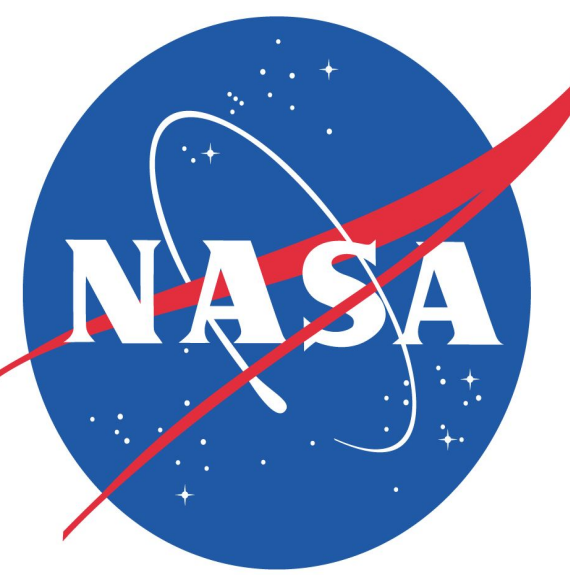# The NASA MERRA-2 Reanalysis Products: Data and Tools Used for Aerosol and Air Quality Studies

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NASA/Goddard EARTH SCIENCES DATA and INFORMATION SERVICES CENTER (GES DISC). **Website:** https://disc.gsfc.nasa.gov/. **Contact us at** gsfc-dl-help-disc@mail.nasa.gov, xiaohua.pan@nasa.gov

1. Introduction

The NASA Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) is reanalysis data spanning from 1980 to the present. It is produced by the NASA Global Modeling and Assimilation Office (GMAO) and distributed by the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). MERRA-2 data has 100 collections, including Earth system variables (mainly from an atmospheric model) such as meteorological, radiation, and aerosol fields. MERRA-2 data has been one of the most popular datasets from NASA that are widely used in interdisciplinary research and applications, with a consistently increasing number of users. For example, more than 7000 unique users accessing the MERRA-2 data at GES DISC in 2021.

This presentation will introduce the MERRA-2 data sets associated with aerosol and air quality studies. We will also update the status of the cloud migration of the MERRA-2 data to Amazon Web Services (AWS).

2. MERRA-2 Data

General features:
- Generated by NASA GMAO (https://gmao.gsfc.nasa.gov/reanalysis/)
- Archived and curated at NASA GES DISC (https://disc.gsfc.nasa.gov)
- Model Version: 5.12.4
- Total of 100 collections (95 standard collections, 4 derived climate statistical collections, and 1 value-added collection - monthly PM2.5 at country level)
- Format: NetCDF4
- Temporal Range: 1980-01-01 to Present
- Temporal Resolution: Hourly, 3-Hourly, Daily, Monthly, and Monthly Diurnal
- Spatial Coverage: Global
- Spatial Resolution:
    2D: 0.5° × 0.625°
    3D: 0.5° × 0.625° × 72 model levels or 0.5° × 0.625° × 42 pressure levels
- Data Latency: ~3 weeks
- Users: Nearly 7,000 in 2022
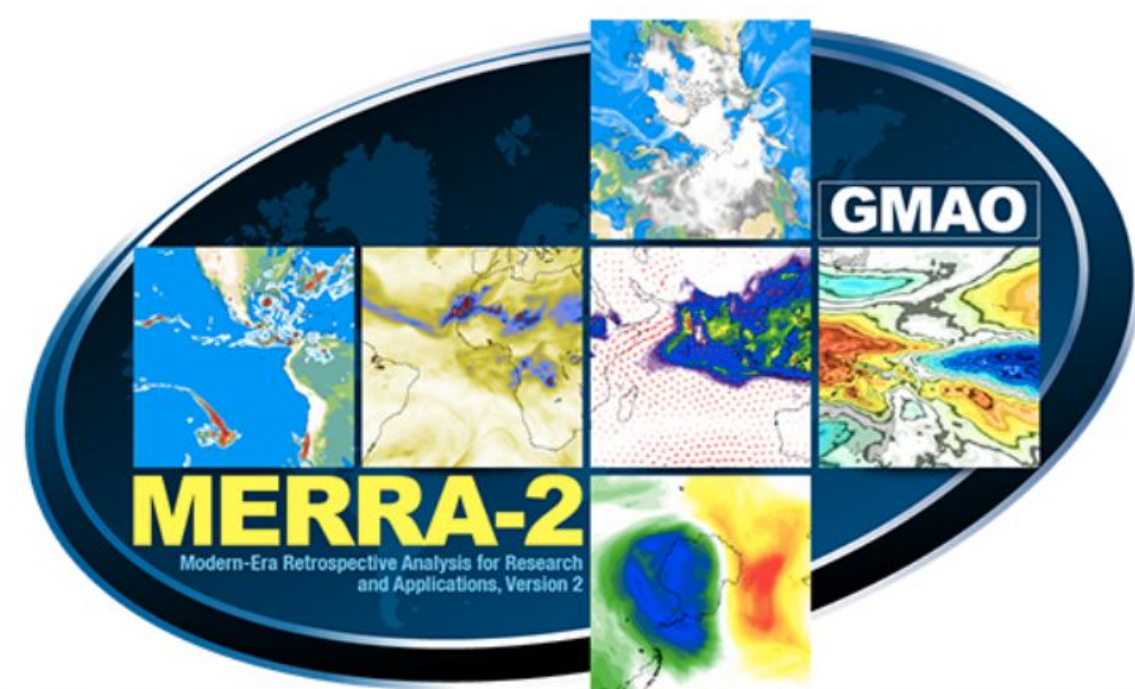
New products:
- Monthly PM2.5 at country level (read data release news)
- Four version 2 of monthly statistical collections based on 1991-2020 climatology (read data release news)

