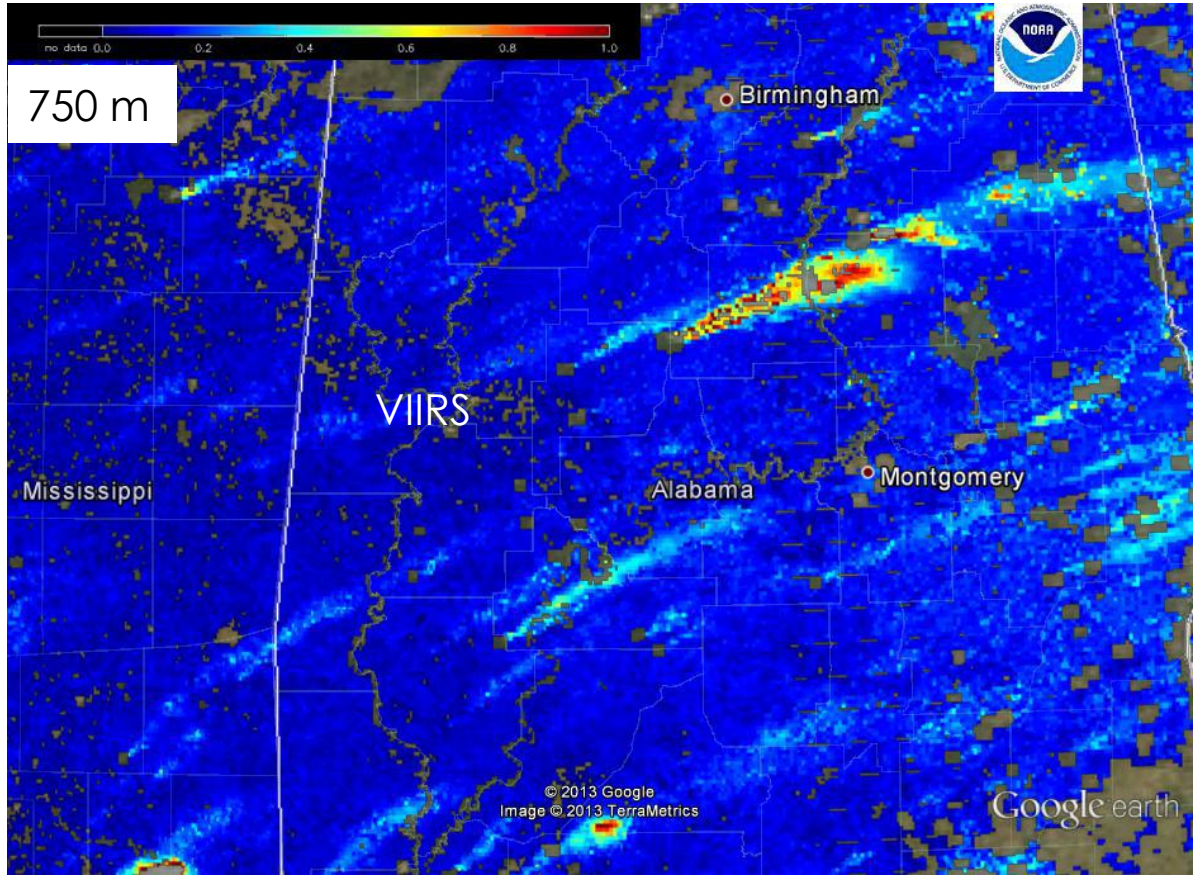
Smoke from Western US Fires – Aerosol Optical Depth

