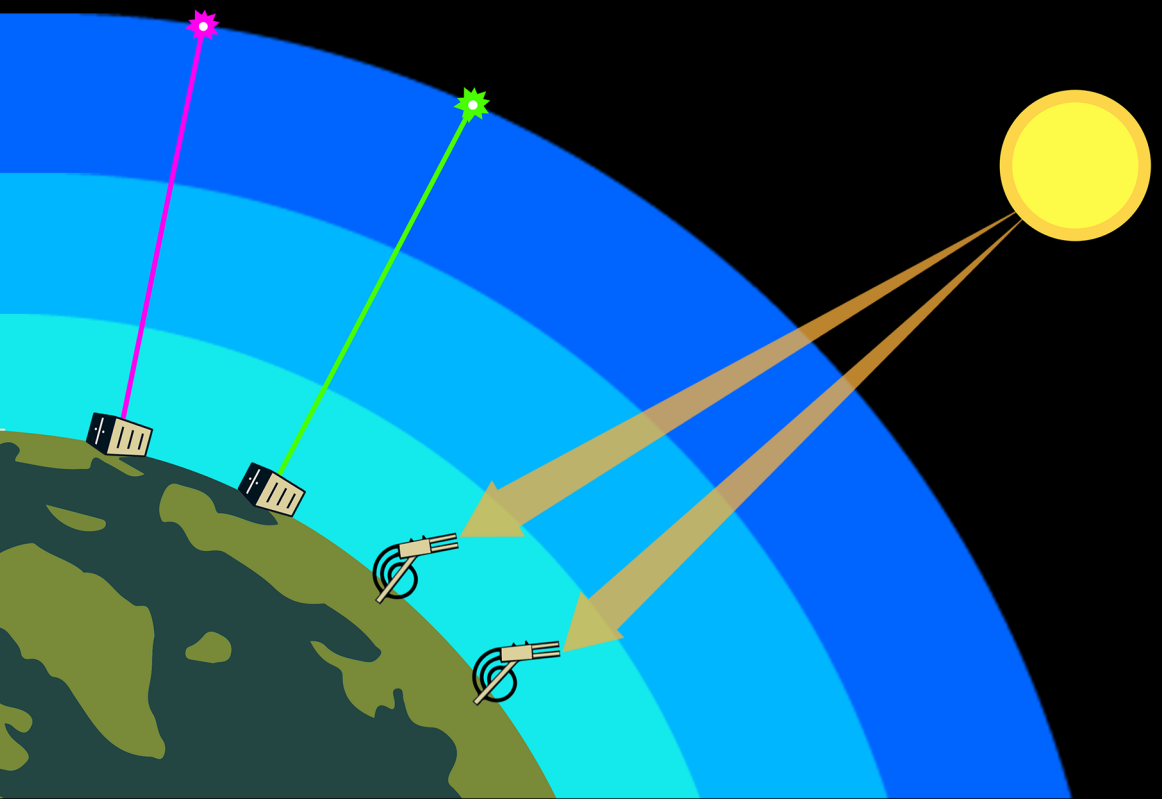
National Aeronautics and Space Administration



NASA Atmospheric Composition Ground Networks Supporting Air Quality and Climate Applications

Part 2: Hands-On Analysis of AERONET Data

Carl Malings (Morgan State University), Pawan Gupta (NASA Goddard Space Flight Center), & Petar Grigorov (Science Systems & Applications, Inc.)

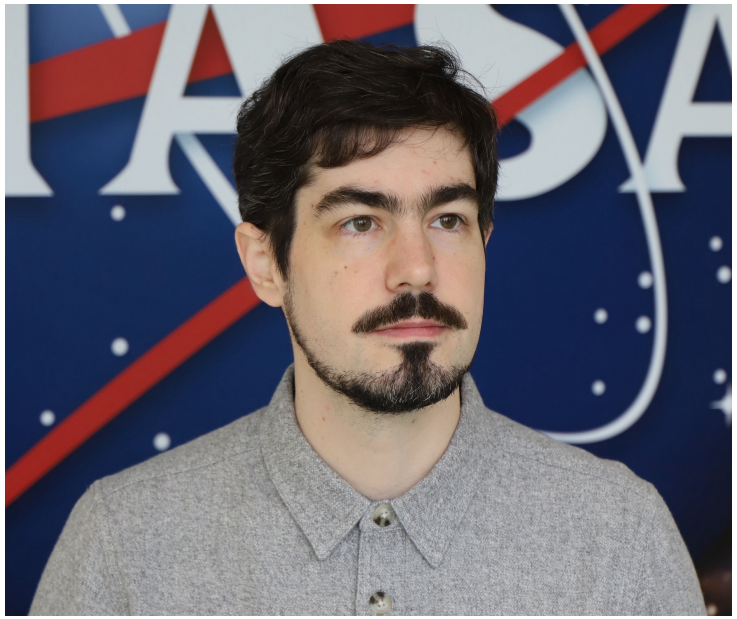
August 13, 2024

Part 2 – Trainers

Dr. Carl Malings

Assistant Research Scientist

Morgan State University, GESTAR-II



Dr. Pawan Gupta

Co-Lead, AERONET

NASA GSFC

Petar Grigorov

Scientific Programmer

Science Systems and Applications, Inc.

Part 2 Objectives

By the end of Part 2, participants will be able to:

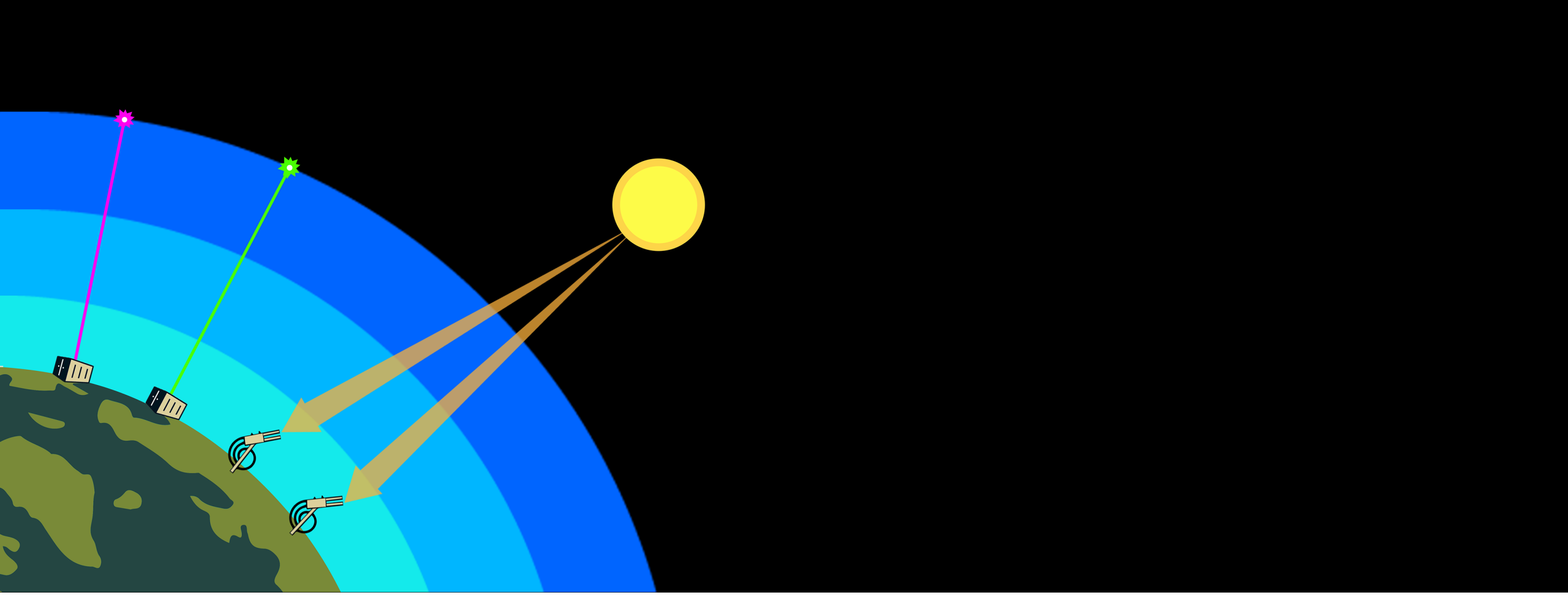
- Access relevant AERONET data for given locations and application purposes.
- Compare and jointly analyze AERONET and satellite aerosol data products for a given location and time.

Review of Prior Knowledge

Network	Type	Primary Measurands	Number of Sites	Vertical Coverage
AERONET	Passive	Aerosols (Optical, Microphysical, Radiative)	~600 active	Total Column

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



Part 2:

Hands-On Analysis of AERONET Data

Outline

- AERONET Webpage
- Site Information
- Data Display
- Data Download
- Alternative Tools
- GitHub – Jupyter Notebooks
- Live Demonstration

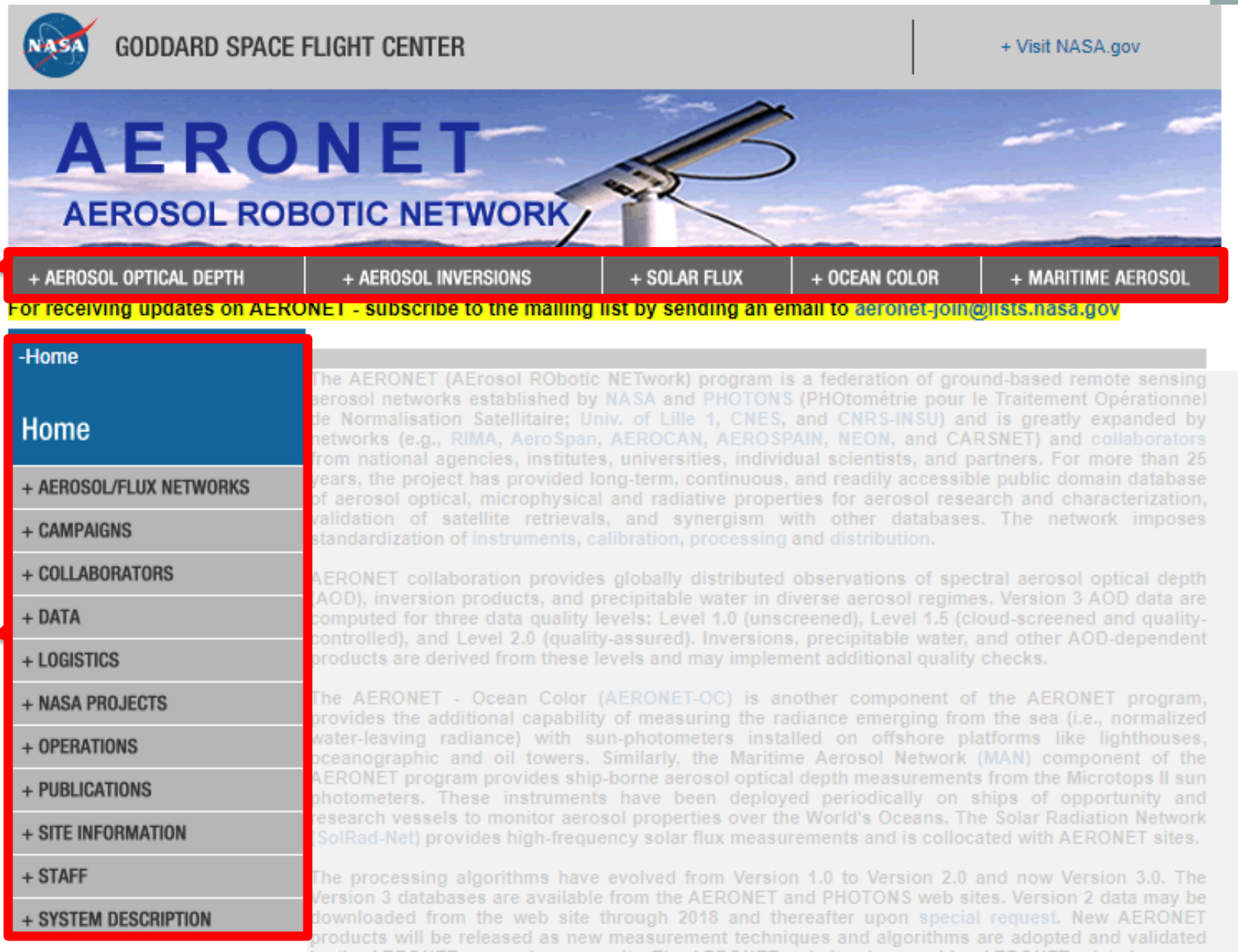
Tour of AERONET Website

https://aeronet.gsfc.nasa.gov/

AERONET Components Pages

Information Buttons:

- Data Access and Dissemination Tools
- Troubleshooting Manuals and Shipping Information
- Data Transfer and Relational Database
- Site Information Pages (photos, contacts, site description, etc.)
- System Overview (measurements, operation calibration, data)



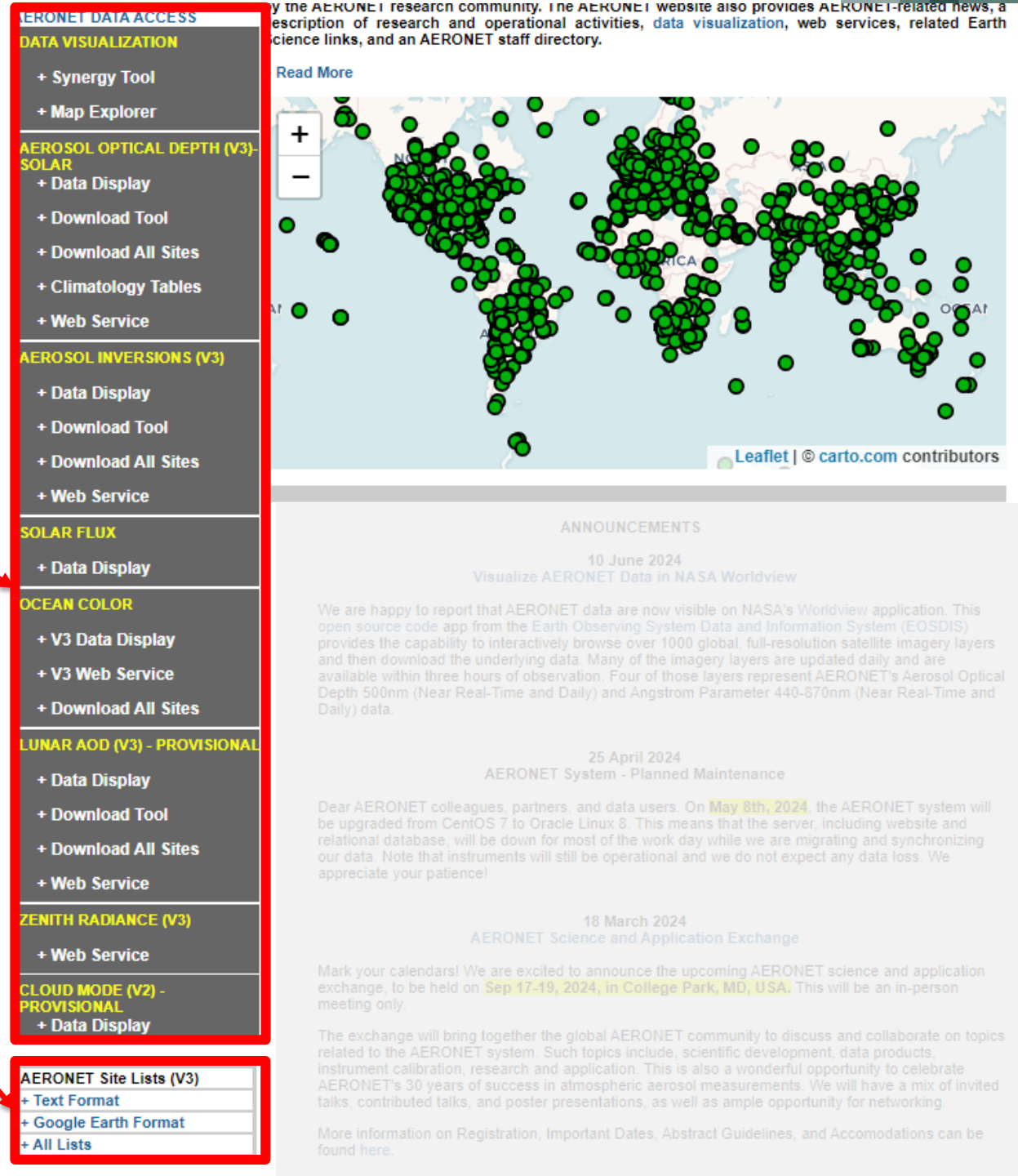
AERONET Webpage Overview

Data Buttons:

- Data Visualization
- Data Mapping
- Data Downloading
- Climatology Tables
- Accessing Web API (Web Service)

Site Lists:

- Display list of AERONET sites along with some key site information
- Can choose format and/or time frame



Sample List – Active Sites

https://aeronet.gsfc.nasa.gov/aeronet_locations_v3.txt

- Contains:
  - Site Name
  - Coordinates
  - Elevation
- Features months with available data
  - 1 = Data Exists
  - 0 = No Data
- Can also generate list of sites for specific year, starting 1993
- Can download as plain text file, or compressed KMZ file for Google Earth

```
AERONET_Database_Site_List,Num=0,Date_Generated=22:07:2024,Months_Available_for_Ye
Site_Name,Longitude(decimal_degrees),Latitude(decimal_degrees),Elevation(meters),J
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GSFC,-76.839833,38.992500,87.000000,1,1,1,1,1,1,1,0,0,0,0,0
Wallops,-75.471950,37.932850,37.000000,1,1,0,0,1,1,1,0,0,0,0,0
Waskesiu,-106.069578,53.914386,569.000000,1,1,1,1,1,1,1,0,0,0,0,0
Key_Biscayne,-80.163330,25.731966,10.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Sevilleta,-106.885002,34.354721,1477.000000,1,1,1,1,1,1,1,1,0,0,0,0,0
Bonanza_Creek,-148.316269,64.742805,353.000000,0,0,0,1,1,1,1,0,0,0,0,0,0
Mauna_Loa,-155.576755,19.536006,3402.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Lille,3.141667,50.611667,60.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Missoula,-114.083336,46.916668,976.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Capo_Verde,-22.935499,16.732500,60.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
UCSB,-119.845360,34.415428,33.000000,0,1,1,1,1,1,1,0,0,0,0,0,0
SERC,-76.555795,38.888901,36.500000,1,1,0,0,1,0,0,0,0,0,0,0,0
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Banizoumbou,2.665190,13.546930,274.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Ascension_Island,-14.414722,-7.976389,30.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Barrow,-156.665000,71.312200,8.000000,0,1,1,1,1,1,1,0,0,0,0,0,0
REUNION_ST_DENIS,55.484740,-20.901390,93.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
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IMAA_Potenza,15.723700,40.601254,770.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
Skukuza,31.587500,-24.991700,265.000000,1,0,0,1,1,1,1,0,0,0,0,0,0
TABLE_MOUNTAIN_CA,-117.680000,34.380000,2200.000000,0,1,1,1,1,1,1,0,0,0,0,0,0
Mexico_City,-99.181667,19.333611,2268.000000,1,1,1,1,1,1,1,0,0,0,0,0,0
```
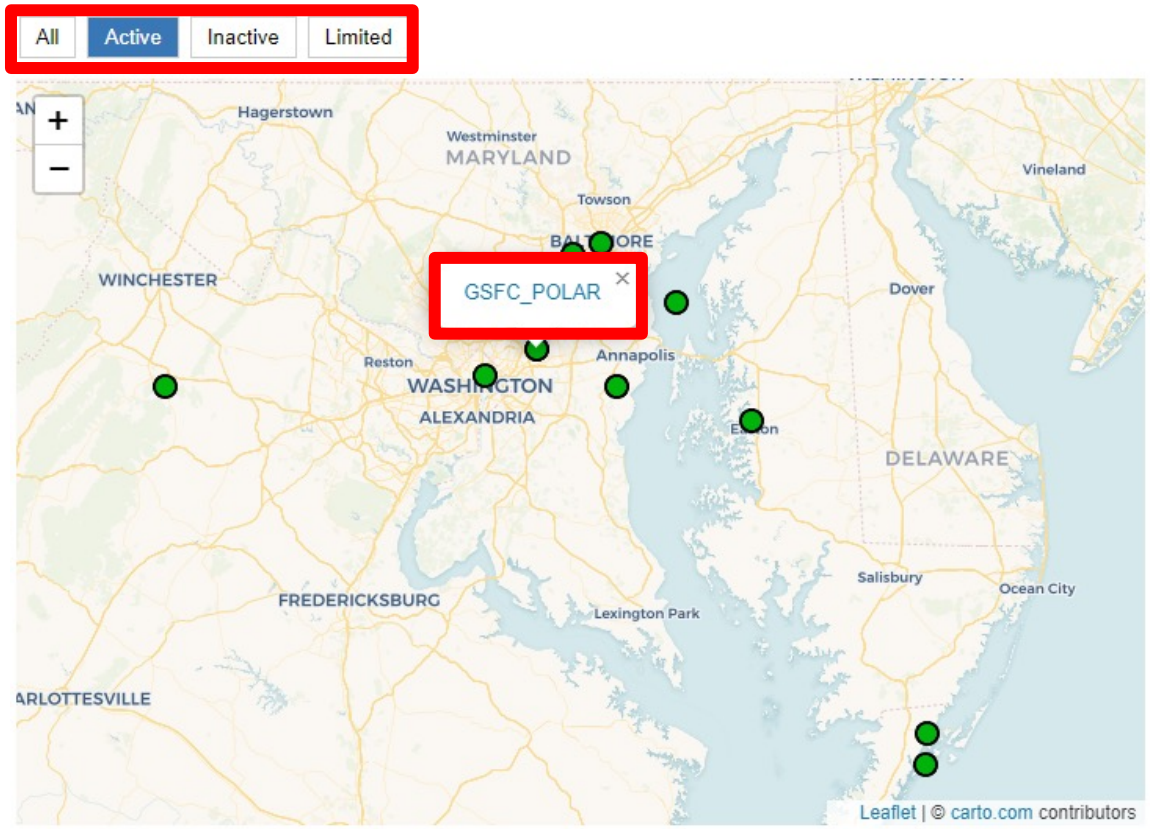

Site Information Map Interface

https://aeronet.gsfc.nasa.gov/new_web/site_info_v3.html



Latitude: 37.854729, Longitude: -78.219910

GSF Search Reset

- GSFC
- GSFC_POLAR

Chesapeake_Bay(39.1N, 76.3W) [Annapolis, MD]	Easton-MDE(38.8N, 76.1W)	GSFC(39.0N, 76.8W) [GSFC, Greenbelt, MD]
GSFC_POLAR(39.0N, 76.8W) [GSFC, Greenbelt, MD]	Howard_Univ-IRB(38.9N, 77.0W) [Washington, DC]	MD_Science_Center(39.3N, 76.6W) [MD Science Center, Baltimore, Maryland]
NEON_SCBI(38.9N, 78.1W) [Front Royal, VA]	NEON_SERC(38.9N, 76.6W) [Edgewater, MD]	SERC(38.9N, 76.6W) [SERC, Annapolis, Maryland]
UMBC(39.3N, 76.7W) [UMBC, Maryland]	Wallops(37.9N, 75.5W) [Wallops Island, Virginia]	WFF_X-75_Sci_Obs(37.8N, 75.5W)

GSFC (GSFC, Greenbelt, MD)

Coordinates: 38.99250° N, 76.83983° W
Elevation: 87.0 m

Image 1 - A view of the AERONET calibration platform

Site Description

This site is located on top of the building that houses the AERONET program at NASA's Goddard Space Flight Center. Here AERONET staff monitor aerosols locally and also calibrate instruments from around the world.

