Australian Bushfire in 2020: Accessing MERRA-2 Data in GES DISC Remotely through OPeNDAP & Calculating Statistics with Python3

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NASA/Goddard EARTH SCIENCES DATA and INFORMATION SERVICES CENTER (GES DISC), website: https://disc.gsfc.nasa.gov/

1. Introduction

The June 2019 to May 2020 Australia bushfire was devastating (***Figure 1***). According to Wikipedia, the fires burned about 18.6 million hectares, and the economic damages exceeded the AU$4.4 billion of the 2009 Black Saturday fires. At its peak, air quality dropped to hazardous levels in all southern and eastern states (***Figure 2,*** *and* ***8***).

In this research showcase, the evolution and transport of thick haze from the 2020 Australia bushfire is tracked using the NASA Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) data. We demonstrated using xarray, a Python3 library, on 1) how to remotely access (without downloading data) the hourly data through a Open-source Project Network Data Access Protocol (OPeNDAP) web service; 2) how to calculate the daily and weekly statistics from hourly data, such as aerosol optical thickness (AOT). 3) We also showed how to derive the surface $PM_{2.5}$ (particulate matter with a diameter of 2.5 μm or less) data from the existing aerosol composition data, and 4) visualized the daily and weekly evolution of Australian bushfire during January 2020 with AOT and $PM_{2.5}$ data.

Figure 1. *Australia bushfires map on Jan. 16, 2020. (Courtesy: https://www.the-sun.com/news/43290/australia-bushfires-what-caused-them-and-what-is-the-latest/)*

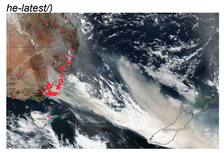

Figure 2. *The fire hotspots (red) in New South Wales and Victoria of Australia and spread of smoke on Jan. 1, 2020, viewed from Suomi NPP /VIIRS. (Courtesy: NASA worldview)*

2. Data - MERRA-2

The NASA Global Modeling and Assimilation Office (GMAO) provides the MERRA-2 reanalysis global data at 0.5 x 0.625 spatial resolution covering the time period of 1980 to present (Gelaro et al., 2017). The NASA GES DISC data center (https://disc.gsfc.nasa.gov/) distributes the MERRA-2 data (***Figure 3***). In this research showcase, we used the MERRA-2 aerosol reanalysis, which is the first multidecadal aerosol reanalysis (Randles et al., 2017, Buchard et al., 2017). In particular, we used the aerosol diagnostics collection, M2T1NXAER.5.12.4, 1-hourly time-averaged single-level global aerosol Assimilation (GMAO 2015).

In the MERRA-2 model system, aerosols include five composites, namely, organic aerosol (OC), black carbon (BC), sulfate (SU), dust (DU), and sea salt (SS). Users can get the AOT (with a variable name "TOTEXTTAU") directly from this aerosol collection, but the surface $PM_{2.5}$ concentration ("TOTSPM25") has to be calculated with the existing individual composite as below:

Surface $PM_{2.5}$: TOTSPM25 = OCSMASS+ BCSMASS+ SO4SMASS*1.375+ DUSMASS25 + SSSMASS25

Figure 3. *Find the OPeNDAP URL of the collection M2T1NXAER.5.12.4 from its landing page in GES DISC website (https://disc.gsfc.nasa.gov/).*

helpful tips

Please refer more information at **MERRA-2 Data Access – Quick Guide** https://disc.gsfc.nasa.gov/information/documents?title=MERRA-2%20Data%20Access%20%E2%80%93%20Quick%20Guide

3. Access data in GES DISC remotely

Procedures

1. Register Earthdata and set up the credential environment for Mac/Linux system. Refer to this HowTo webpage for more details and instructions for Windows system

1.1 Create an Earthdata account and link GES DISC with your account by following the top two (or three) steps in the GES DISC data access instruction page link: https://disc.gsfc.nasa.gov/data-access.