https://www.star.nesdis.noaa.gov/jpss/mapper



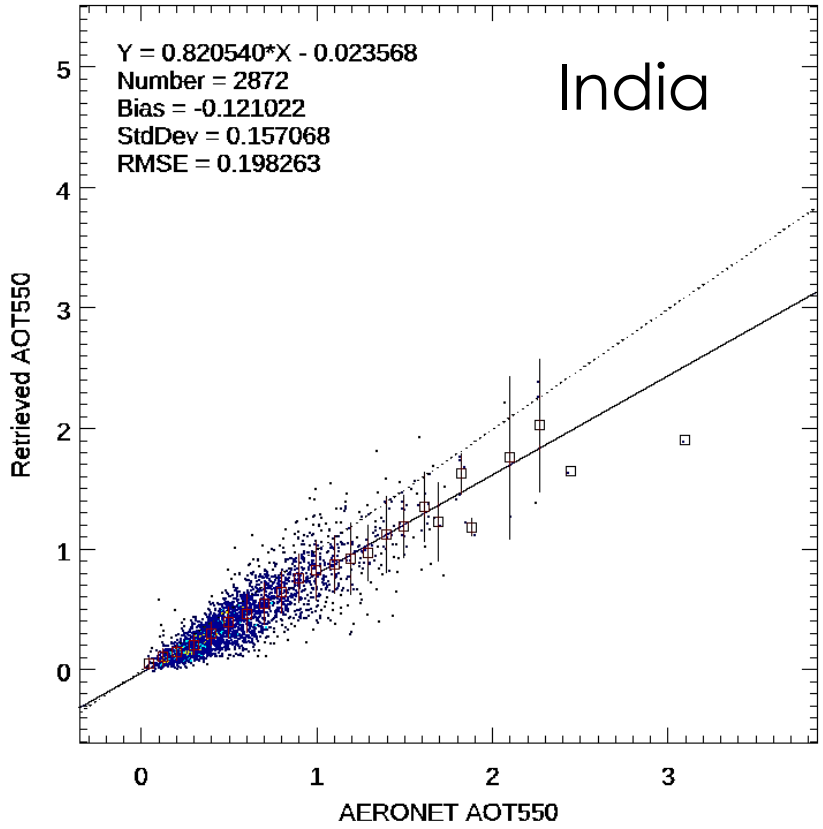
Low vs. High Resolution AOD Data

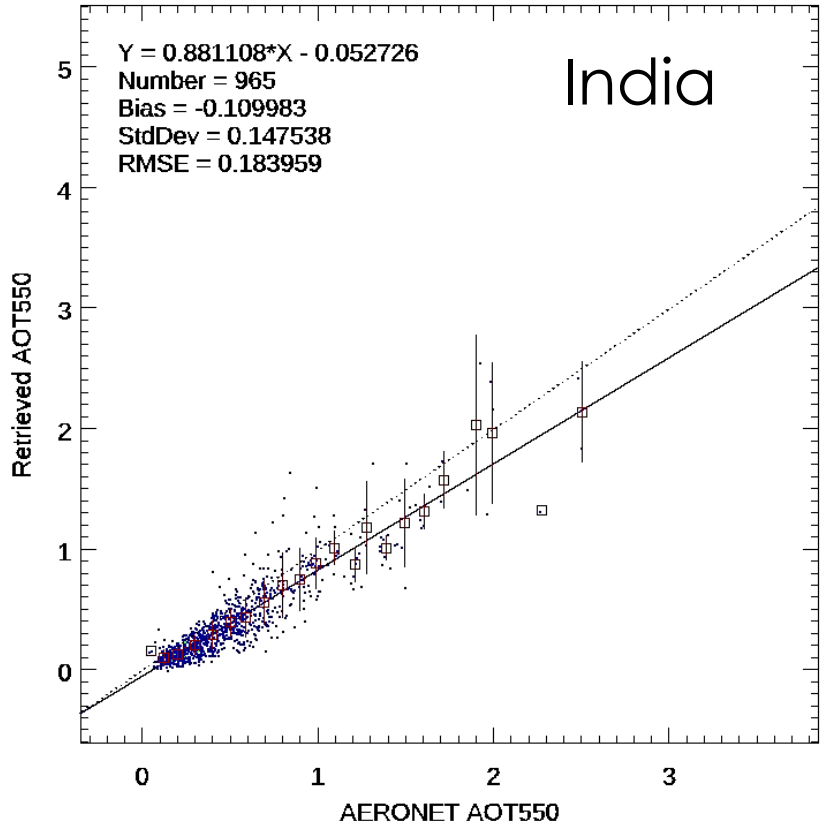




Side Courtesy of Shobha Kondragunta

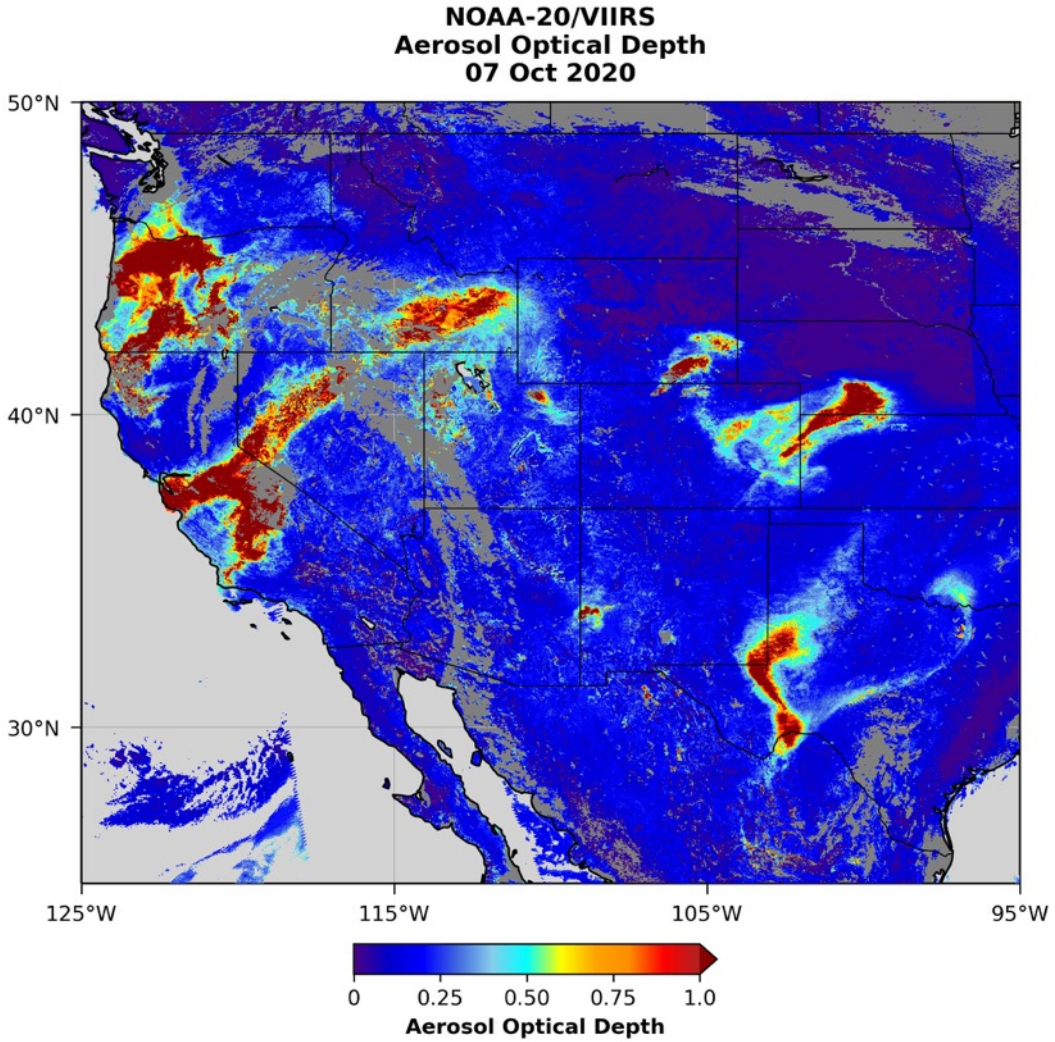
Validation

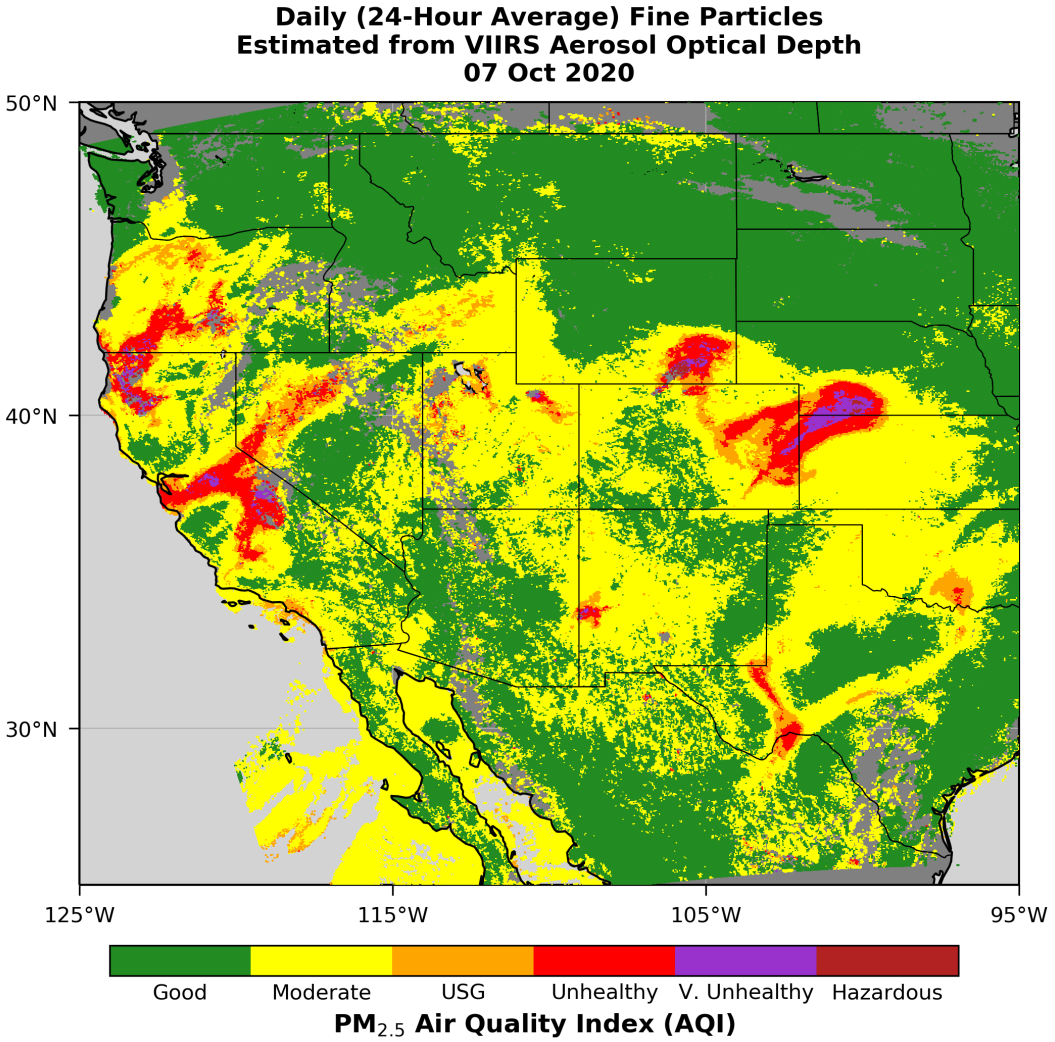




Slide by Hongqing Liu (NOAA)

Aerosol Optical Depth – Application

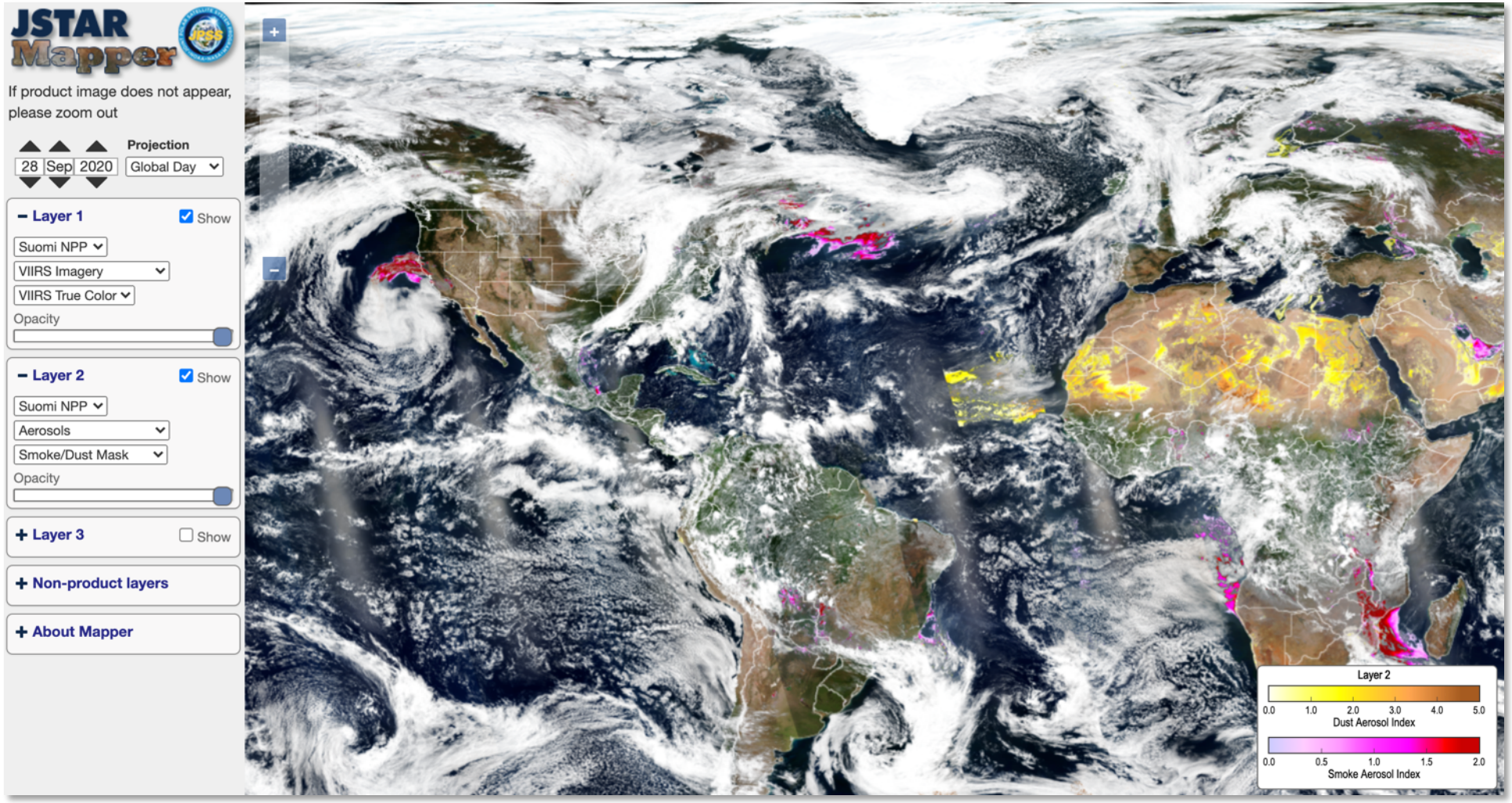




https://twitter.com/AerosolWatch/status/1314208278222569472

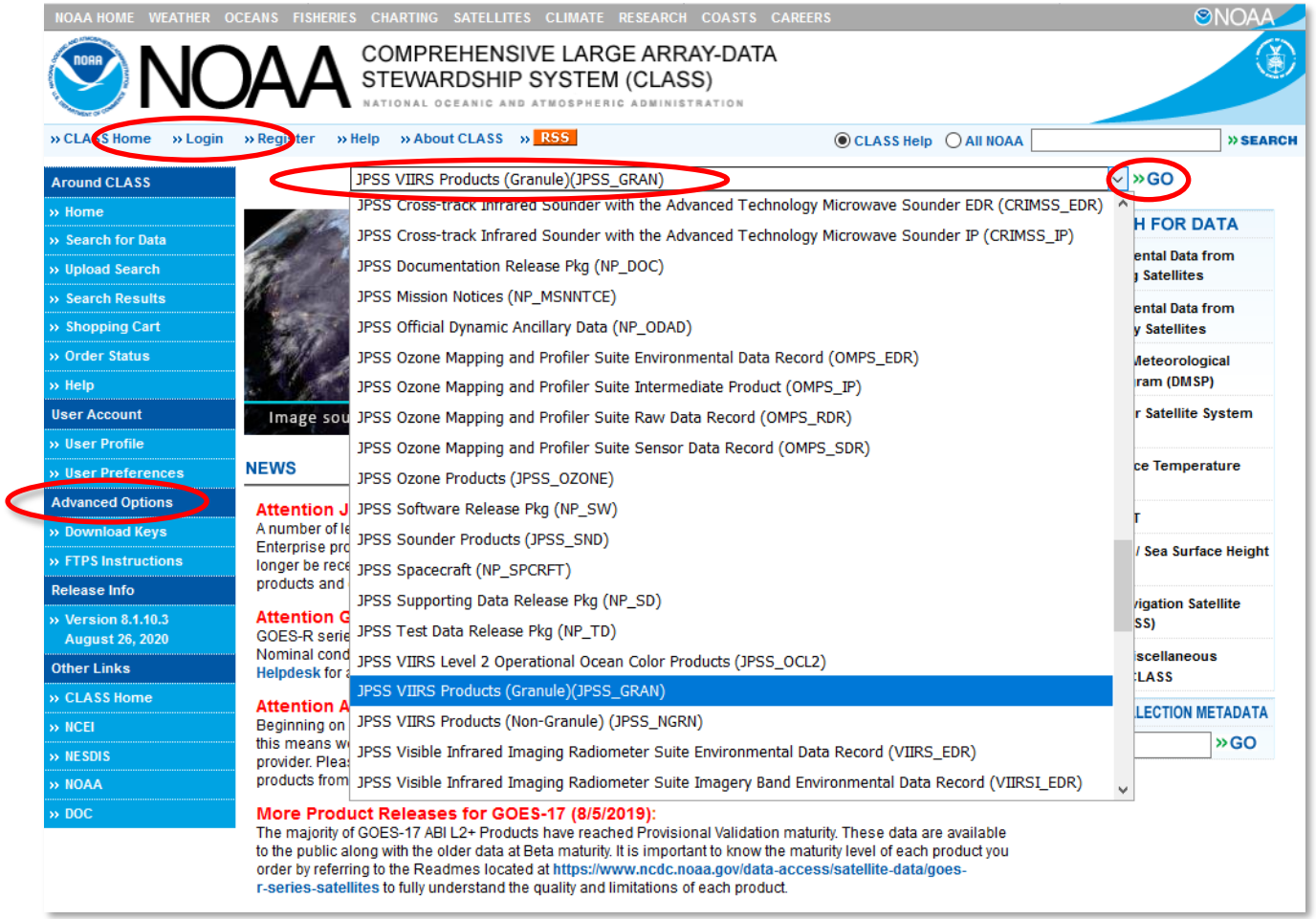
NOAA Data Visualization

https://www.star.nesdis.noaa.gov/jpss/mapper/



NOAA Data Download

- NOAA CLASS
  - https://www.avl.class.noaa.gov/saa/products/welcome
- Register; Login; User Preference
- Select JPSS VIIRS Products (Granule)(JPSS_GRAN) from the drop-down list at the top of the CLASS page and click GO