Contact Information

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Site Manager(s):	• Jason Kraft • Email: Jason.Kraft@nasa.gov • Jason Kraft NASA Goddard Space Flight Center Code 618 Building 33, F541 Phone: 301-614-6634 Email:Jason.Kraft@nasa.gov
Responsible Institution(s):	• NASA--National Aeronautics and Space Administration http://www.nasa.gov

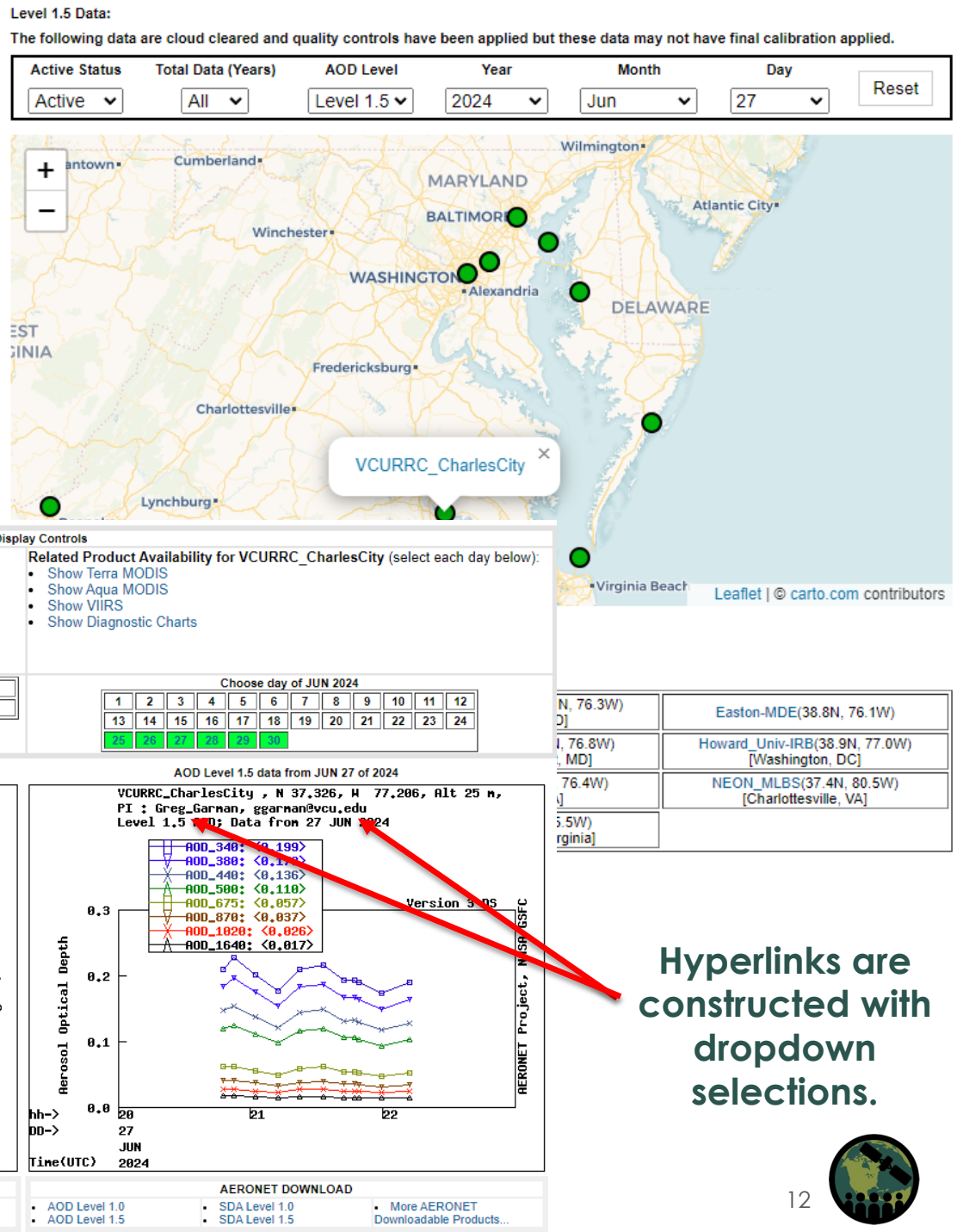
AERONET Data Display Interface

https://aeronet.gsfc.nasa.gov/new_web/draw_map_display_aod_v3.html

- Similar functionality to the Site Info Mapper
- Used for solar/lunar AOD and inversion products, as well as water-leaving radiances

Additional Functionality:

- Filter based on site activity, level of data, and time using dropdown menus
- On-click popup container with link to data display page (example below)



Hyperlinks are constructed with dropdown selections.

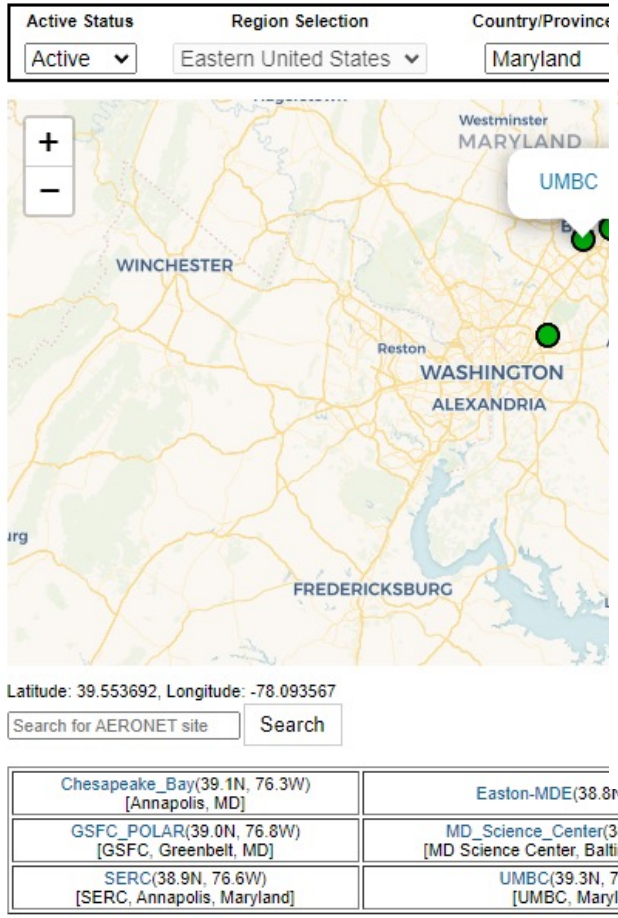
AERONET Data Download Interface

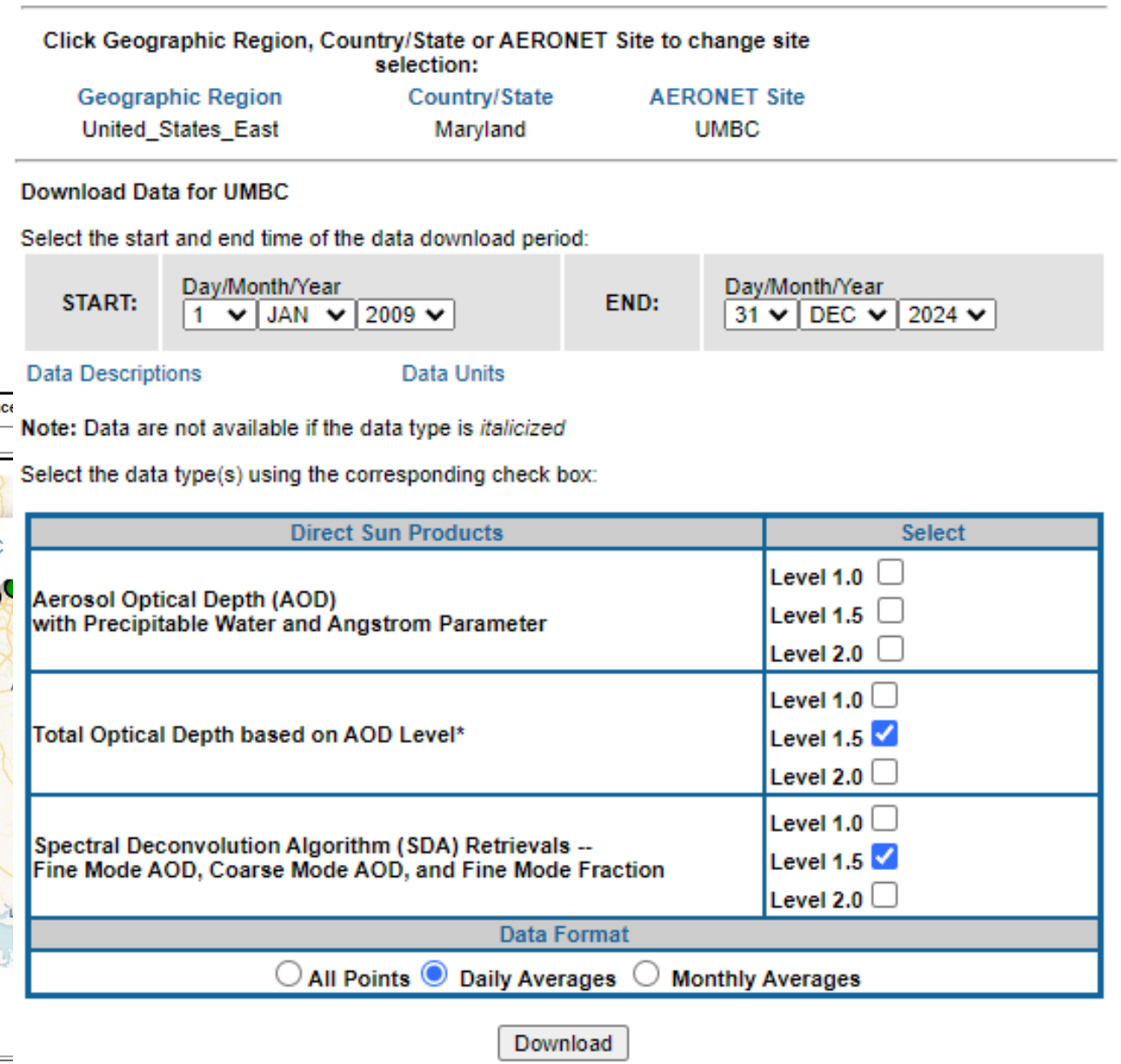
https://aeronet.gsfc.nasa.gov/new_web/webtool_aod_v3.html

Used for solar/lunar AOD and inversion products

Additional Functionality:

- Filter based on activity, region, country/province, and site using dropdown menus
- On-click popup container with link to download data for the selected site

