Flowchart of Resources and Data Products for Health and Air Quality Applications with an Emphasis on Satellite Data

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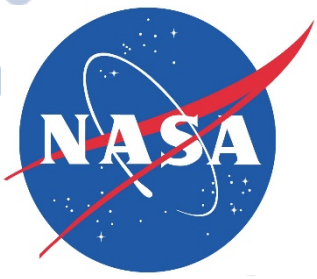


CONTENTS

Work for this document was funded by the NASA Health and Air Quality Applied Sciences Team (HAQAST). The ideas in this resource have been shaped by helpful feedback from the NASA HAQAST Ambassadors and we welcome ongoing input as we refine this document and develop the flowchart for health and air quality applications.

Introduction

This document is intended to be a resource for users that are interested in using satellite data but are new to the data products and their capabilities. This document contains a flowchart that will guide users from a general question or need to a specific resource. For brevity this document focuses on the United States, but this resource will be extended to provide data products for global applications. The possible end points of the flowchart include tutorials on the NASA Health and Air Quality Applied Sciences Team (HAQAST) website, Applied Remote Sensing Training (ARSET) tutorials, recommended publications, and websites with more information. The flowchart has a color scheme consisting of red and shades of blue, as shown in Figure 1. The starting point is the darkest shade of blue, shifting to lighter blues as the user advances through the flowchart. To promote a user-friendly experience, the user can click on the box guiding them to another page of the document. This clickable box will bring the user to the corresponding page in the document. The end points were selected using the HAQAST website,[1] the ARSET website,[2] and the Environmental Protection Agency (EPA) website.[3] End points with a tutorial available on the ARSET or HAQAST website will be indicated with the respective logo in the red box of the flowchart. The links for all end point resources are provided at the bottom of the page or in the tutorials and readings section of this document. These logos are shown in Figure 2. For any feedback please navigate to the Health and Air Quality Community Forum.[4] On this forum you can create an account and post any suggestions or comments in the "Flowchart Feedback" category.

Audience: Novice users
Platform: Interactive website with clickable boxes
End Points: HAQAST tutorials, ARSET tutorials, websites, suggested readings, and publications
Goal: Guide users from a general question to a specific resource
Starting Question Examples:
How can I get started looking at the variation of formaldehyde concentrations in my state?
There is a smoke plume out west, where can I go to see it in real time?
How can I see the change in aerosol optical depth over a couple of hours?
Where can I go to see locations of active fires?

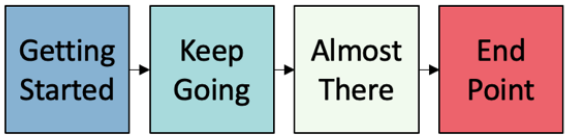
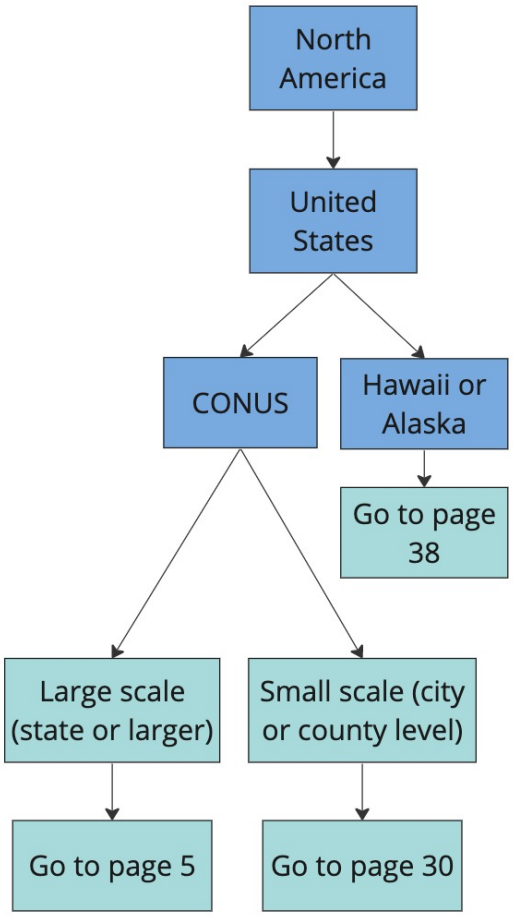