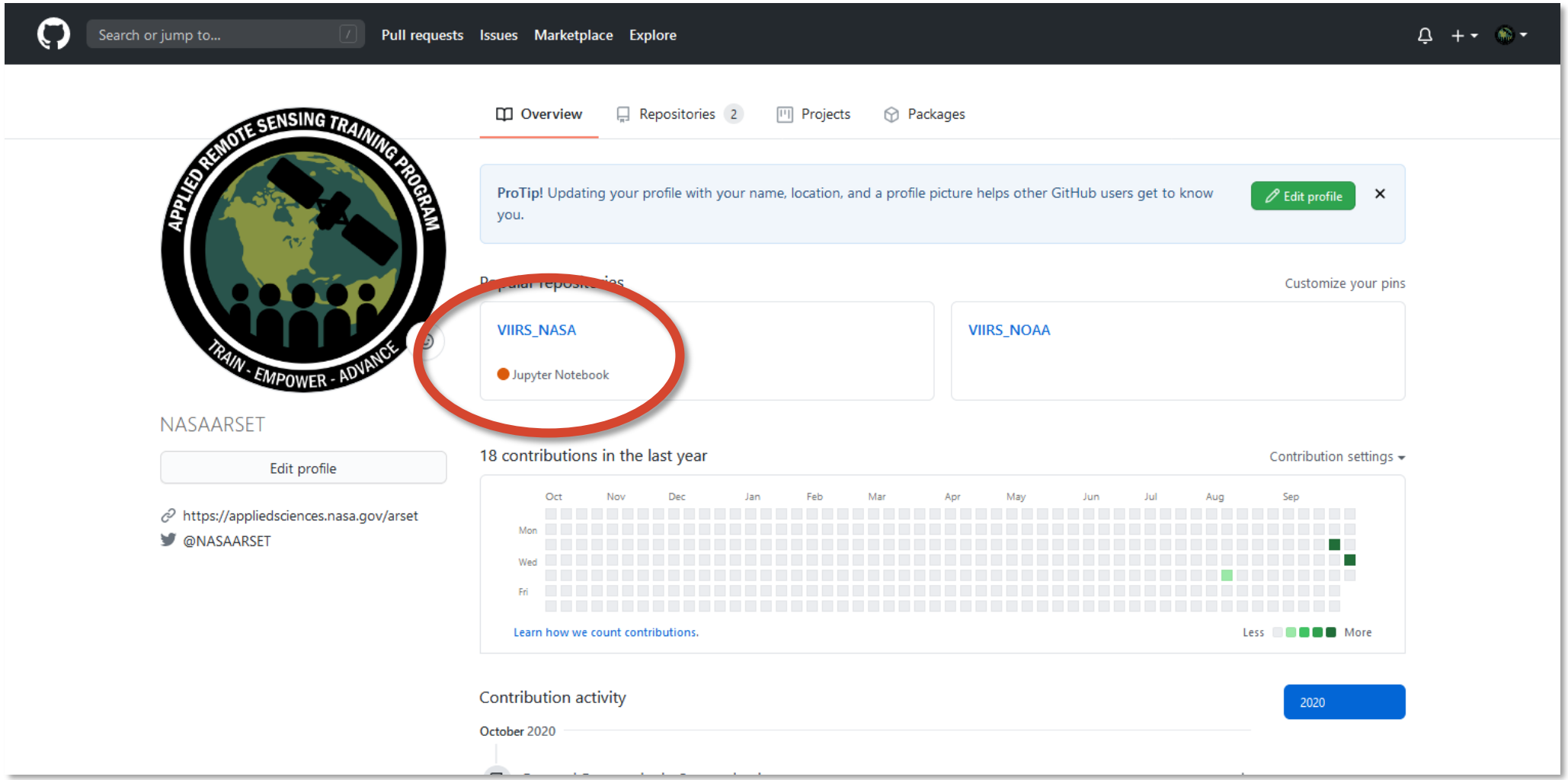
More Details – Click Here

Data Reading, Mapping, and Extracting – Jupyter Notebook Demonstration

Download Jupyter Notebooks and Save to Your Computer

Download Jupyter Notebooks and Save to Your Computer

Step 1: Go to https://github.com/NASAARSET/, click on VIIRS_NASA



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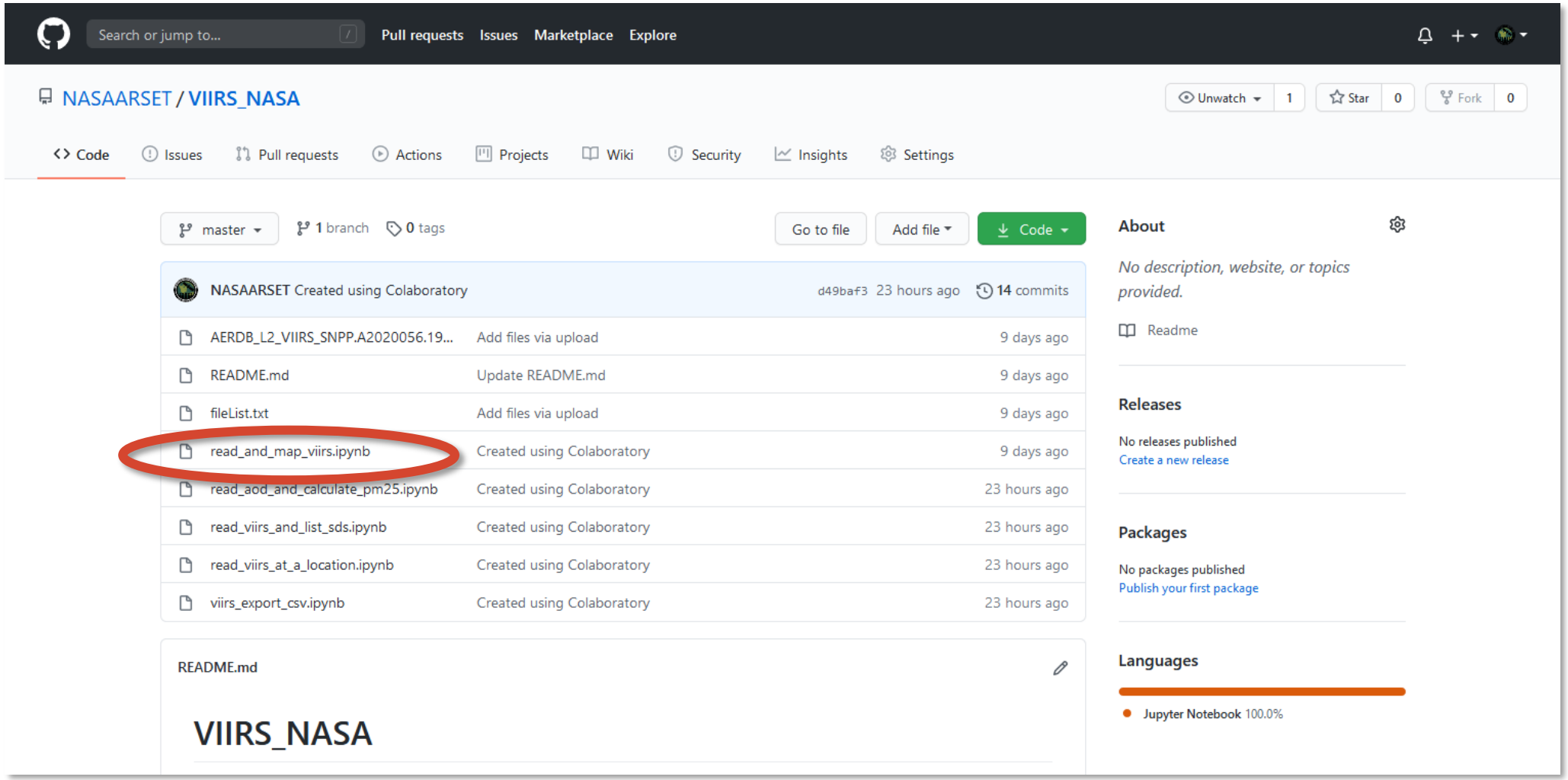
Step 2: Click on read_and_map_viirs.ipynb



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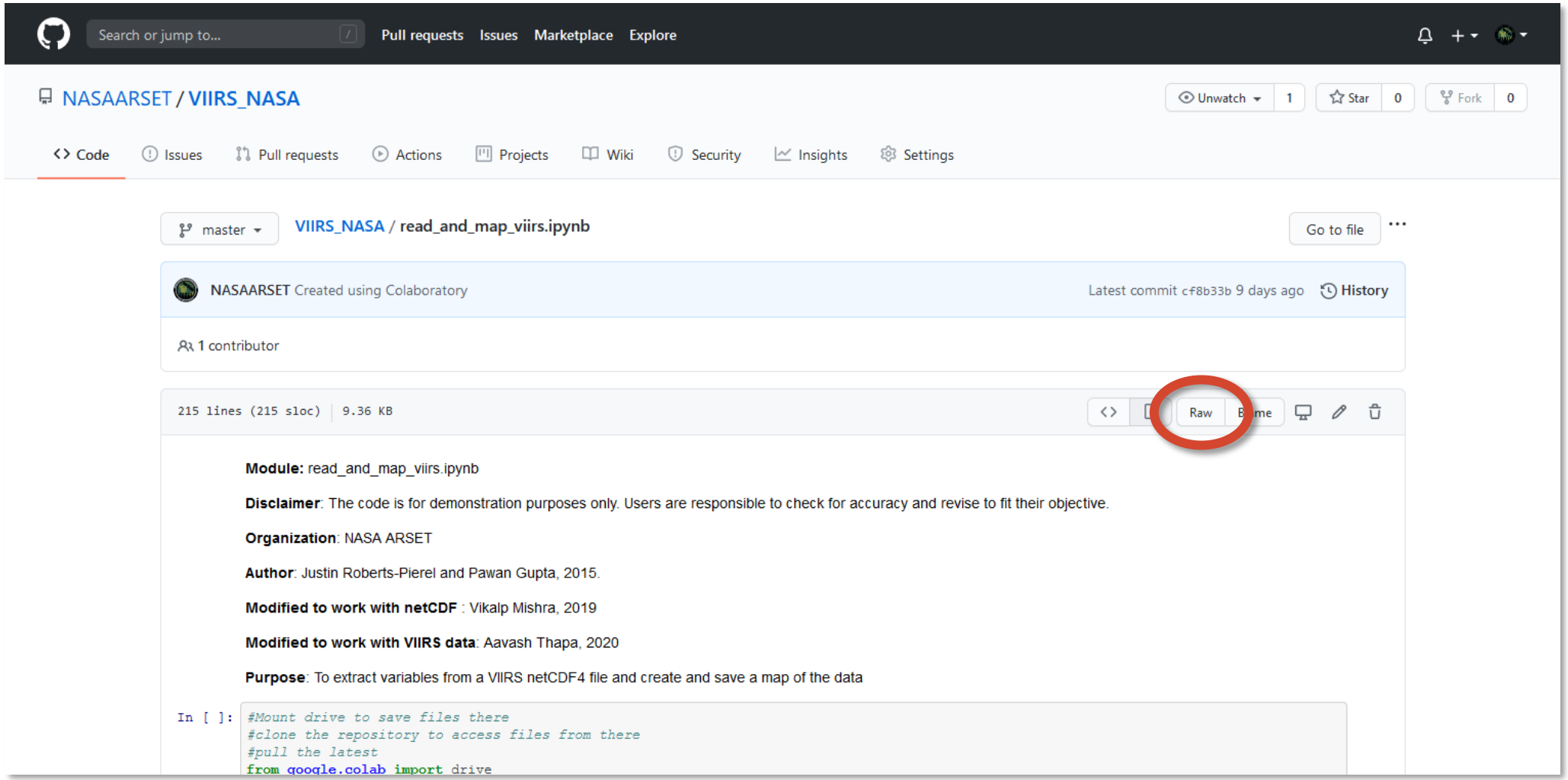
Step 3: Above the code, click 'Raw'. This will display the raw code.