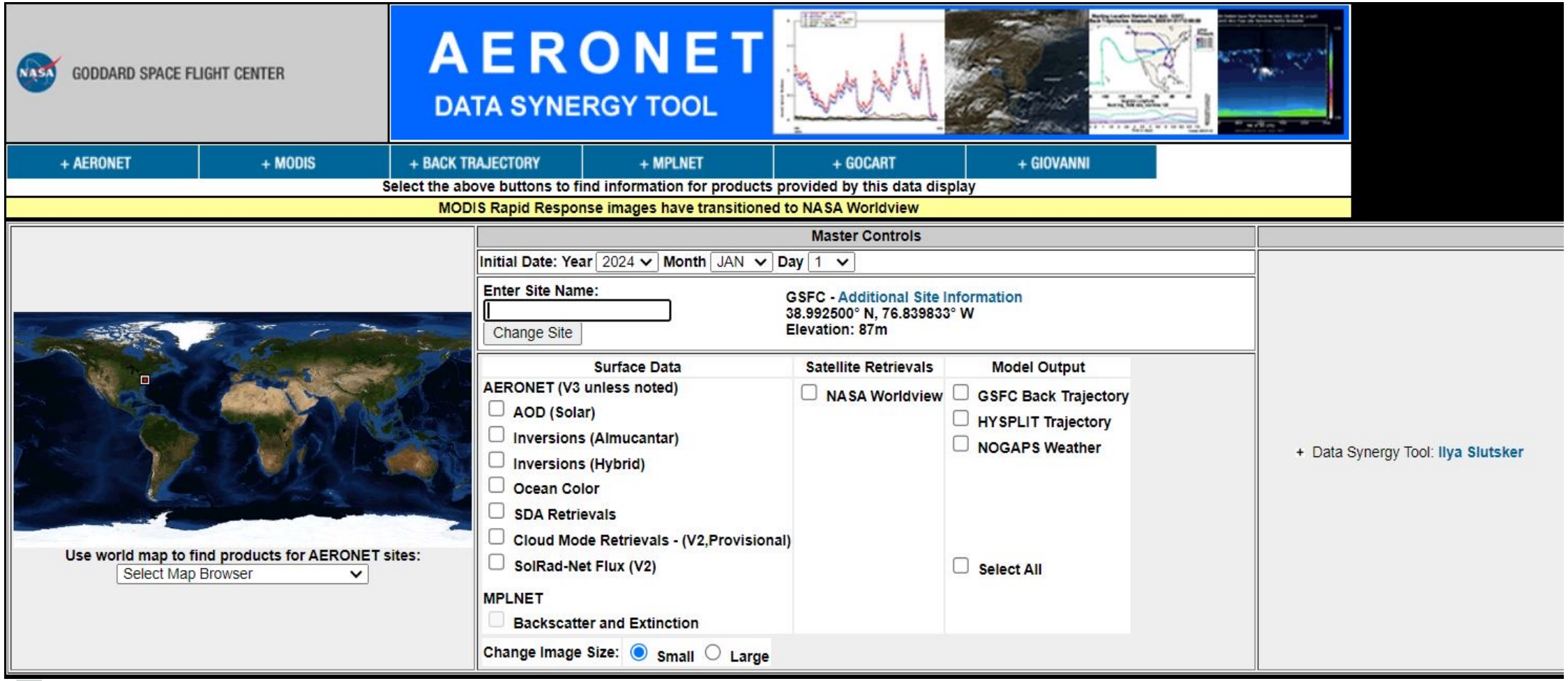




Alternative Tools: Synergy Tool

https://aeronet.gsfc.nasa.gov/cgi-bin/bamgomas_interactive

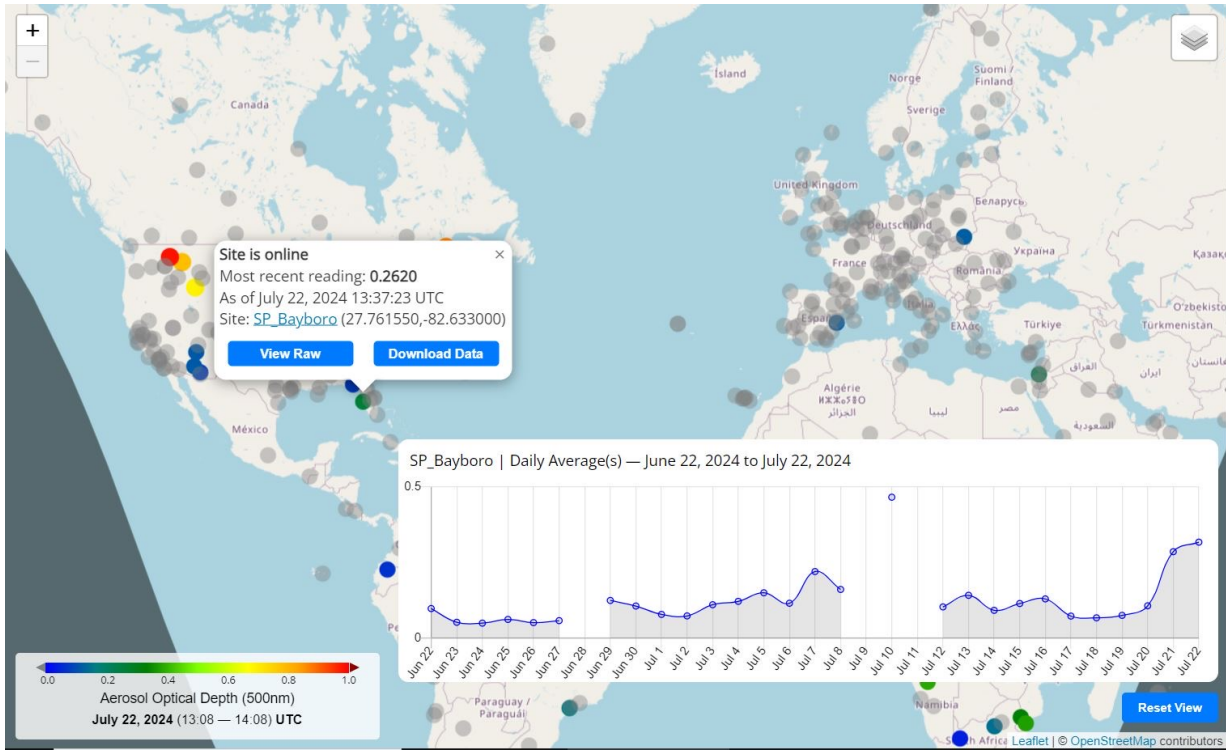
Collocates AERONET data with other surface and satellite databases (e.g., MODIS, MPLNET).



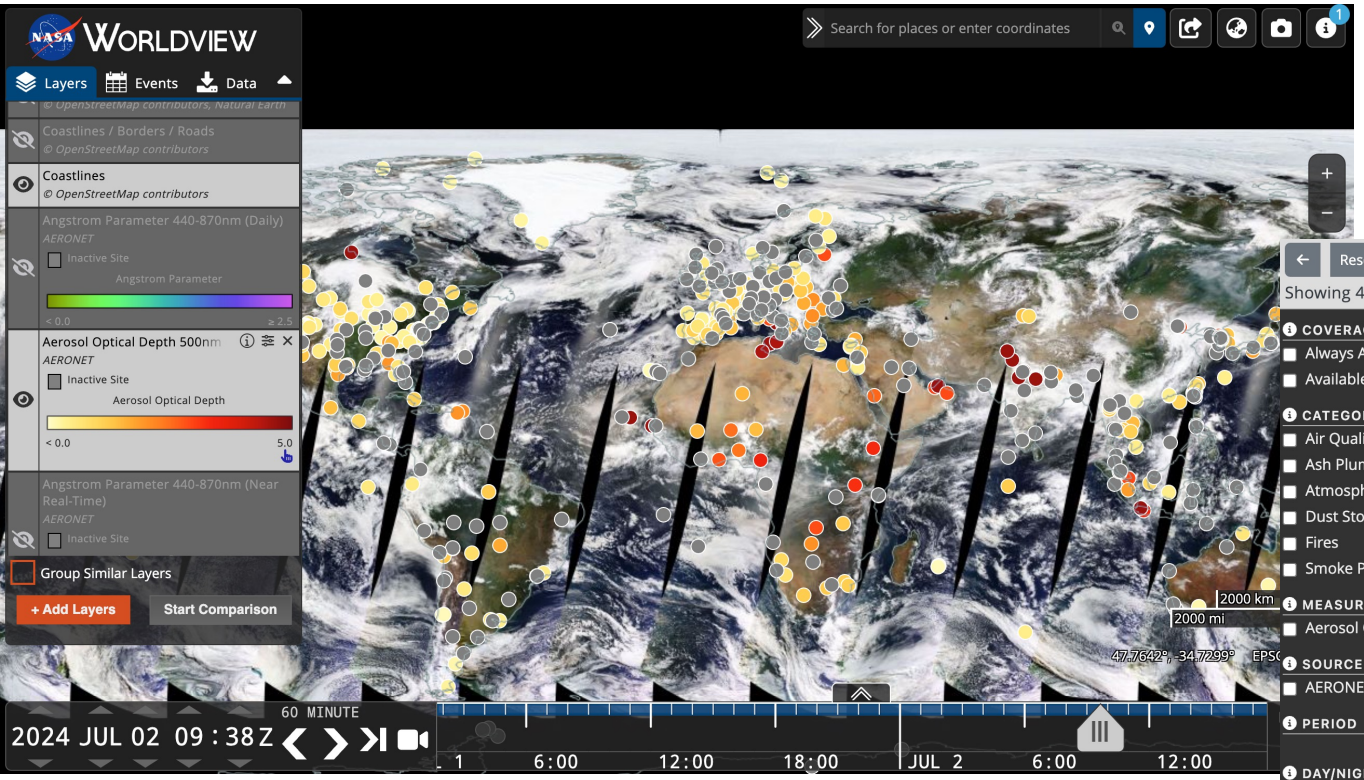
Alternative Tools: AERONET Map Explorer

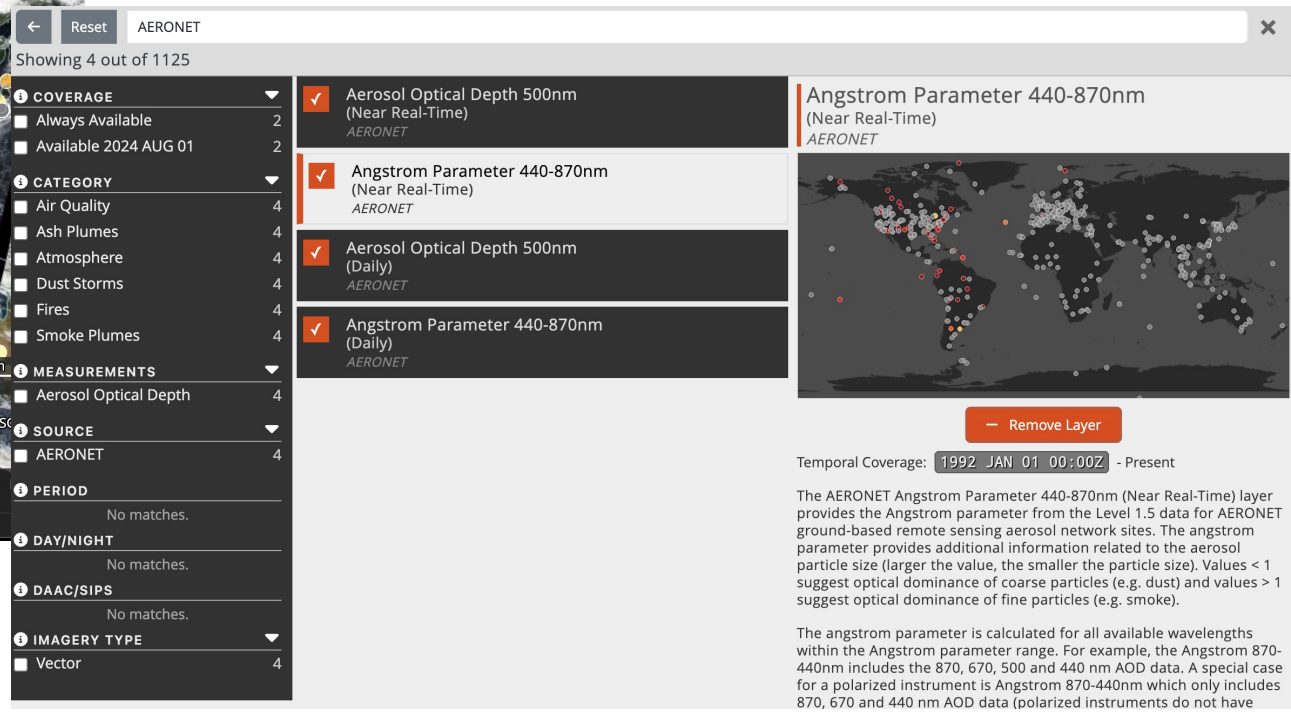
https://aeronet.gsfc.nasa.gov/new_web/aeronet_map_tool/index.html

- Obtains AERONET data from Web API and plots them either in near-real time or as daily averages.
- Popup containers show site activity, most recent reading with timestamp, as well as time-series.
- Ability to select channel, site, mode, day/time, as well as to download the data.