Figure 1: Color scheme

Figure 2: ARSET logo (left) and HAQAST

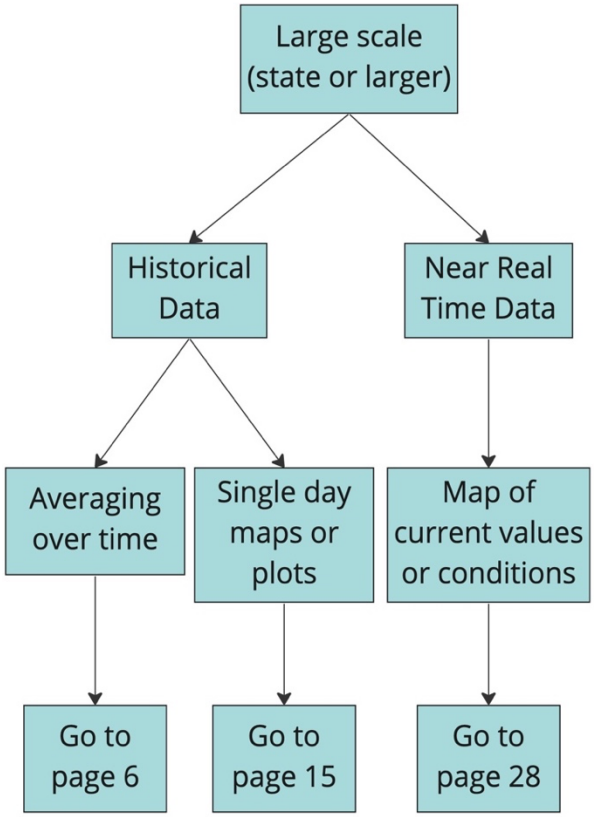
[1] NASA HAQAST - https://haqast.org/data-and-tools/
[2] NASA ARSET - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset
[3] EPA - https://www.epa.gov/outdoor-air-quality-data
[4] Health and Air Quality Community Forum - https://haq.community.forum/

Flowchart



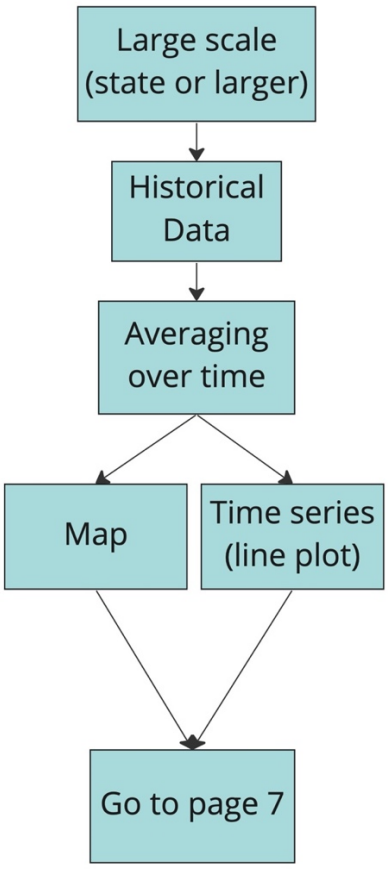
Upon starting the flowchart, the user will first determine the location of interest. Since this document is focusing on the United States, they will first choose between the Continental United States (CONUS) and Hawaii or Alaska.

- If they indicate that they are interested in CONUS, they will then determine what spatial scale they are interested in.
- If they determine they are looking at a large scale (approximately a state or larger), then they will be guided to page 5.
- If they determine they are looking at a small scale (approximately city or county level), then they will be guided to page 30.
- If they indicate that they are interested in Hawaii or Alaska, they will be guided to page 38.



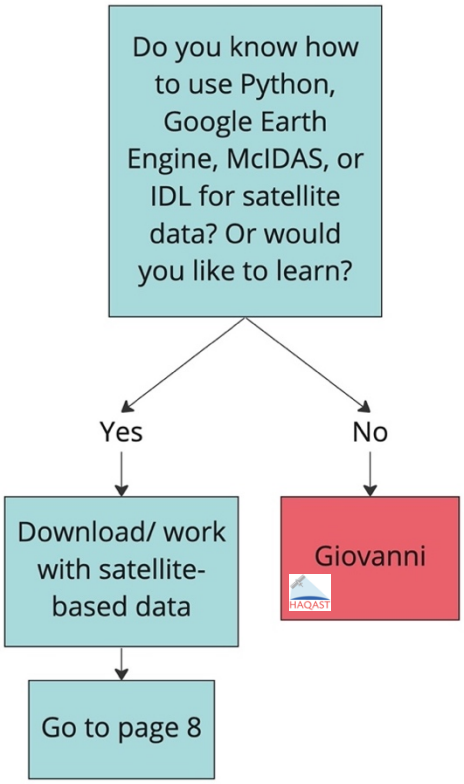
If the user previously indicated they are interested in a large spatial scale, they will then determine if they are looking for historical data or near real time data.