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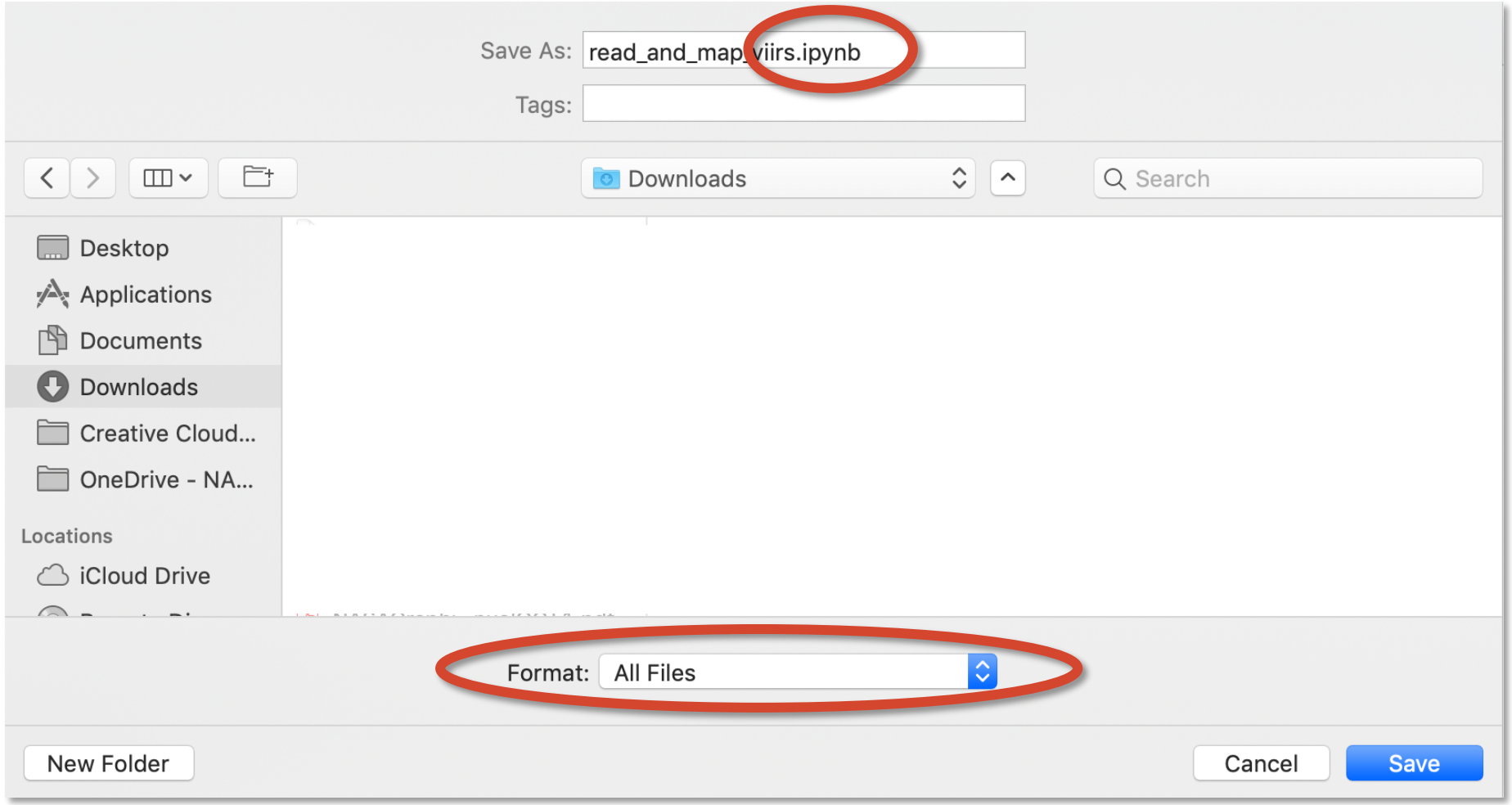
Step 4: Click Ctrl+S to save to your computer as a .ipynb file.


```
{
  "nbformat": 4,
  "nbformat_minor": 0,
  "metadata": {
    "colab": {
      "name": "read_and_map_viirs.ipynb",
      "provenance": [],
      "collapsed_sections": []
    },
    "kernelspec": {
      "name": "python3",
      "display_name": "Python 3"
    }
  },
  "cells": [
    {
      "cell_type": "markdown",
      "metadata": {
        "id": "im8zRbMslQLL"
      },
      "source": [
        "**Module:** read_and_map_viirs.ipynb\n",
        "\n",
        "**Disclaimer**: The code is for demonstration purposes only. Users are responsible to check for accuracy and revise to fit their objective.\n",
        "\n",
        "**Organization**: NASA ARSET\n",
        "\n",
        "**Author**: Justin Roberts-Pierel and Pawan Gupta, 2015.\n",
        "\n",
        "**Modified to work with netCDF** : Vikalp Mishra, 2019 \n",
        "\n",
        "**Modified to work with VIIRS data**: Aavash Thapa, 2020\n",
        "\n",
        "**Purpose**: To extract variables from a VIIRS netCDF4 file and create and save a map of the data"
      ]
    },
    {
      "cell_type": "code",
      "metadata": {
        "id": "Y7U02gkECz6c"
      },
      "source": [
        "#Mount drive to save files there\n",
        "#clone the repository to access files from there\n",
        "#pull the latest\n",
        "from google.colab import drive\n",
        "drive.mount('/content/drive', force_remount=True)\n",
        "! git clone https://github.com/NASAARSET/VIIRS_NASA.git\n",
        "! git -C VIIRS_NASA/ pull"
      ]
```

Download Jupyter Notebooks and Save to Your Computer

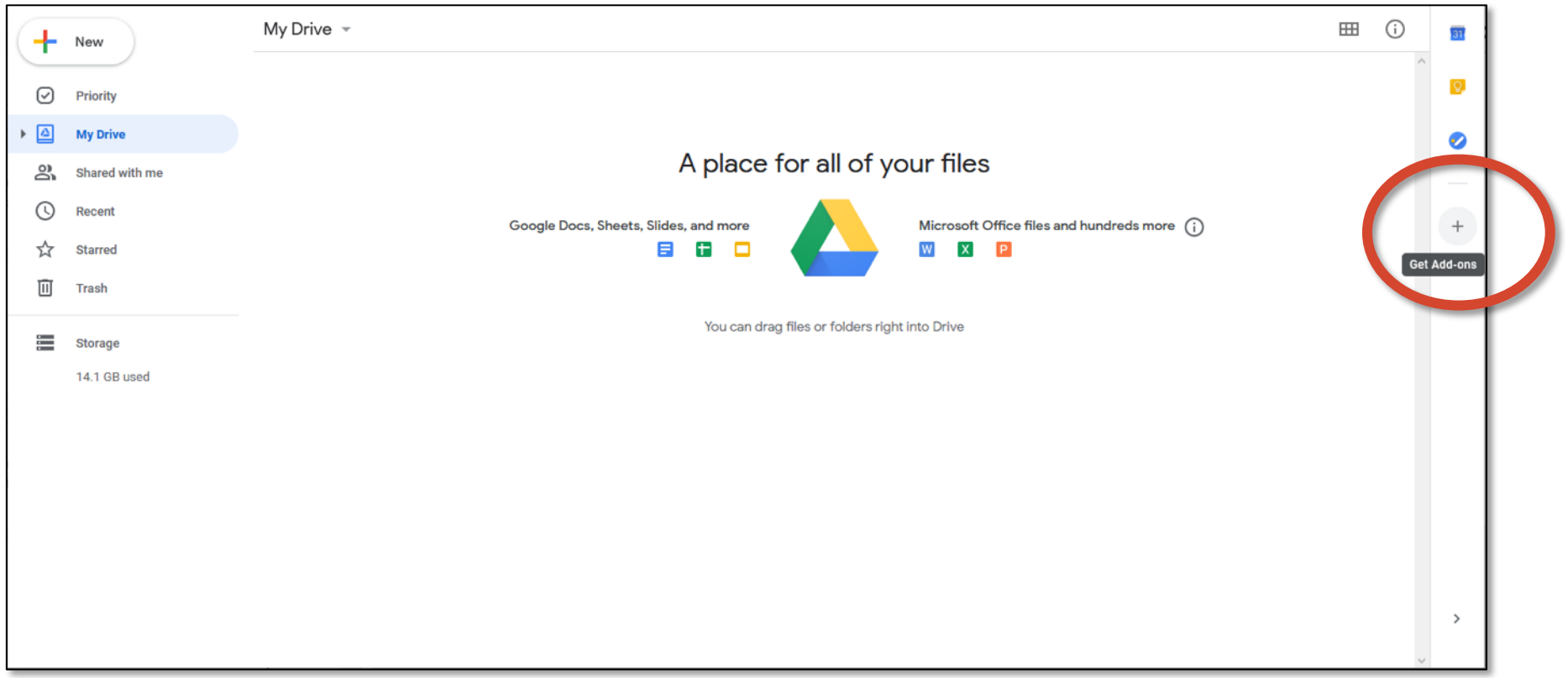
Make sure you save the file with the extension ".ipynb"!



Install Google Colaboratory Add-on and Add Notebooks to ‘Colab Notebooks’ folder on Google Drive

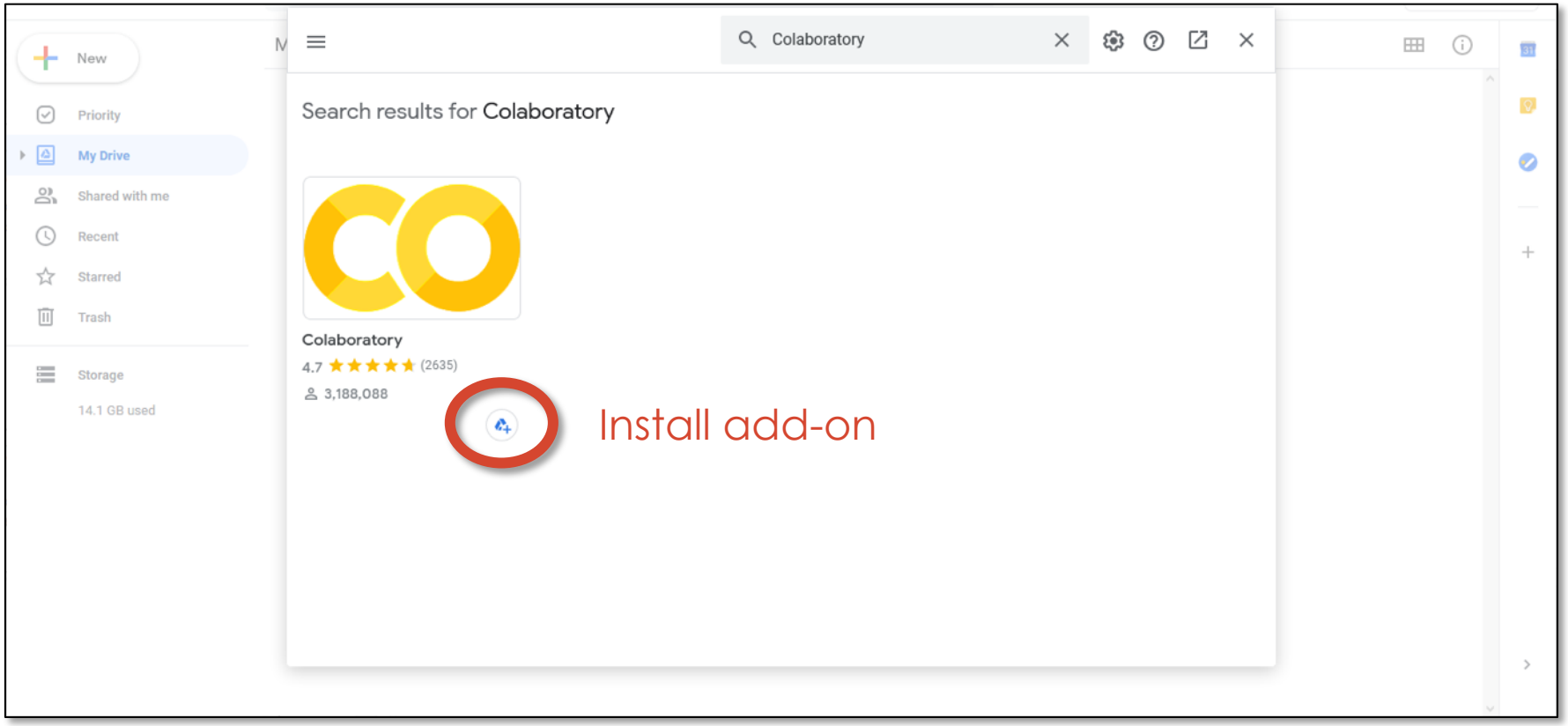
Add Your Notebooks to Google Drive

Step 1: Go to drive.google.com and click the + on the right to add add-ons.