Products in the AWS Cloud:
- 99 MERRA-2 collections are in AWS US west-2 region as of May 25, 2023. Earthdata Cloud

Recommendation to users:
- Please cite the dataset DOI when using MERRA-2 data (see example shown below). We collect and promote your paper in our publication database

Global Modeling and Assimilation Office (GMAO) (2022), MERRA-2 statM_2d_edi_Nx: 2d, Single-Level, Monthly Extremes Detection Indices based on 1991-2020 V2, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: [*Data Access Date*], 10.5067/O8AX56DO60MI

## 3. Key MERRA-2 Collections and Variables Useful for Aerosol and Air Quality Studies

Measurements	Data Collection	Parameters (variable long-name in the collection)	Temporal Feature
Aerosol Optical Depth (AOD)	M2T1NXAER_5.12.4 (i.e., tavg1_2d_aer_Nx)	total aerosol extinction aot [550 nm]	1 hourly averaged
	M2TMNXAER_5.12.4 (i.e., tavgM_2d_aer_Nx)	total aerosol extinction aot [550 nm]	monthly mean
& PM2.5	M2T1NXAER_5.12.4 (i.e., tavg1_2d_aer_Nx)	surface mass concentration of SO_4, BC, OC, dust, and sea salt	1 hourly averaged
	M2TMNXAER_5.12.4 (i.e., tavgM_2d_aer_Nx)	surface mass concentration of SO_4, BC, OC, dust, and sea salt	monthly mean
@ $PM_{1.0}$ & PM_{10}	M2I3NVAER_5.12.4 * (i.e., inst3_3d_aer_Nv)	mixing ratio of SO_4, BC, OC, dust, and sea salt	3 hourly instantaneous
Carbon Monoxide (CO)	M2T1NXCHM_5.12.4 (i.e., tavg1_2d_chm_Nx)	CO surface concentration	1 hourly averaged
	M2TMNXCHM_5.12.4 (i.e., tavgM_2d_chm_Nx)	CO surface concentration	monthly mean
Meteorological Conditions	M2T1NXSLV_5.12.4 (i.e., tavg1_2d_slv_Nx)	wind, specific humidity, air temperature at 2-meter, 10-meter, 850 hPa	1 hourly averaged
	M2TMNXSLV_5.12.4 (i.e., tavgM_2d_slv_Nx)	wind, specific humidity, air temperature at 2-meter, 10-meter, 850 hPa	monthly mean
	M2T1NXFLX_5.12.4 (i.e., tavg1_2d_slv_Nx)	PBL height, precipitation	1 hourly averaged
	M2TMNXFLX_5.12.4 (i.e., tavgM_2d_slv_Nx)	PBL height, precipitation	monthly mean
	M2T3NVASM_5.12.4 * (i.e., tavg3_3d_asm_Nv	wind, relative humidity, air temperature, pressure, height at model levels	3 hourly averaged

& Surface $PM_{2.5}$ can be derived by variables listed in that collection:
    TOTSPM25 = OCSMASS+ BCSMASS+ SO4SMASS*1.375+ DUSMASS25 + SSSMASS25.
@ $PM_{1.0}$ and PM_{10} the formula can be found at the MERRA-2 project FAQ .
* In 3D (the rest collections in this table are in 2D).