AERONET Data in NASA Worldview





Available Layers

The Web API – Explanation of Variables and Sample Data File

https://aeronet.gsfc.nasa.gov/print_web_data_help_v3_new.html

Table 2: Explanation of Data Types for the Web Service

Data Types	Explanation
AOD10	Aerosol Optical Depth Level 1.0
AOD15	Aerosol Optical Depth Level 1.5
AOD20	Aerosol Optical Depth Level 2.0
SDA10	SDA Retrieval Level 1.0
SDA15	SDA Retrieval Level 1.5
SDA20	SDA Retrieval Level 2.0
TOT10	Total Optical Depth based on AOD Level 1.0 (all points only)
TOT15	Total Optical Depth based on AOD Level 1.5 (all points only)
TOT20	Total Optical Depth based on AOD Level 2.0 (all points only)

AERONET Data Download (Version 3 Direct Sun)

AERONET Version 3;
Version 3: AOD Level 1.5
The following data are cloud cleared and quality controls have been applied but these data may not have final calibration applied. These data may change.
Contact: PI=Pawan_Gupta_and_Elena_Lind; PI Email=pawan.gupta@nasa.gov_and_elena.lind@nasa.gov
AERONET_Site,Date(dd:mm:yyyy),Time(hh:mm:ss),Day_of_Year,Day_of_Year(Fraction),AOD_1640nm,AOD_1020nm,AOD_870nm,AOD_865nm,AOD_779nm,AOD_675nm,AOD_667nm,AOD_620nm,AOD_560nm,AOD_555nm,870_Angstrom_Exponent,380-500_Angstrom_Exponent,440-675_Angstrom_Exponent,500-870_Angstrom_Exponent,340-440_Angstrom_Exponent,440-675_Angstrom_Exponent[Polar],Data_Quality_Level,AERONET_Instrument_Number,AERONET_Site_Name,Site_Latitude(Degrees),Site_Longitude(Degrees),Site_Elevation(m),Solar_Zenith_Angle(Degrees),Optical_Air_Mass,Sens

GSFC,01:07:2024,10:38:13,183,183.443206,0.003819,0.010138,0.012266,-999.000000,-999.000000,0.015941,-999.000000,-999.000000,-999.000000,-999.000000,-999.000000,-999.000000,-999.000000,-999.000000,0.025779,-999.0(
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AERONET Web Service:
https://aeronet.gsfc.nasa.gov/cgi-bin/print_web_data_v3

The following tables and examples show how to use the AERONET web data service for Version 3 products.

Table 1: Explanation and Values for Mandatory and Optional Web Service Parameters

Mandatory Parameters	Explanation	Values
year,month,day	Starting time moment (year= 1992 to present), (month=1 to 12), (day = 1 to max num, depends on month)	Year: 1993 to present (must be 4-digits) Month: 1 to 12 Day: 1 to max_day_of_month
AVG	Data Format	All points: AVG=10 Daily average: AVG=20
[data_type]	Data Types (See Table 2)	[data_type]=1
Optional Parameters		
year2,month2,day2	Ending time moment**	Year: 1993 to present (must be 4-digits) Month: 1 to 12 Day: 1 to max_day_of_month **if year2,month2, and day2 are omitted, then the current day is assumed
hour, hour2	Specified beginning (hour) and ending hour (hour2)	Hour: 0 to 23 if not specified, then the hour is set to zero; time2 is incremented to next day and hour2=0
site	AERONET site name	Exact match of AERONET database name If none specified, then all sites are searched for data during the time interval specified AERONET Site Name List
lat1,lon1,lat2,lon2	Bounding Box **	lat1,lon1 - Lower Left lat2,lon2 - Upper Right **values must be in decimal degrees (including the decimal)
lunar_merge	Enable Lunar AOD (Provisional) Only Download	0 - No Lunar 1- Lunar Data (Provisional)
ldp_year, ldp_month, ldp_day	Request data records after user specified date based on the last processing date of the record **	Year: 1993 to present (must be 4-digits) Month: 1 to 12 Day: 1 to max_day_of_month ** All Points format only
if_no_html	Determine whether html formatting is printed	0 - HTML formatting printed (default) 1 - No HTML formatting printed

AERONET GitHub Codes

https://github.com/pawanpgupta/AERONET/tree/Python

1. Reads Aerosol Optical Depth (AOD) data from Web API, and plots values on a world map. The results can be either daily averages, hourly averages, or total average over specified time frame.
2. Works similarly to Ex. 1, but with an interactive twist: dynamic plots with sliders and animations with play/pause/stop buttons,
3. Works similarly to Ex. 1, but instead reads AERONET Inversions data from Web API.
4. Reads AOD data from Web API, and produces a variety of plots, including time-series, calendar plot, tile plots, yearly averages with regression line.

Materials for ARSET Training - visualizing AERONET data. This repository contains materials for reading and mapping AERONET data, as well as producing time-series plot. Scripts require input from user such as time range, coordinates, level data, averaging type, product/channel. AERONET's Web API is used for extracting the data. An additional script collocates AERONET's ground based measurements with VIIRS satellite aerosol measurements and produces a scatter plots. Similar input parameter are used as the Web API codes.

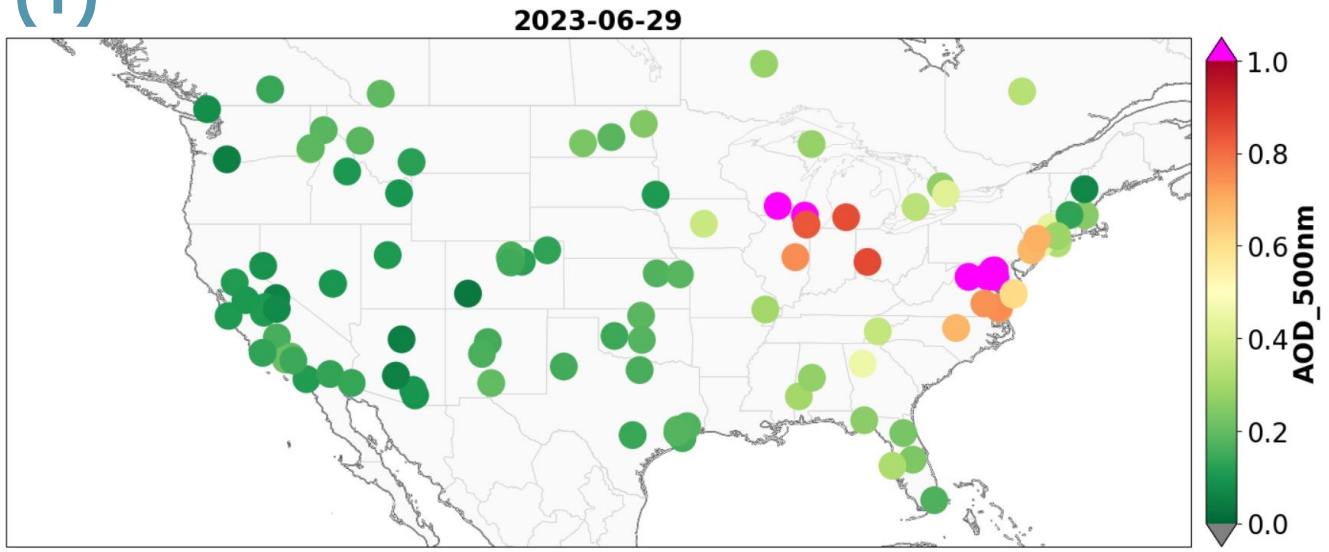
Materials

Lecture Topic	Interactive Link
1. Read and Map AERONET Data (AOD)	Open in Colab
2. Read and Map AERONET Data (AOD - Interactive)	Open in Colab
3. Read and Map AERONET Data (Inversions)	Open in Colab
4. AERONET Time Series Plots	Open in Colab
5. VIIRS - AERONET Comparison	Open in Colab

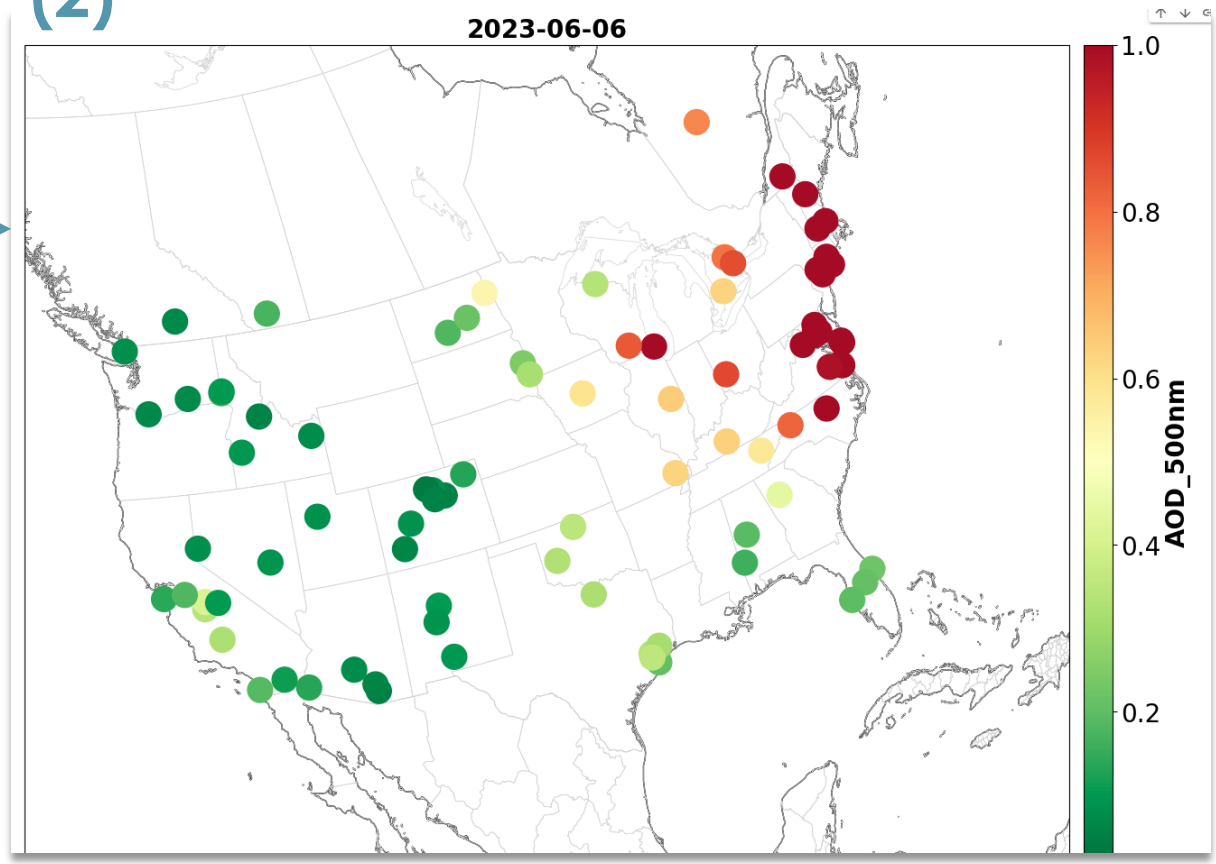
Sample Output – Read and Map AERONET Data

- Code produces spatial patterns of aerosol optical depth (AOD) at a specified wavelength.
- User can select date range, region, wavelength AOD, and averaging type to display.
- Two projections are used when plotting the AOD:
  1. Plate Carrée
  2. Orthographic

(1)