- If the user chooses historical data, they will then choose between averaging over time or single day maps/plots.
- If they indicate that they would like to average data over time, they will be guided to page 6.
- If they indicate that they would like single day maps or plots, they will be guided to page 15.
- If the user chooses near real time data instead of historical data, it is assumed that they would like a map of current values or conditions and they will be guided to page 28.



If the user previously determined that they are looking at a large spatial scale, a historical timeframe, and they would like to average satellite data over time, they will then determine if they would like to create a map or a time series (line plot).

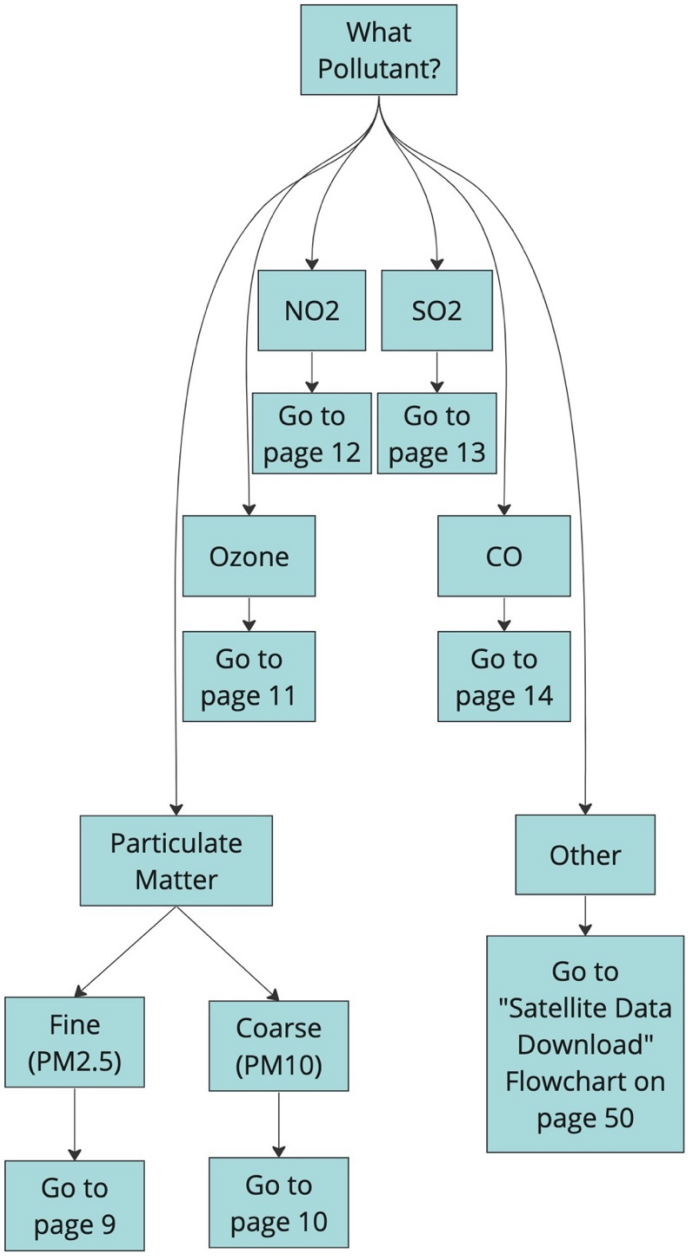
- In both cases, the user will be guided to page 7.