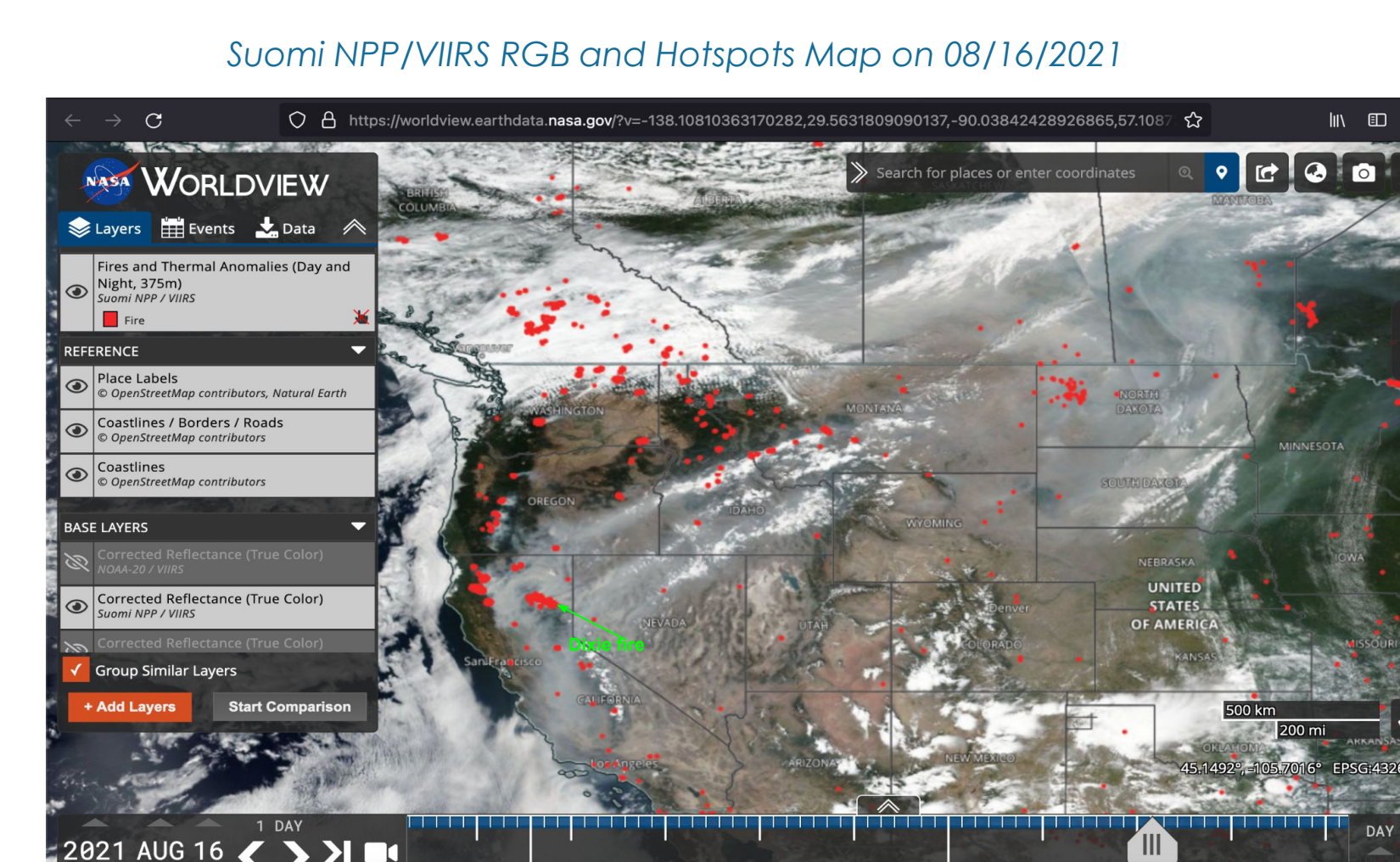## 4. GES DISC Data Services and User Support