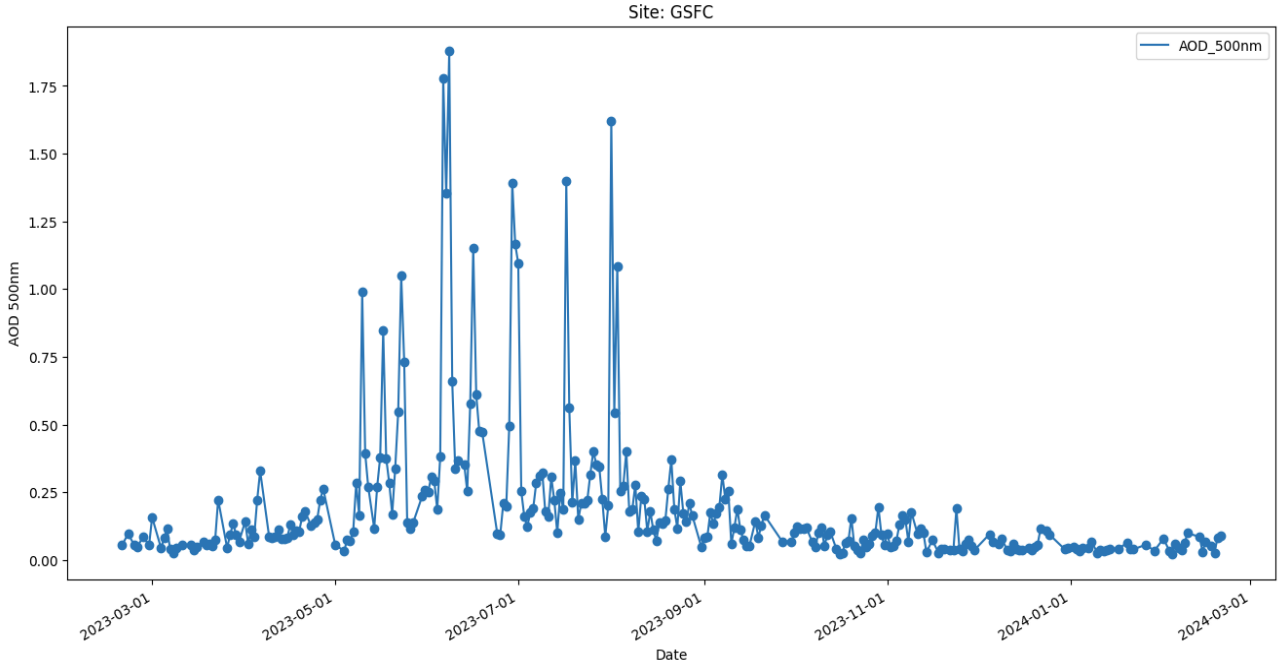
(2)



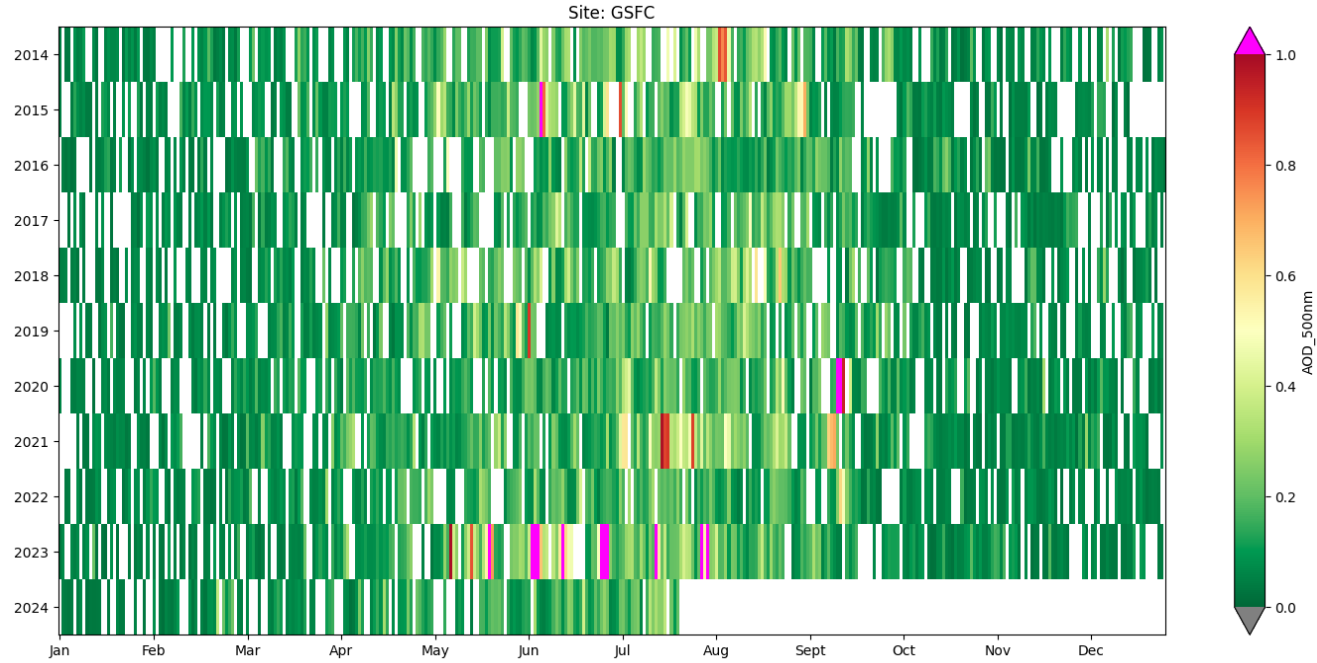
Sample Output – AERONET Time Series Plots

- Identical functionality as the Read and Map code – data is being read from Web API.
- Code produces a variety of time plots, both for short-term and long-term trends.
- Input parameters include site, date range, averaging type, AOD channel, level data.
- Featured Visuals:
  - Time-Series Graph (1)
  - Tile Plot (2)
  - Calendar Plot (3)
  - Annual Variability Plot (4)

(1)

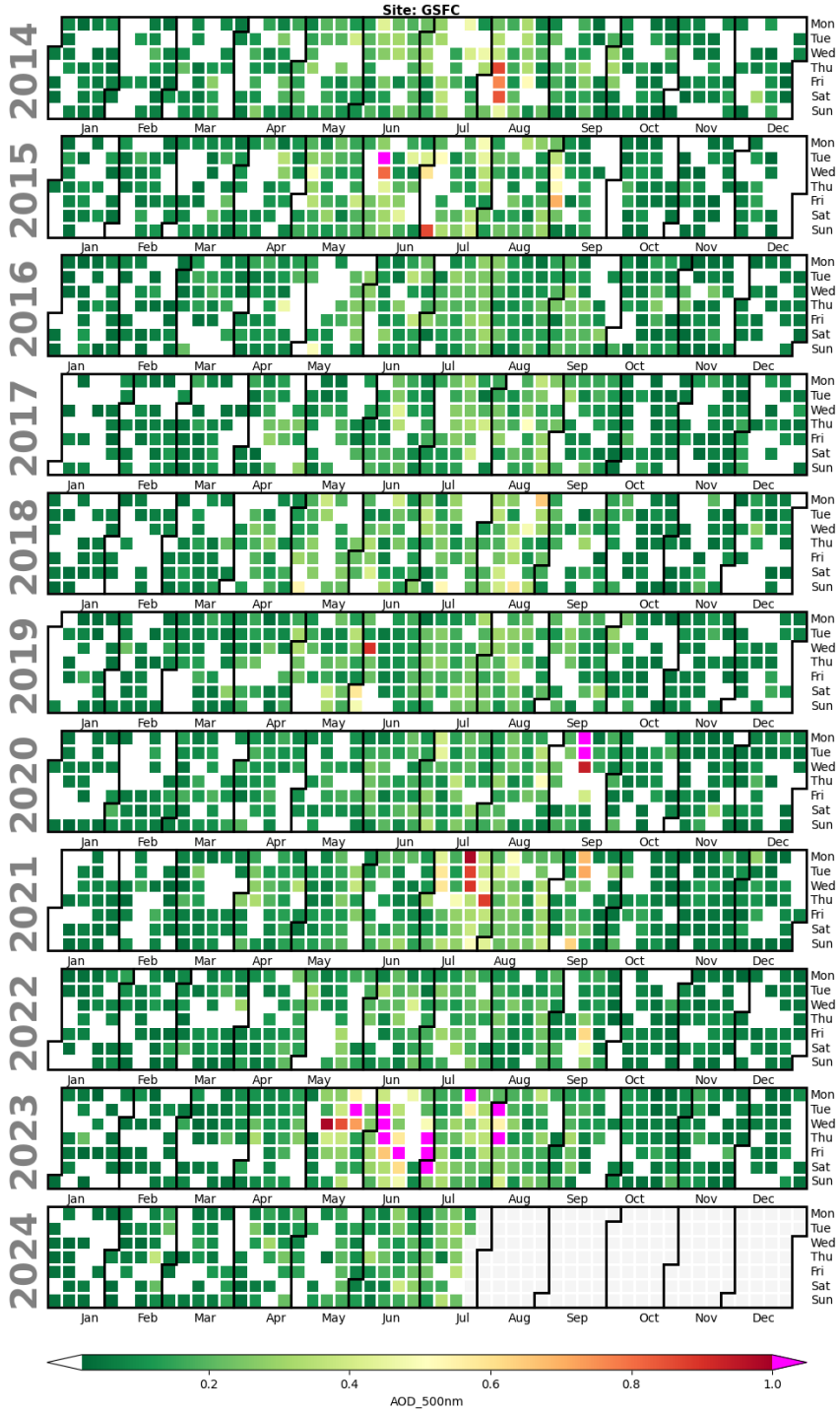


(2)

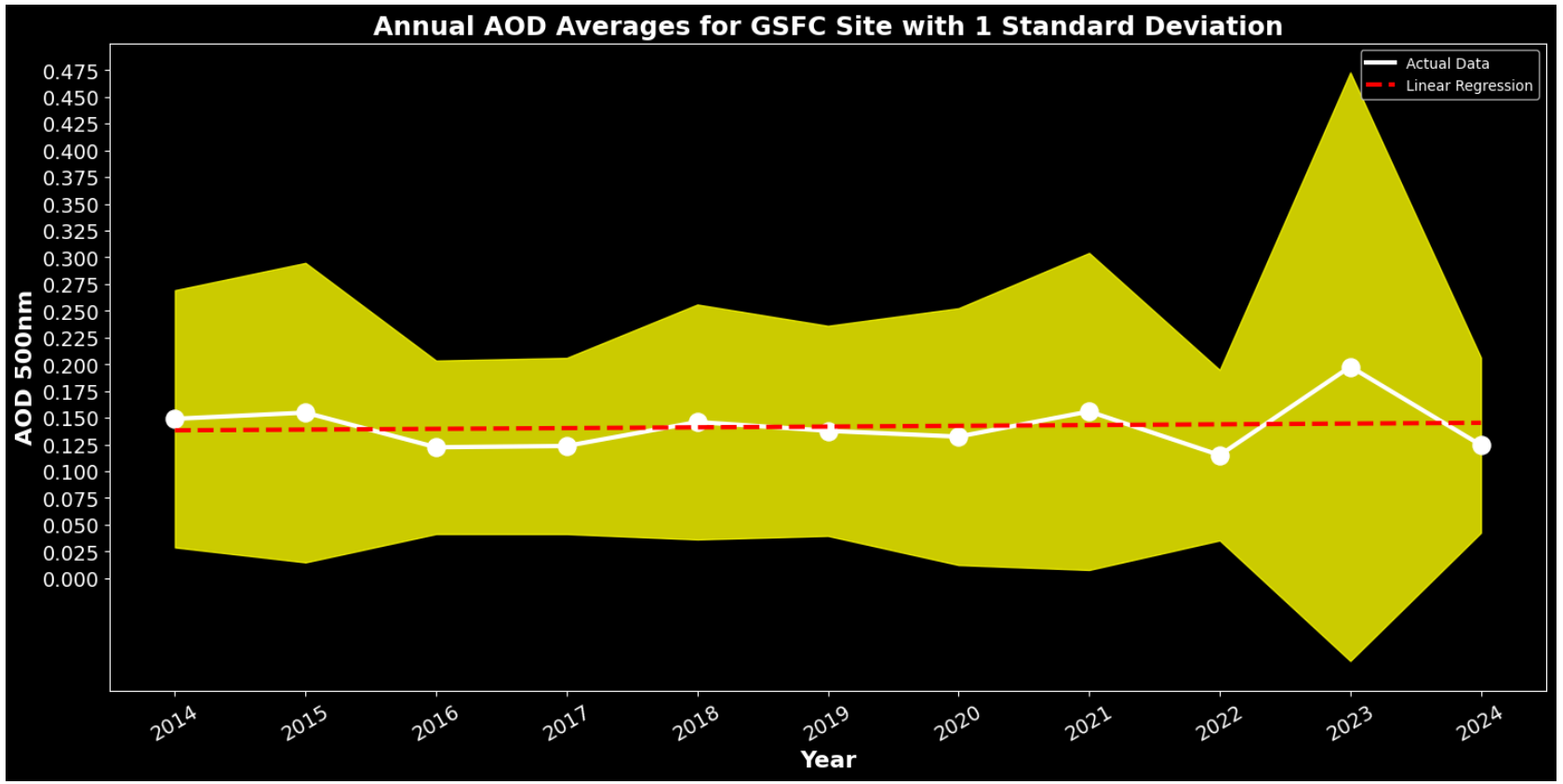


Sample Output – AERONET Time Series Plots

(3)