Add Your Notebooks to Google Drive

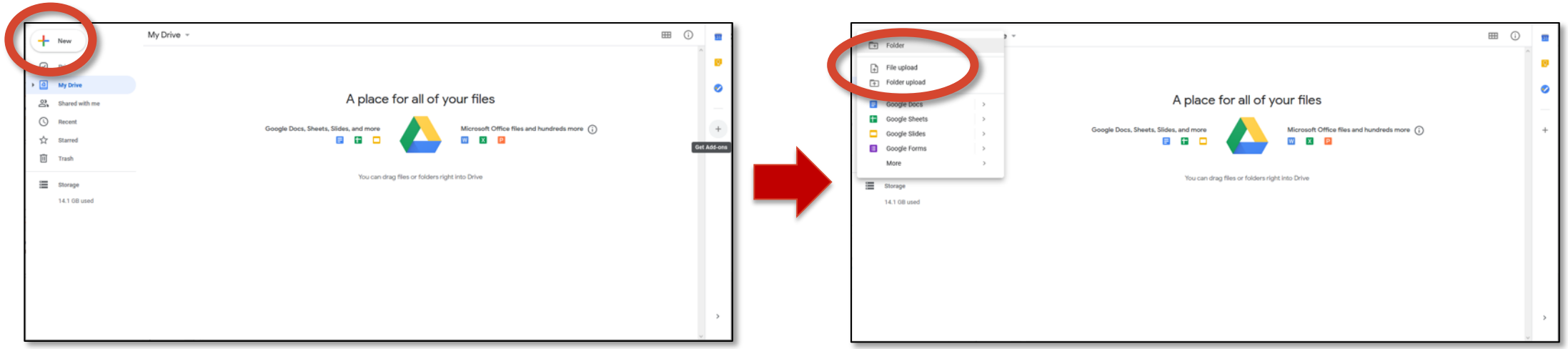
Step 2: Search for “Colaboratory" and install.



Add Your Notebooks to Google Drive

Step 3: Add Notebook to Google Drive by dragging over files, or clicking New → File Upload.

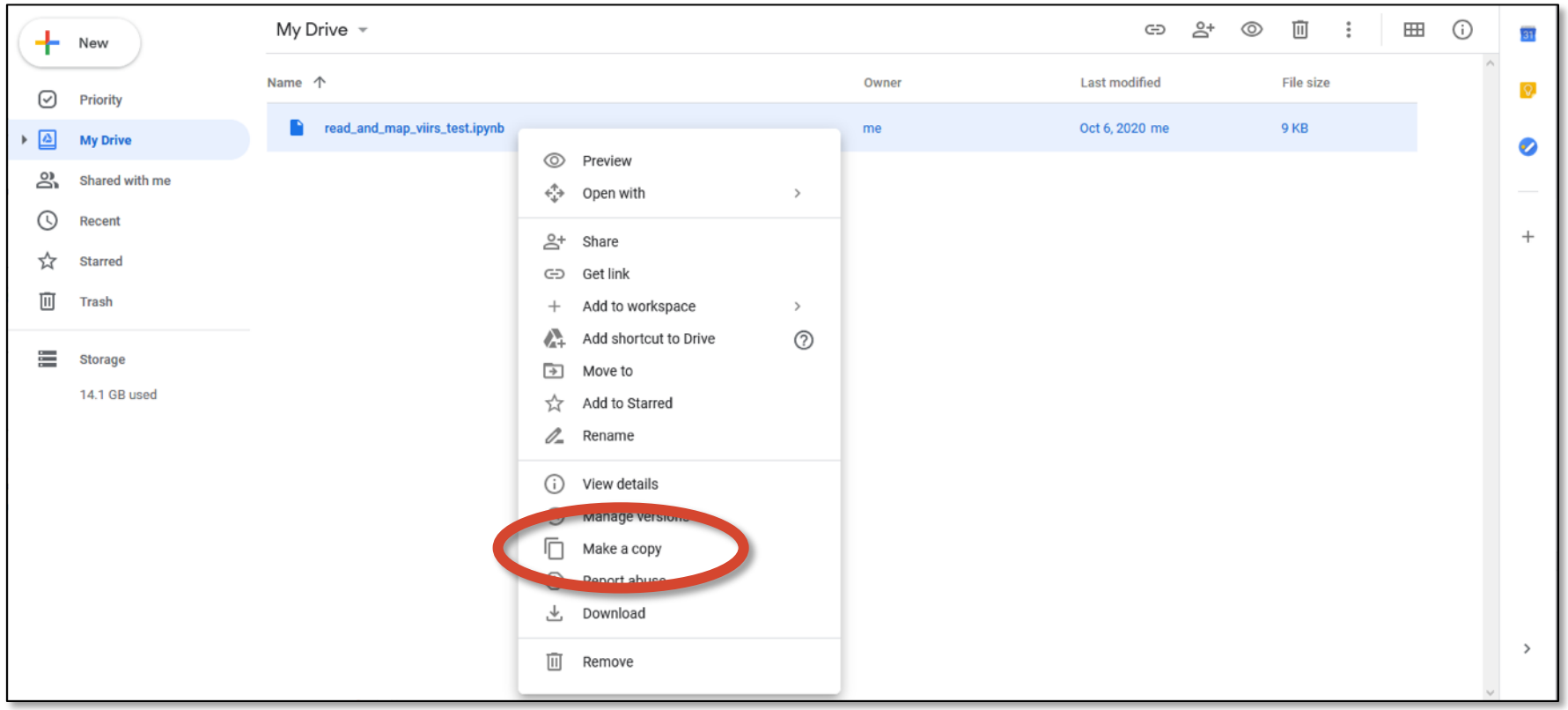
* If you already had Colaboratory installed, add the file to your Colab Notebooks folder. *



Add Your Notebooks to Google Drive

Step 3a: Right-click on your file and click "Make a copy". *This will create the Colab Notebooks folder in your Google Drive. The file copy will be inside this folder.*

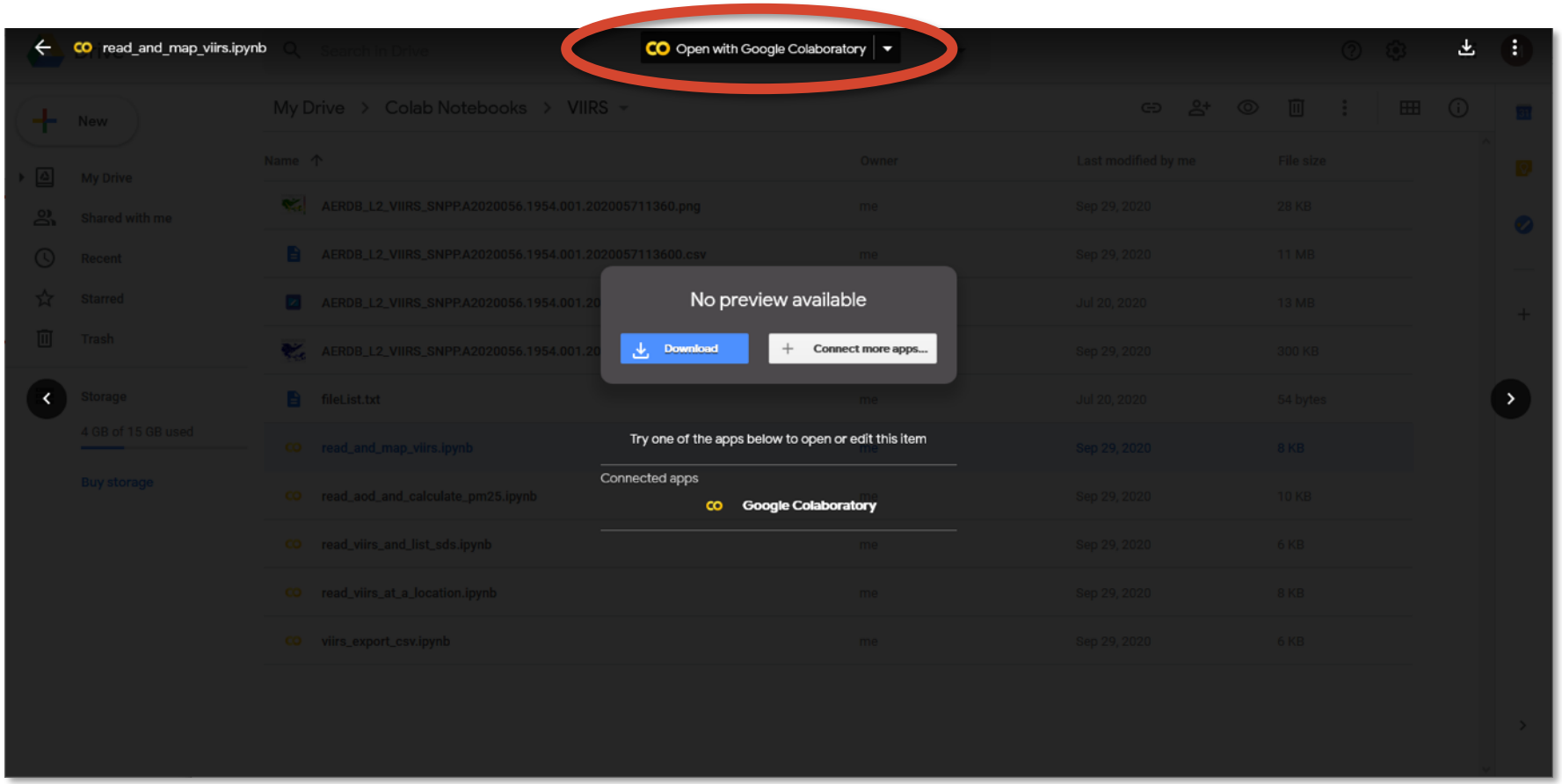
* This step is only necessary if you had to install Colaboratory. *