- **Value-added services for data**
    - Giovanni
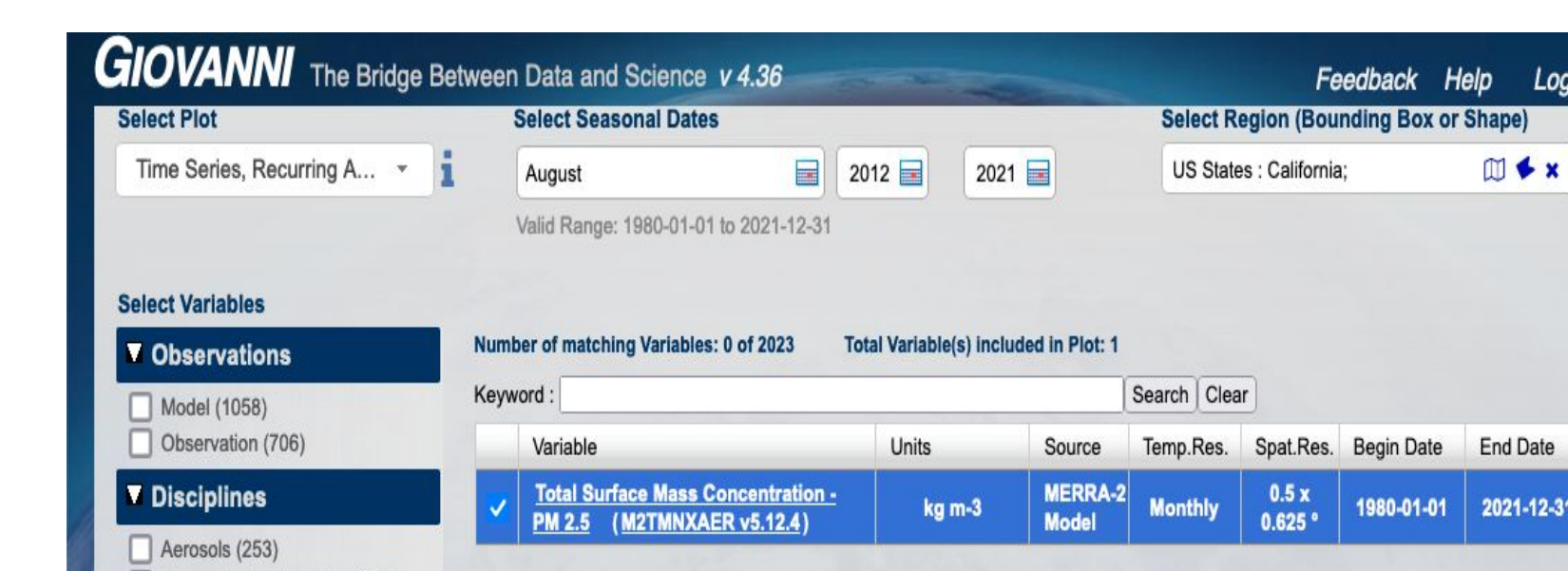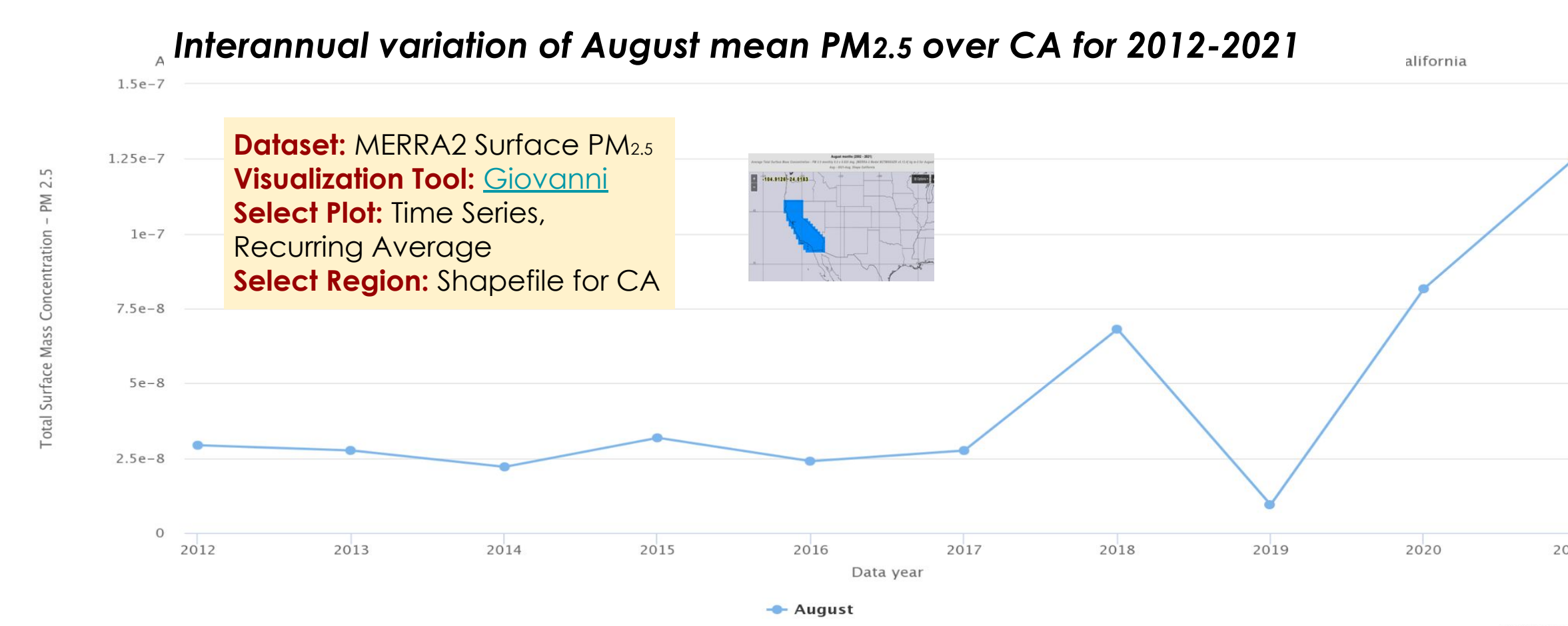   - Subsetting, reformatting, and regridding
    - Cloud dashboard
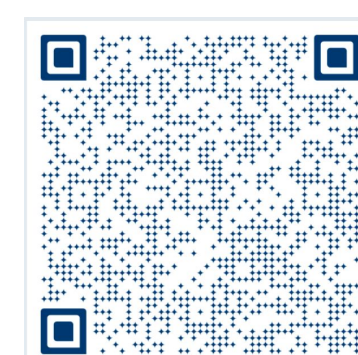
- **Multi-tiered user support**
    - - GES DISC Help Desk: Contact us at   gsfc-dl-help-disc@mail.nasa.gov
    - - Forum: forum.earthdata.nasa.gov
    - - Social Media Platform (e.g., Twitter @NASAEarthdata, and Youtube NASA Earthdata channel)