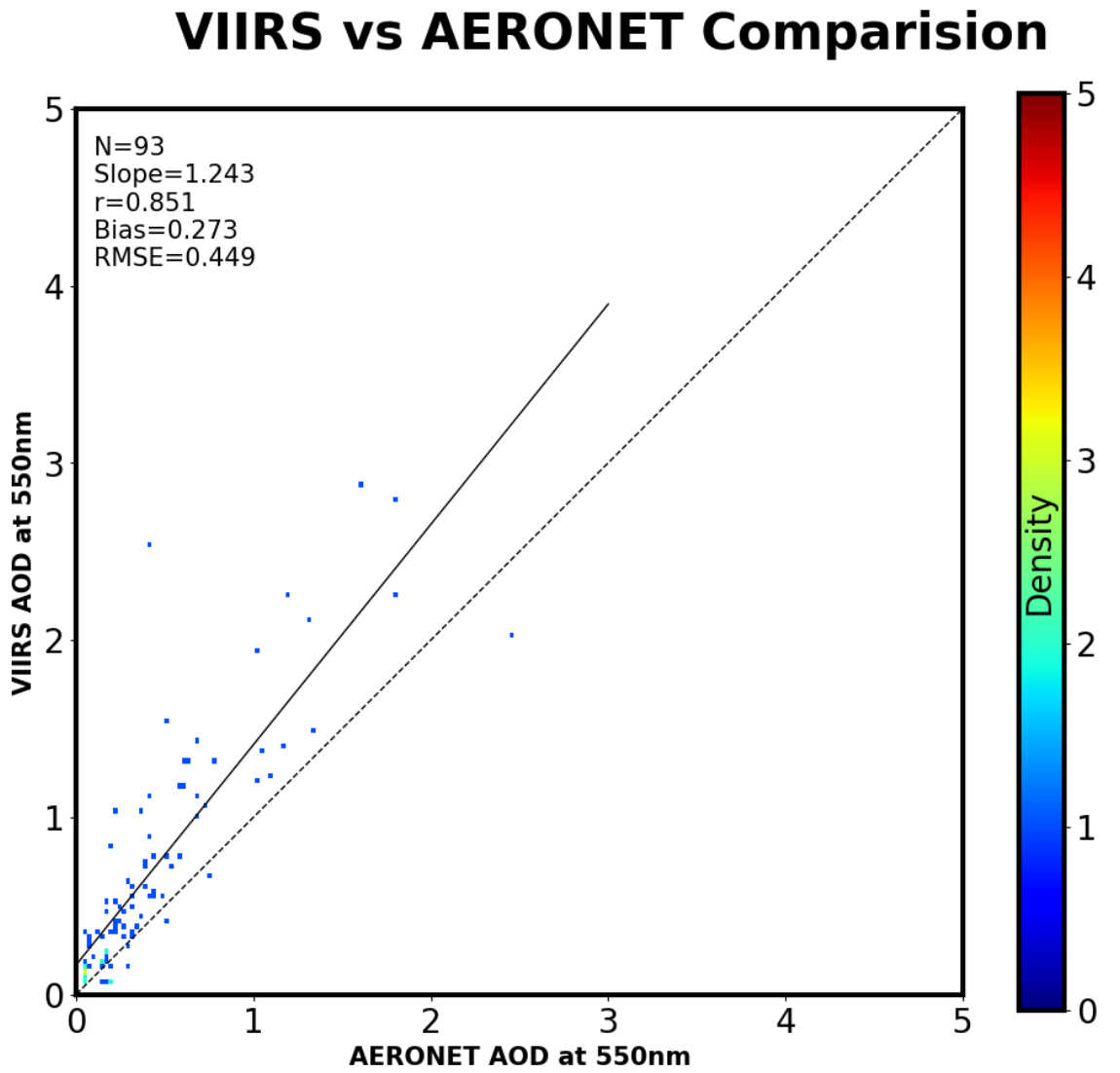


(4)



Sample Output: VIIRS – AERONET Comparison

- Code uses LAADS query file to read multiple NetCDF files from EOSDIS and retrieve AOD 550 nm data from the VIIRS satellite.
- Similar input parameters are used to access AERONET web API and retrieve AOD data for 440 nm, 500 nm, and 675 nm channels.
- Performs data collocation, where AERONET and VIIRS data are matched based on location and time.
- Functions for spatial averaging and statistical comparison are used for analysis, where AOD 550 nm for AERONET is interpolated using the 3 channels.
- Produces collocated data, as well as comparison graph.



AERONET Google Colab Codes - Preliminaries

- **Primary Requirement:** Google Account and Internet Access

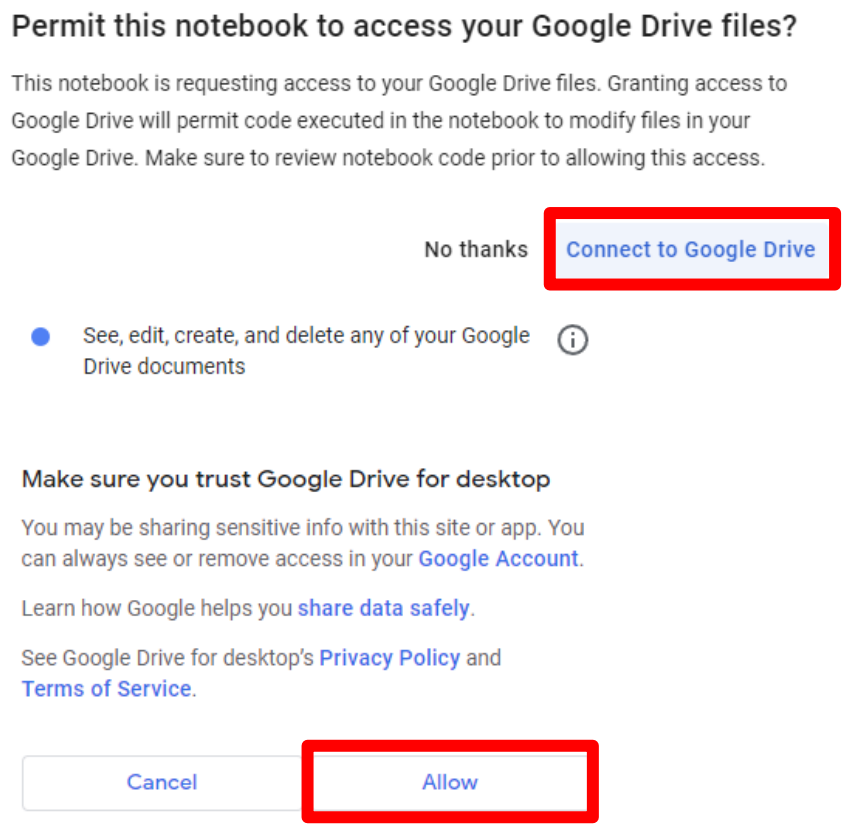
Required Libraries – Cell 1

```
!pip install cartopy
!pip install --no-binary shapely shapely --force
!pip install beautifulsoup4
!pip install requests
!pip install geopandas
```

```
from bs4 import BeautifulSoup
import requests
import shutil
import numpy as np
import datetime
import pandas as pd
import geopandas as gpd
import matplotlib.pyplot as plt

import cartopy.crs as ccrs
import cartopy.feature as cfeature
from copy import deepcopy as dc
```

Connecting Local Drive to Colab Notebook – Cell 2



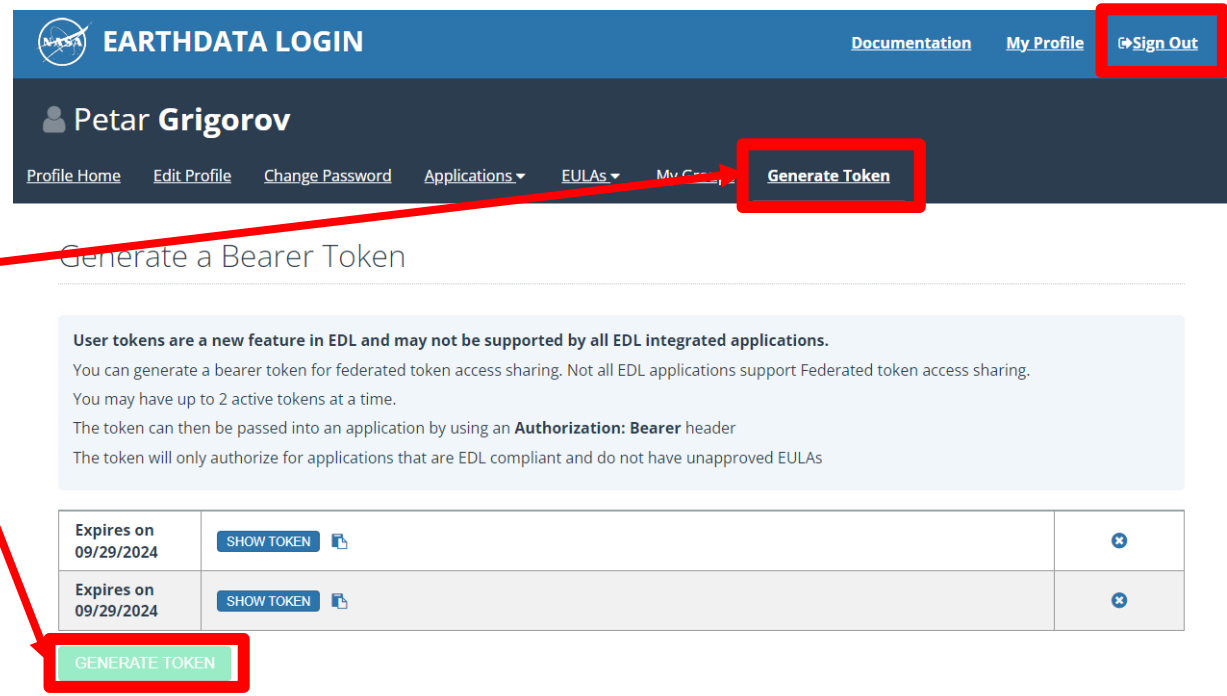
Input Parameters – Cell 3

```
dt_initial = '20230615'
dt_final = '20230629'
level = 1.5
average_type = 1
vis_min = 0.0
vis_max = 1.0
feature_choice = 1
wavelength = 500
Angstrom_exp = '440-675'
long_west,long_east = -130,-65
lat_south,lat_north = 25,50
```

VIIRS – AERONET Collocation Code Preliminaries

- **Requirements:**
  1. Earthdata Credentials: https://urs.earthdata.nasa.gov/
  2. Generate token.
  3. Copy and place token in code (cell 6 – *auth*).
  4. Ensure LAADS applications are approved for profile authentication *(Applications -> Authorized Apps)*.
  5. Download query file from LAADS: https://ladsweb.modaps.eosdis.nasa.gov/search/.
  6. Ensure LAADS and AERONET coordinate box inputs match.