1.2 Work on authentication of remotely accessing data by setting up environment variables in your local machine (from which you access data) following steps below by taking Mac/Linux system for example. In your $HOME directory, create three files below (Note: only need to add the new lines if files exist):

- Create a **".netrc"** file using the following commands in sequence, replacing <uid> and <password> with your Earthdata username and password:
  touch $HOME/.netrc
  echo "machine urs.earthdata.nasa.gov login <uid> password <password>" >> ~/.netrc
  chmod 600 ~/.netrc
- Create a **".urs_cookie"** file
  touch $HOME/.urs_cookies
- Create a **".dodsrc"** with two lines below to tell Data Access Protocol (DAP) clients to use the ".netrc" file for authentication information, replacing <absolute path of home directory> with the absolute path of your home directory, e.g., /Users/YourName (note that ~ or $HOME doesn't work):
  HTTP.COOKIEJAR=<absolute path of home directory>/.urs_cookies
  HTTP.NETRC=<absolute path of home directory>/.netrc

2. Remotely access MERRA-2 data in GES DISC with Python3

```
# Read the OPeNDAP URLs with xarray (only shows 2 days for demonstration)
ds = xarray.open_mfdataset(['https://goldsmr4.gesdisc.eosdis.nasa.gov/opendap/MERRA2/M2T1NXAER.5.12.4/2020/01/MERRA2_400.tavg1_2d_aer_Nx.20200101.nc4',
'https://goldsmr4.gesdisc.eosdis.nasa.gov/opendap/MERRA2/M2T1NXAER.5.12.4/2020/01/MERRA2_400.tavg1_2d_aer_Nx.20200102.nc4'])
```

Note: This showcase is written in Python3 (v3.9.2), with these major libraries: xarray (0.17.0), matplotlib (3.4.1), and cartopy (0.18.0). It will take about 5 minutes to open 1-month data.

4. Calculate Statistics

Calculate the weekly mean (sel_var_weekly_mean) from the selected hourly variable value (sel_var_value) using the library, xarray. Note that an ISO calendar week is used here, i.e., from Monday to Sunday, and only available data are counted towards weekly mean. For example, for the 1st week of 2020, only 5 days are counted, from Jan. 1, 2020 (Wed.) to Jan. 5, 2020 (Sun.) since we read data from Jan.1 to 31, 2020. But for the 2nd week of 2020, all seven days are available and thus counted.

```
# Select an hourly variable, e.g., "TOTEXTTAU" (i.e., AOT), and obtain its value
    sel_var_value = ds["TOTEXTTAU"]
# Calculate the weekly mean (i.e., the mean of each week at each grid), see Fig 4 & 5
    sel_var_weekly_mean = sel_var_value.resample(time="1w").mean(dim='time', skipna=True)
```

References

Gelaro, Ronald, et al., 2017. The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2). *J. Clim.*. Vol. 30, No. 14, pp. 5419-5454. DOI: 10.1175/JCLI-D-16-0758.1 ISSN: 0894-8755

Randles, C. A., et al., 2017. The MERRA-2 Aerosol Reanalysis, 1980 Onward. Part I: System Description and Data Assimilation Evaluation. *J. Clim.*. Vol. 30, No. 17, pp. 6823-6850. DOI: 10.1175/JCLI-D-16-0609.1 ISSN: 0894-8755, 1520-0442

Buchard, V., et al., 2017. The MERRA-2 Aerosol Reanalysis, 1980 Onward. Part II: Evaluation and Case Studies. *J. Clim.*. Vol. 30, No. 17, pp. 6851-6872. DOI: 10.1175/JCLI-D-16-0613.1 ISSN: 0894-8755, 1520-0442

Global Modeling and Assimilation Office (GMAO) (2015), MERRA-2 tavgM_2d_int_Nx: 2d,Monthly mean,Time-Averaged,Single-Level,Assimilation,Vertically Integrated Diagnostics V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: July 12, 2021, 10.5067/FQPTQ4OJ22TL