Run Jupyter Notebooks using Google Colaboratory

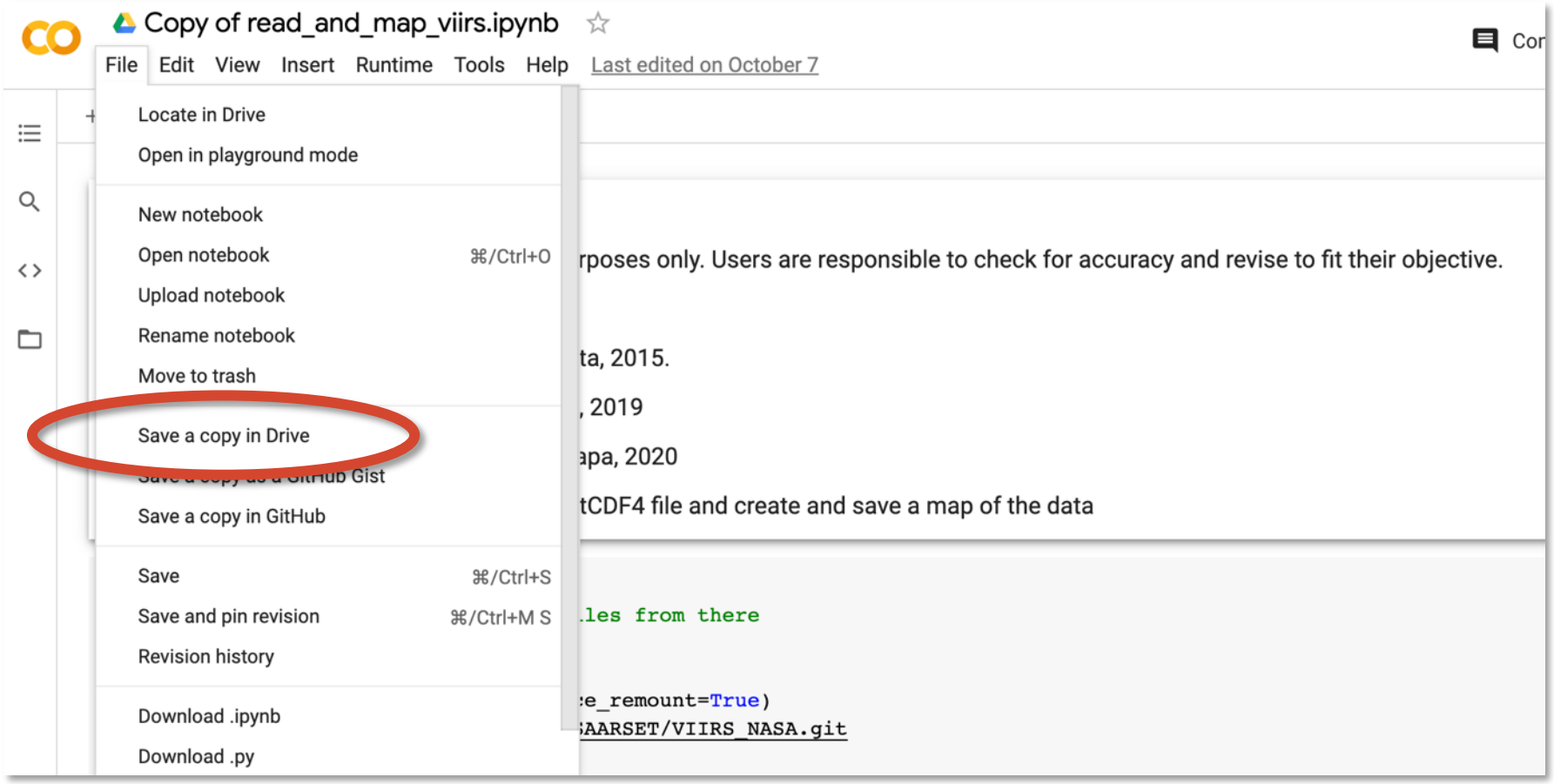
Run your Jupyter Notebook

Step 1a: Double click your file to open it and choose Open with Google Colaboratory.



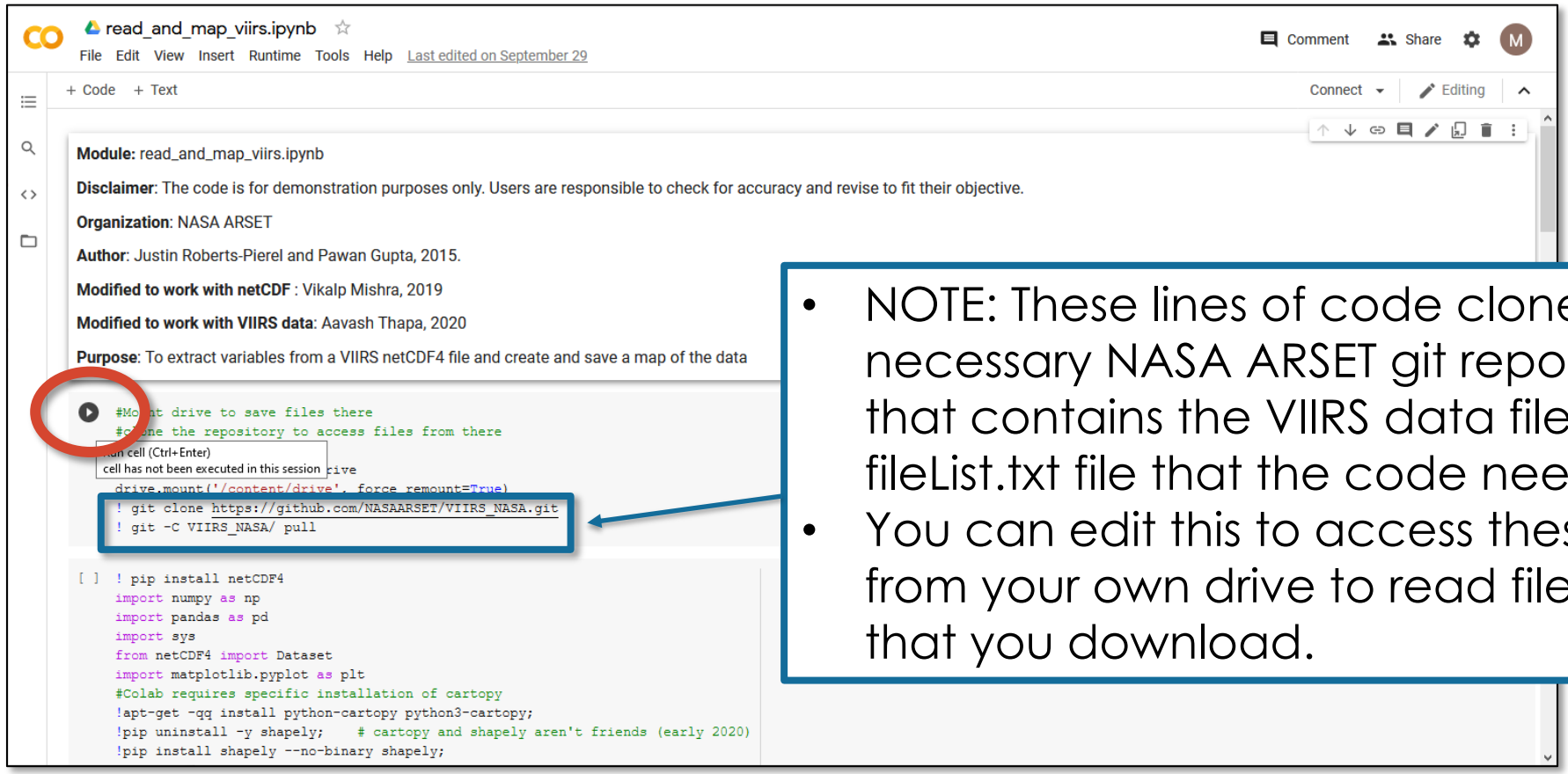
Run your Jupyter Notebook

Step 1b: Once open, click File > Save a copy in Drive. This will automatically create a duplicate copy in a folder called “Colab Notebooks”.



Run your Jupyter Notebook

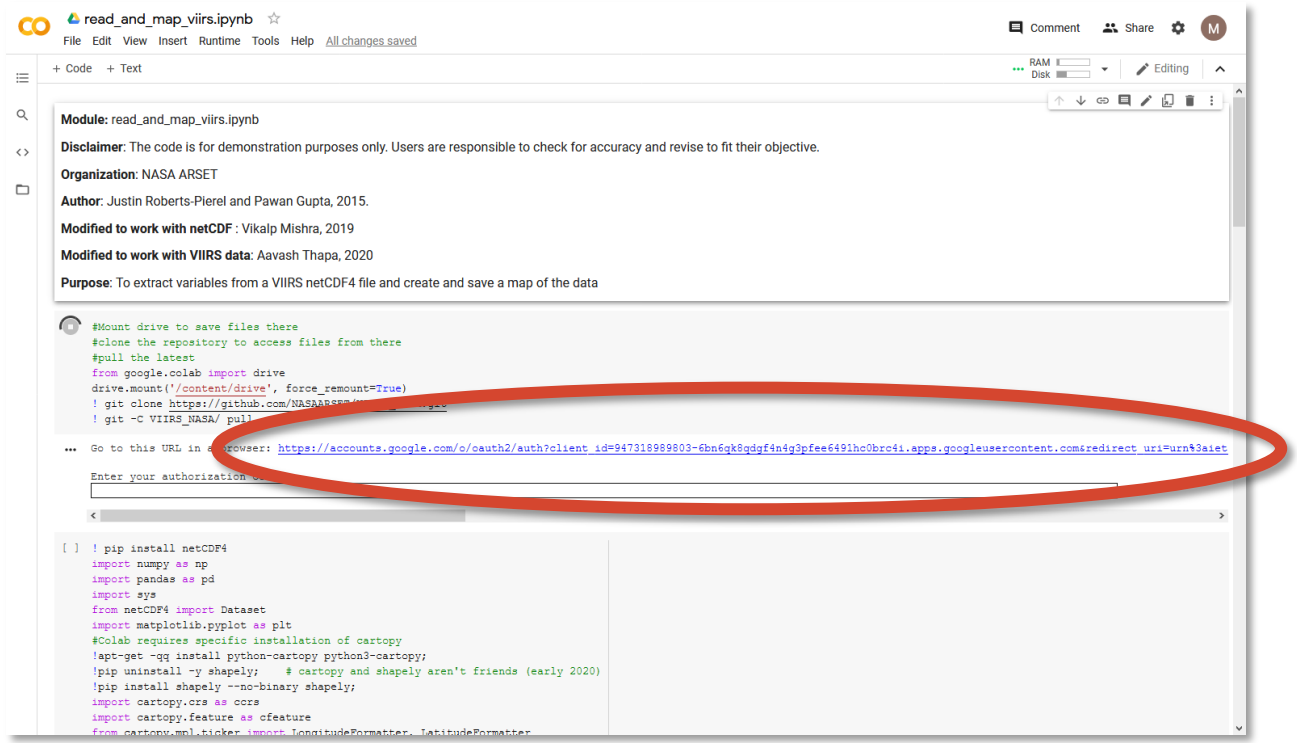
Step 2: Run each cell of your notebook in order.

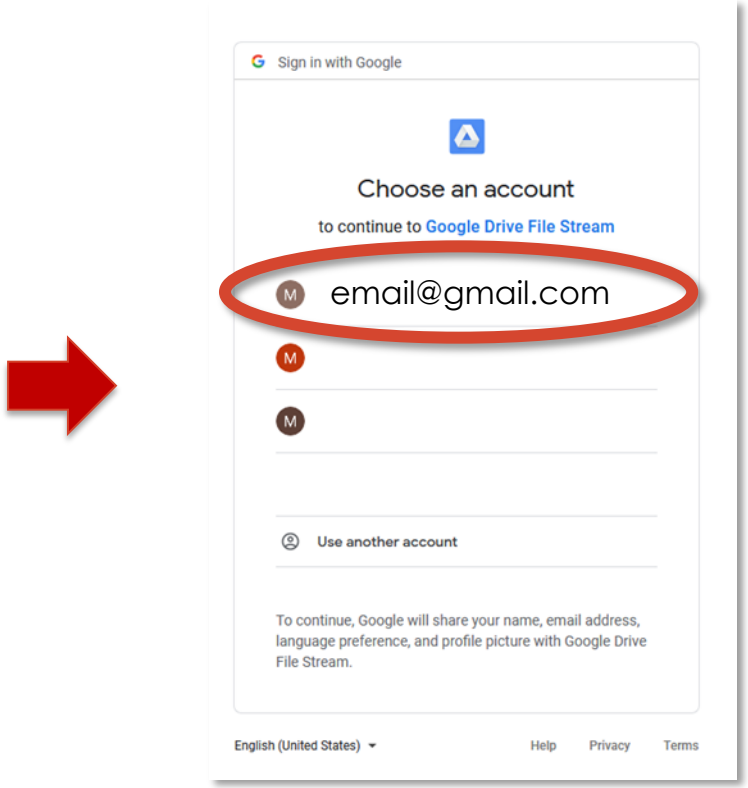


- NOTE: These lines of code clone the necessary NASA ARSET git repository that contains the VIIRS data file and fileList.txt file that the code needs.
- You can edit this to access these from your own drive to read files that you download.