Interannual variation of August mean PM2.5 over CA for 2012-2021

california

Dataset: MERRA2 Surface PM2.5
Visualization Tool: Giovanni
Select Plot: Time Series, Recurring Average
Select Region: Shapefile for CA

- **Case Study with Giovanni**

Suomi NPP/VIIRS RGB and Hotspots Map on 08/16/2021

Screenshot from NASA Worldview

- **Documentation:**
    - MERRA-2 Project Page

- **Data How-to:**
    - How to remotely access MERRA-2 with Python3 and calculate monthly average surface PM2.5 for world countries (link)
    - How to Use the Web Services API for Subsetting MERRA-2 Data - revised (link)
    - How to Access MERRA-2 Data using OPeNDAP with Python3 and Calculate Daily/Weekly/Monthly Statistics from Hourly Data (link)
    - How to Compile Your Own Variable List from Multiple GES DISC's Products using My Dashboard (link)
    - How to Directly Access MERRA-2 Data from an S3 Bucket with Python from a Cloud Environment (link)

Data Tutorial:
- ARSET training, "Tools for Analyzing NASA Air Quality Model Output", showing how to search for MERRA-2 variables and documents on the GES DISC website, and demonstrating how to use data tools for the MERRA-2 data such as Giovanni and the Level 3 and Level 4 subsetter (Part 1 of the training series)