5. Visualize the 2020 Australian Bushfire

5.1 weekly mean

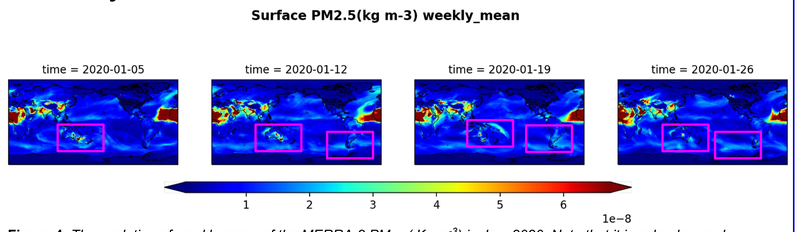

Figure 4. *The evolution of weekly mean of the MERRA-2 $PM_{2.5}$ (Kg m^{-3}) in Jan. 2020. Note that it is calendar week, starting from Monday to Sunday of each week. The time in the subtitle is labeled as the last day (Sunday) of that week..*

High surface $PM_{2.5}$ concentration was pronounced in the central and southeastern Australia in the 1st week of Jan. 2020 (see the highlighted magenta box in the leftmost panel of ***Figure 4***), the PM2.5 was elevated in South America (the 2nd week of Jan. 2020). Fire died down in the 3rd week. In the 4th week, fire further extinguished, however, the elevated $PM_{2.5}$ was evident in the southern hemisphere.

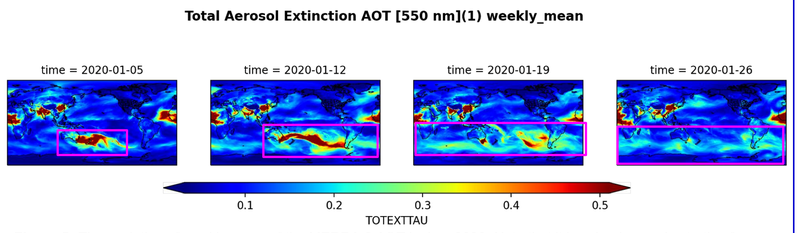

Figure 5. *The evolution of weekly mean of the MERRA-2 AOT in Jan. 2020. Note that it is calendar week, starting from Monday to Sunday of each week. The time in the subtitle is labeled as the last day (Sunday) of that week..*

The transported smoke is evident in the weekly mean AOT plot which represents column aerosol loading (***Figure 5***). Heavy smoke indicated by AOT was concentrated in the southeastern Australia and transported westward passing New Zealand (the 1st week of Jan. 2020) and reaching South America (the 2nd week of Jan. 2020). Fire died down in 3rd week, but the transported smoke circulated around the southern hemisphere. In the 4th week, fire further extinguished, however, the transported smoke was still evident in the southern hemisphere.

5.2 daily mean over a selected area

Figure 6. *The map of Australia, and the state of New South Wales is studied below.*

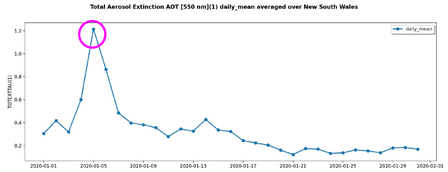

Figure 7. *The evolution of daily mean of the MERRA-2 AOT over New South Wales in Australia in Jan. 2020.*

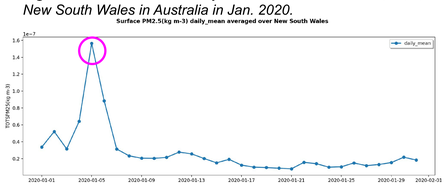

Figure 8. *The evolution of daily mean of the MERRA-2 $PM_{2.5}$ over New South Wales in Australia in Jan. 2020.*

New South Wales in southeastern Australia experienced the most fatalities (26 out of 34) and homes lost (2448 out of 3500+) in Australia during the 2019-20 bushfires. The daily mean aerosol loading over this region (administrative region subsetted with the shapefile, refer to ***Figure 6***) peaked on Jan. 5, 2020, with AOT reaching ~1.2 (***Figure 7***) and $PM_{2.5}$ ~160 ug m-3 (***Figure 8***) which was in a very unhealthy level according to the EPA standards. The daily mean aerosol loading in this region gradually decreased afterward.