Run your Jupyter Notebook

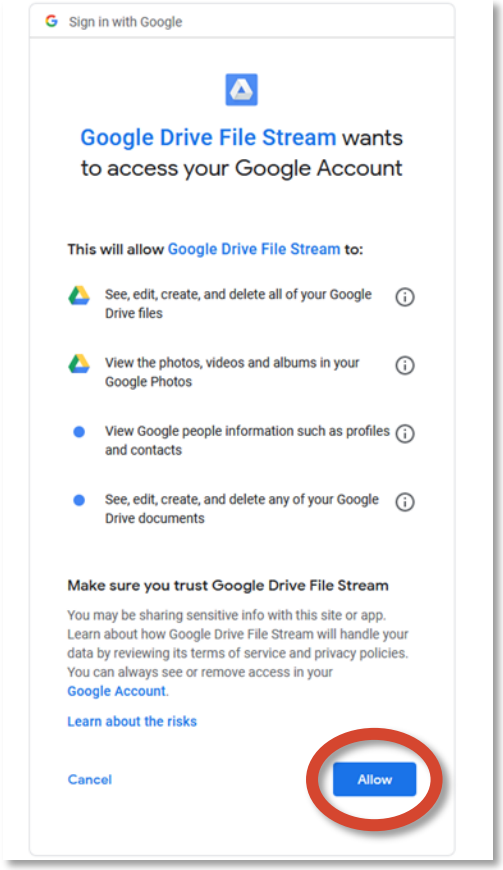
Step 2a: The first time you run each code you will need to get an authorization code from Google File Stream. Click the link and choose your google drive account.

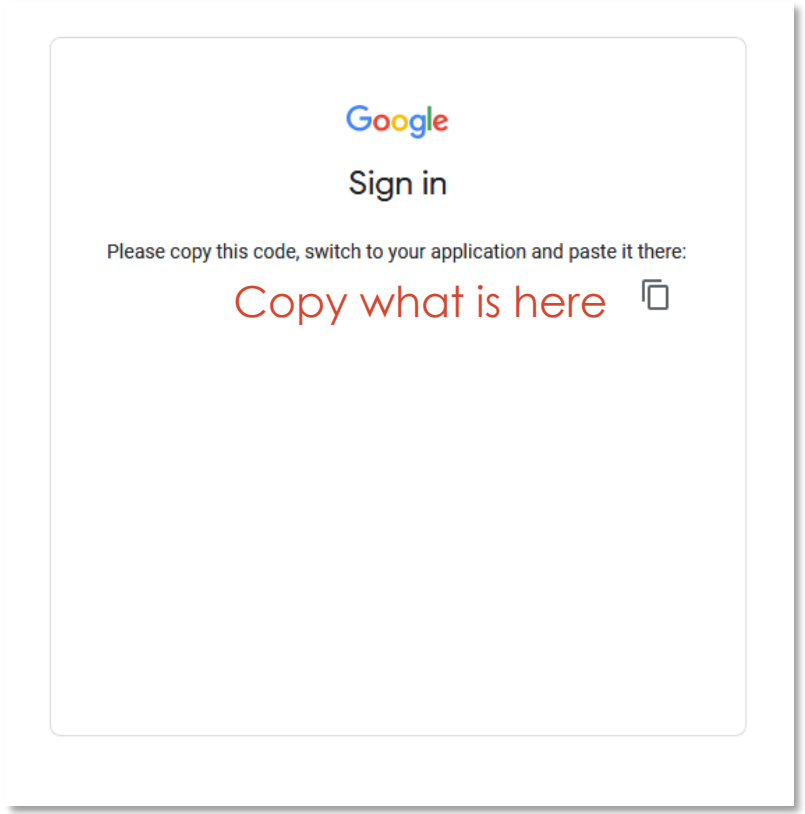




Run your Jupyter Notebook

Step 2b: Click Allow and copy the code.

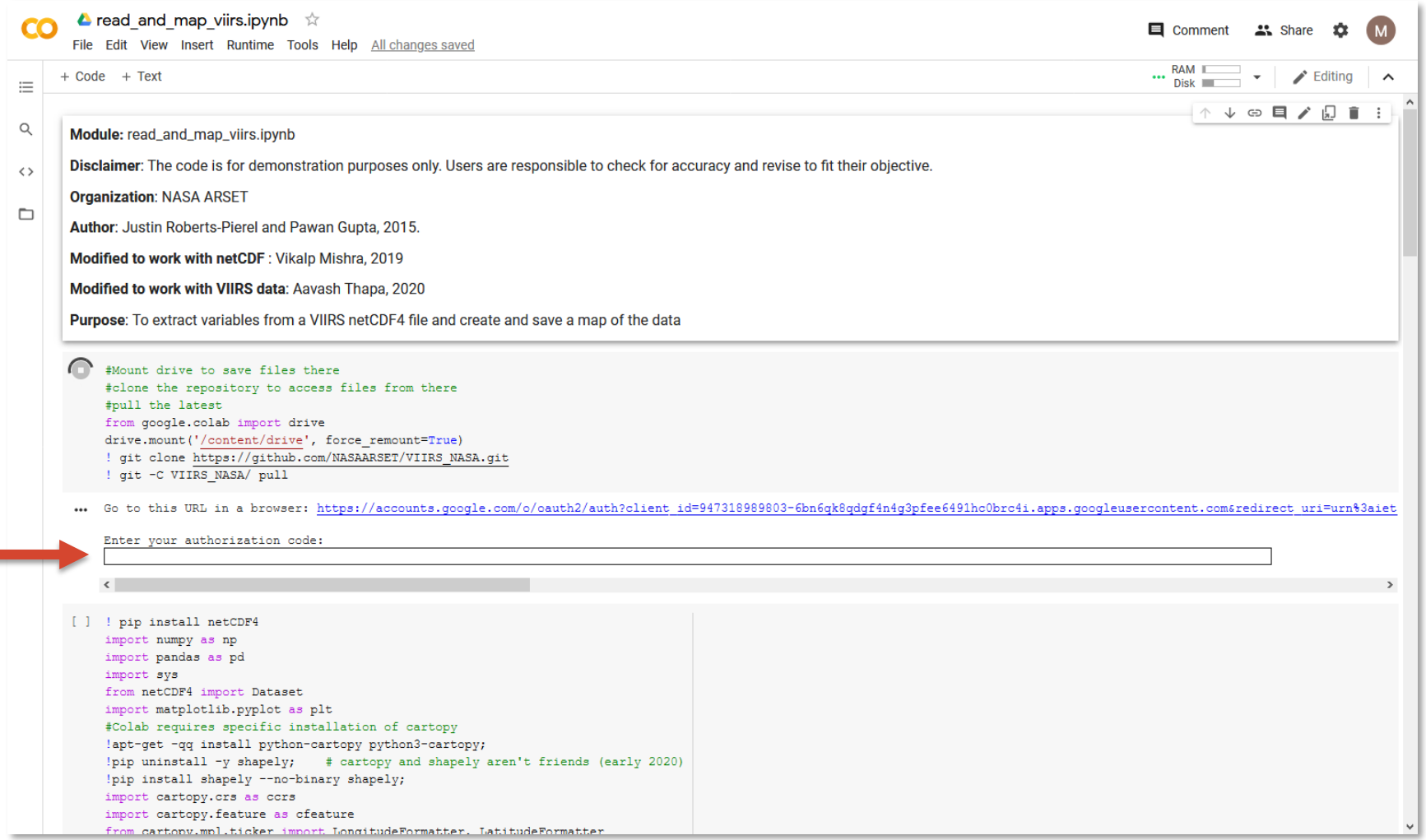




Run your Jupyter Notebook

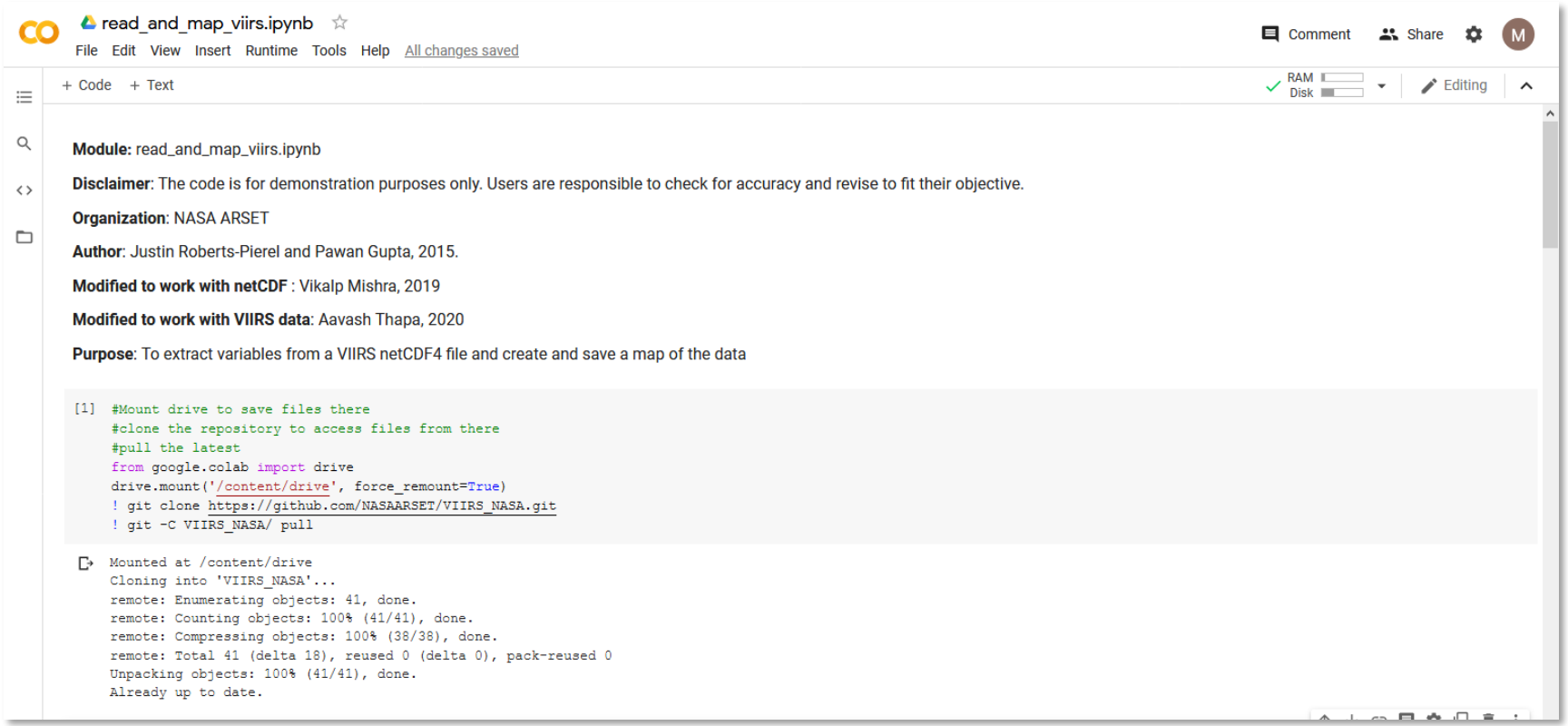
Step 2c: Paste the code into the notebook and hit Enter.