(1)



(2)

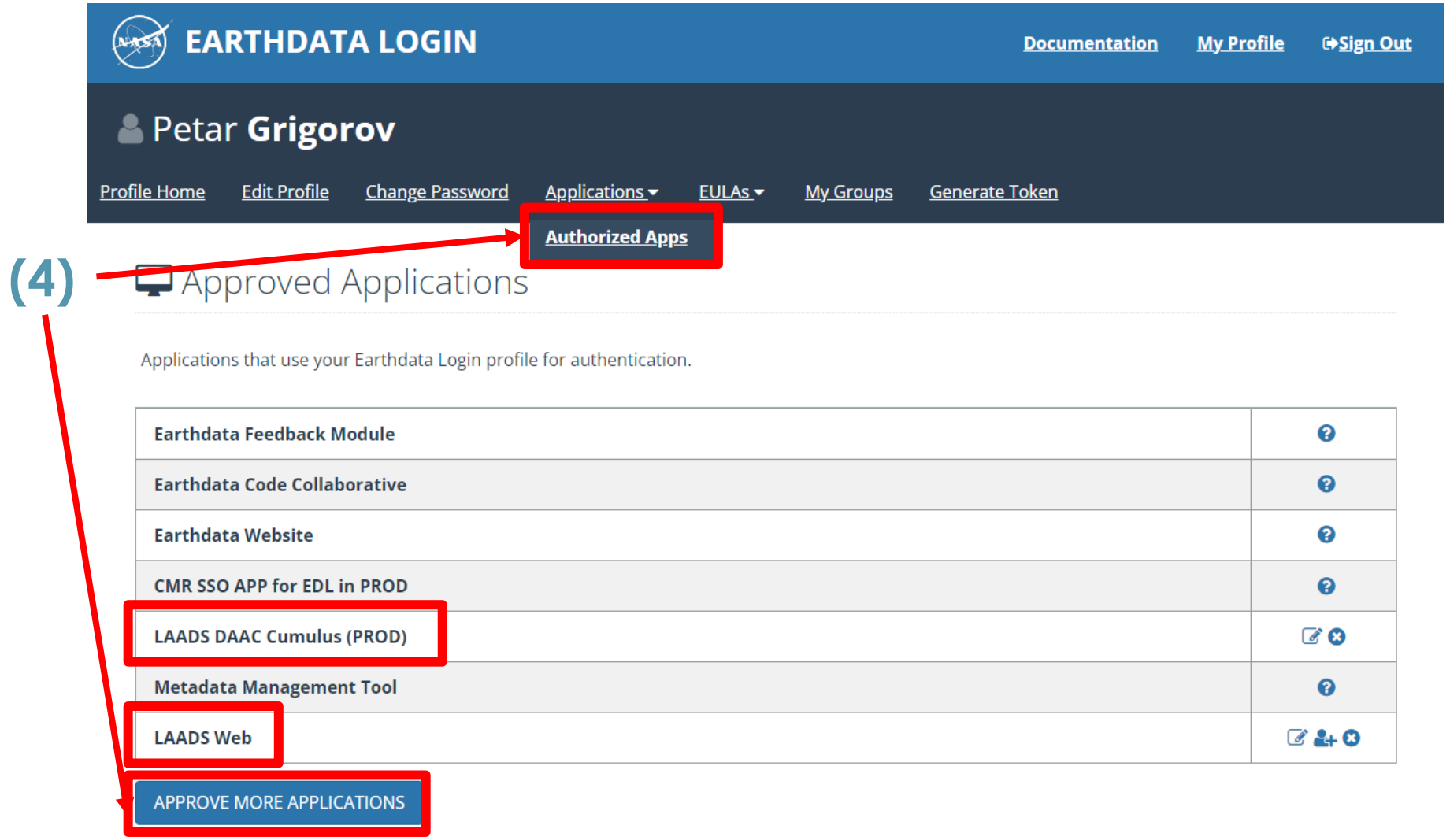
```
download_path = working_directory + "AERDT/"
if not os.path.exists(download_path):
  os.makedirs(download_path)

#auth = {"Authorization": "Bearer eyJ0eXAiOiJKV1QiLCJvcmlnaW4iOiJFYXJ0aGRhdGEgTG9
auth = {"Authorization": "Bearer eyJ0eXAiOiJKV1QiLCJvcmlnaW4iOiJFYXJ0aGRhdGEgTG9
```

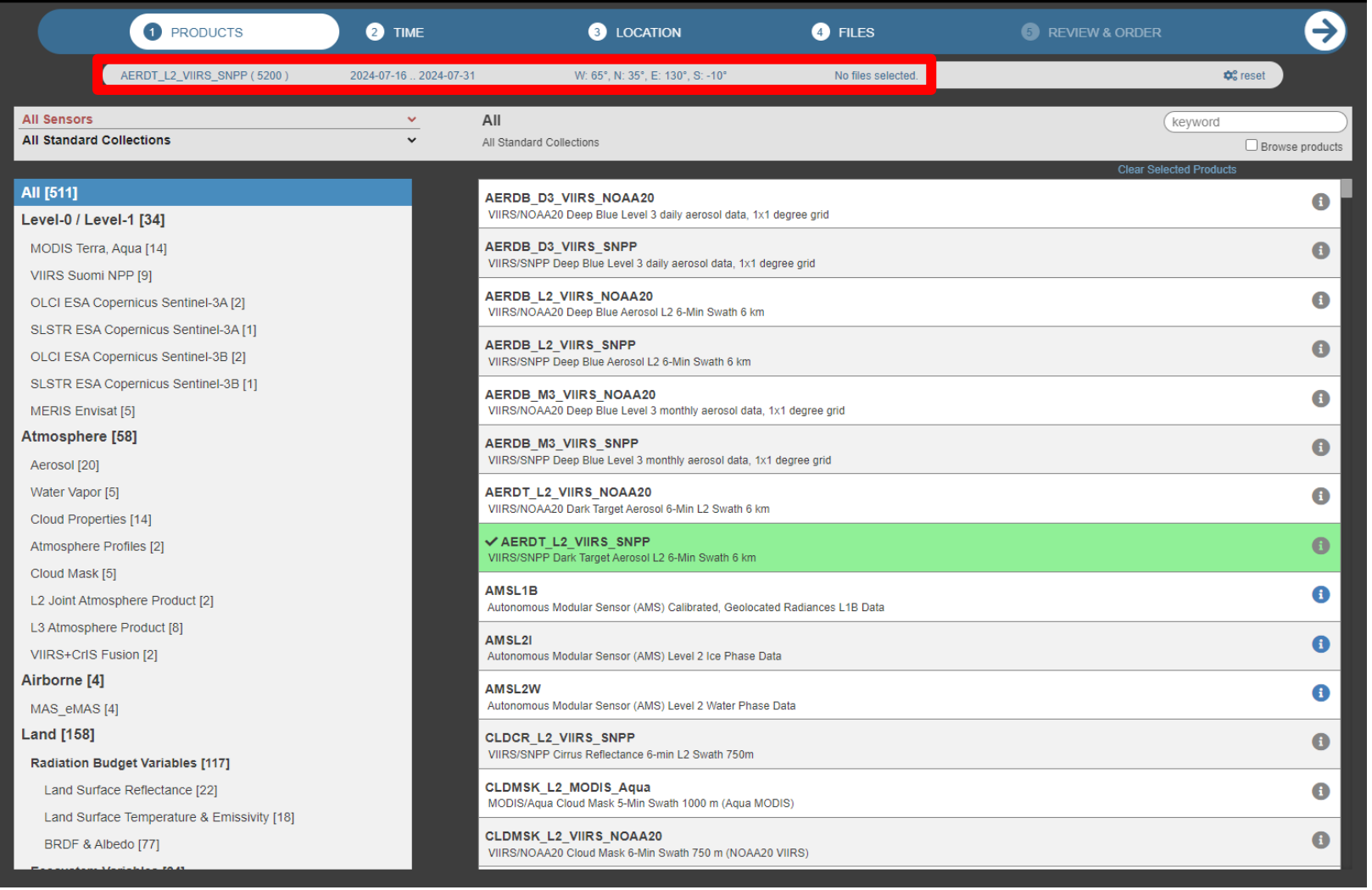
(3)

VIIRS – AERONET Collocation Code Preliminaries (LAADS Applications)

- Select "Applications > Authorized Apps"
- Select "Approve More Applications"
- Search "laads"
- Select "Authorize"



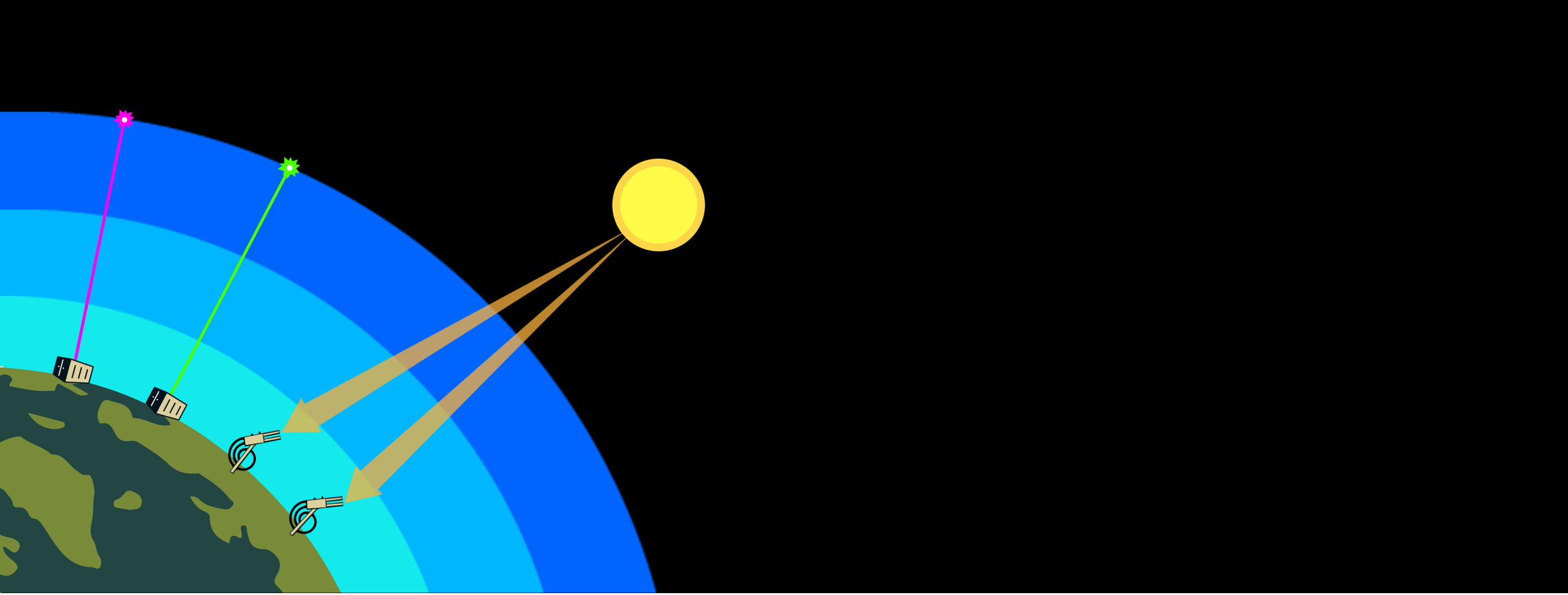
(5) VIIRS – AERONET Collocation Code Preliminaries (Query File)



- Select Product: AERDT_L2_VIIRS_SNPP
- Select Timeframe
- Specify Coordinates
- Download list of files as .csv, do not download the files themselves
- Ensure coordinates match for proper collocation (cell 7)

(6)

```
# Defining Global Variables
level =15 # AERONET data level --- 15 for Level 1.5
#average_type=2 #daily (1), hourly (2), timeavg (3)
AOD_min=0.0
AOD_max=1.0
long_west,long_east,lat_south,lat_north = 65., 130., -10., 35.
```



Part 2:
Summary

Summary

Network	Type	Primary Measurands	Number of Sites	Vertical Coverage
AERONET	Passive	Aerosols (Optical, Microphysical, Radiative)	~600 Active	Total Column

- There are many ways to access and analyze AERONET data:
  - The AERONET website links to interactive site maps, data visualizations, and download tools.
  - The data synergy tool allows comparison with satellite data and other ground networks.
  - The Web API allows programming languages to access data automatically.
  - The AERONET GitHub page includes examples of code to access data using the Web API.

Acknowledgments

- AERONET Team
- AERONET Site PIs
- AERONET Site Managers
- NASA HQ
- International Partners

Looking Ahead to Part 3

- We will learn about Pandora, another ground-based passive remote sensor.
- Pandora complements AERONET with information on trace gases like ozone and nitrogen dioxide.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 08/22/2024
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 09/05/2024**

- **Certificate of Completion:**
  - Attend all five live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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- aeronet-join@lists.nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Programs:

- DEVELOP
- SERVIR

Resources

- AERONET Website
  - AERONET Site Information Map
  - AERONET Data Display Interface
  - AERONET Data Download Interface
  - AERONET Data Synergy Tool
  - AERONET Map Explorer
  - AERONET GitHub


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!