Paste here



Run your Jupyter Notebook

Step 2c: Paste the code into the notebook and hit Enter.



Run your Jupyter Notebook

Step 3: Run the next cell to import the necessary libraries.

read_and_map_viirs.ipynb

File Edit View Insert Runtime Tools Help All changes saved

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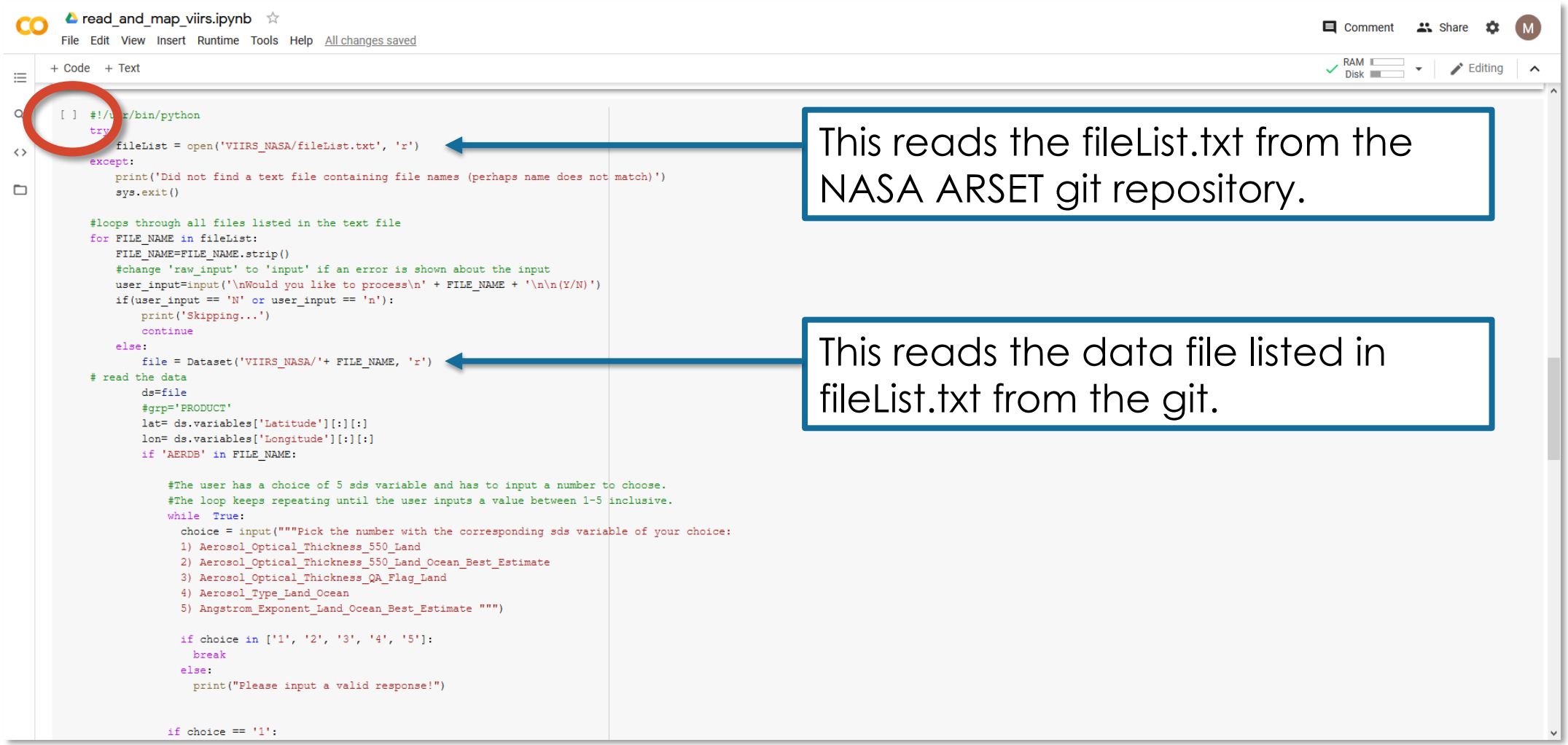
RAM Disk Editing

```
! pip install netCDF4
import numpy as np
import pandas as pd
import sys
from netCDF4 import Dataset
import matplotlib.pyplot as plt
#Colab requires specific installation of cartopy
!apt-get -qq install python-cartopy python3-cartopy;
!pip uninstall -y shapely;    # cartopy and shapely aren't friends (early 2020)
!pip install shapely --no-binary shapely;
import cartopy.crs as ccrs
import cartopy.feature as cfeature
from cartopy.mpl.ticker import LongitudeFormatter, LatitudeFormatter
from matplotlib.axes import Axes
from cartopy.mpl.geoaxes import GeoAxes
GeoAxes._pcolormesh_patched = Axes.pcolormesh
from textwrap import wrap
```

```
Collecting netCDF4
  Downloading https://files.pythonhosted.org/packages/09/39/3687b2ba762a709cd97e48dfaf3ae36a78ae603ec3d1487f767ad58a7b2e/netCDF4-1.5.4-cp36-cp36m-manylinux1_x86_64.whl (4.3MB)
     |████████████████████████████████| 4.3MB 2.6MB/s
Requirement already satisfied: numpy>=1.9 in /usr/local/lib/python3.6/dist-packages (from netCDF4) (1.18.5)
Collecting cftime
  Downloading https://files.pythonhosted.org/packages/81/f4/31cb9b65f462ea960bd334c5466313cb7b8af792f272546b68b7868fccd4/cftime-1.2.1-cp36-cp36m-manylinux1_x86_64.whl (287kB)
     |████████████████████████████████| 296kB 26.9MB/s
Installing collected packages: cftime, netCDF4
Successfully installed cftime-1.2.1 netCDF4-1.5.4
Selecting previously unselected package python-pkg-resources.
(Reading database ... 144617 files and directories currently installed.)
Preparing to unpack .../0-python-pkg-resources_39.0.1-2_all.deb ...
Unpacking python-pkg-resources (39.0.1-2) ...
Selecting previously unselected package python-pyshp.
Preparing to unpack .../1-python-pyshp_1.2.12+ds-1_all.deb ...
Unpacking python-pyshp (1.2.12+ds-1) ...
Selecting previously unselected package python-shapely.
Preparing to unpack .../2-python-shapely_1.6.4-1_amd64.deb ...
Unpacking python-shapely (1.6.4-1) ...
Selecting previously unselected package python-six.
Preparing to unpack .../3-python-six_1.11.0-2_all.deb ...
Unpacking python-six (1.11.0-2) ...
Selecting previously unselected package python-cartopy:amd64.
Preparing to unpack .../4-python-cartopy_0.14.2+dfsg1-2build3_amd64.deb ...
Unpacking python-cartopy:amd64 (0.14.2+dfsg1-2build3) ...
```

Run your Jupyter Notebook

Step 4: Run the last cell to run the code.



This reads the fileList.txt from the NASA ARSET git repository.

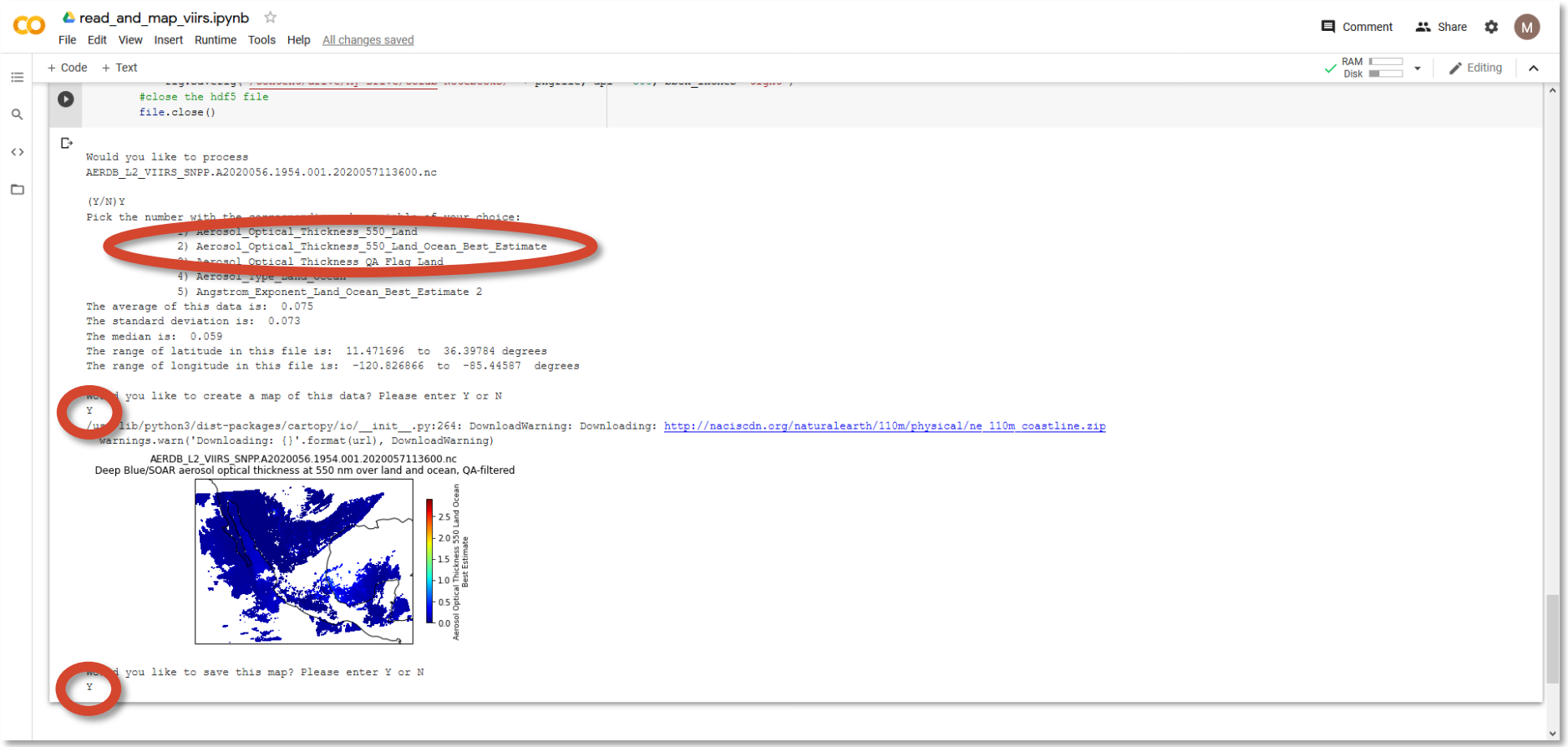
This reads the data file listed in fileList.txt from the git.

Run your Jupyter Notebook

Step 4: Enter Y to process the file.

Run your Jupyter Notebook

Step 5: Enter 2 (Aerosol_Optical_Thickness_550_Land_Ocean_Best_Estimate**) and then enter Y to create a map. Then enter Y to save it to your Google Drive/Colab Notebooks/ folder.**



Questions

- Please enter your questions into the Q&A box.
- We will post the questions and answers to the training website following the conclusion of the course.

Contacts

- Contacts
  - Pawan Gupta: pawan.gupta@nasa.gov
  - Melanie Follette-Cook: melanie.cook@nasa.gov

- General ARSET Inquiries
  - Ana Prados: aprados@umbc.edu

- ARSET Website:
  - appliedsciences.nasa.gov/arset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Thank You!