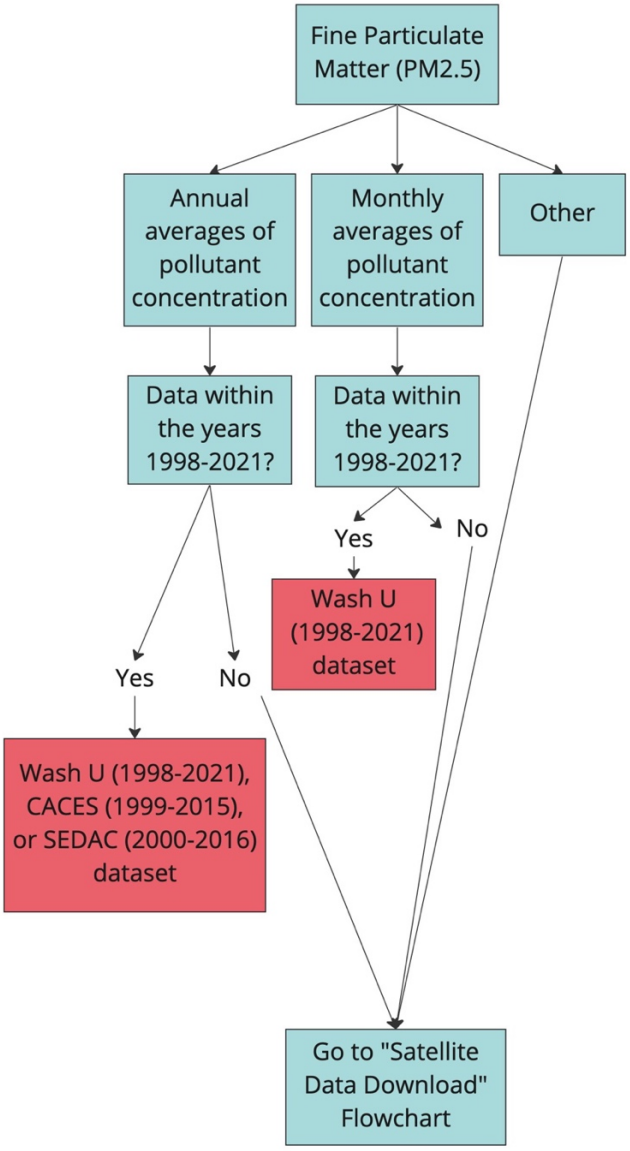
The user will then indicate if they know how to use Python, Google Earth Engine, the Man computer Interactive Data System (McIDAS), or Interactive Data Language (IDL) for satellite data, or if they would like to learn. Additionally, satellite data is available for a wide range of parameters related to health and air quality. Examples include pollutant concentrations, population density, or precipitation rates.

- If they do, they will be guided to download satellite-based data and advance to page 8 of this document. Downloading the data allows the user to create a wide range of plots and analyze the data in a way that makes the most sense for their research question.
- If the user is not familiar with any satellite-relevant applications, they will be guided to NASA Giovanni.[5] Giovanni has the capabilities to create a variety of maps and plots to display satellite imagery without coding skills. Some examples available include a time averaged map, animations, or a time series plot. Additionally, the user can select the time frame and the region of the globe. There is also a tutorial for Giovanni on the HAQAST website. See (1) on page 53 for this tutorial.

[5] NASA Giovanni - https://giovanni.gsfc.nasa.gov/giovanni/



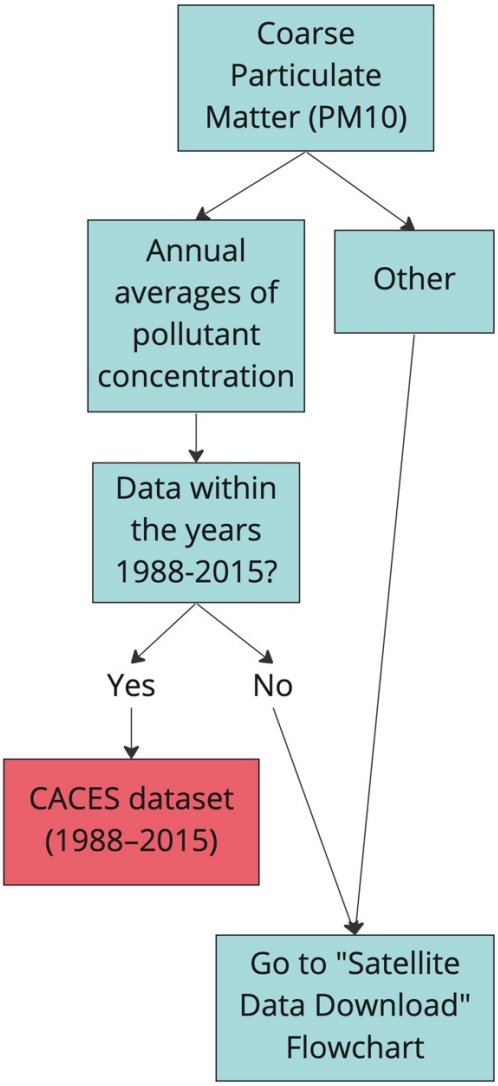
The user will then indicate which pollutant they are interested in. Based on their answer, they will be guided to a specific page of this document.



If the user previously indicated they are interested in fine particulate matter, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages, monthly averages, or something else.
- If they indicate that they are interested in annual averages, they will then determine if the time frame of interest is within 1998-2021.
- If it is, they will be guided to the Washington University in St. Louis dataset,[6] the CACES dataset,[7] or the SEDAC dataset.[8] The websites of these datasets offer publications that have utilized the datasets. It is recommended to explore these websites for more information.
- If they indicate that they are interested in monthly averages, they will then determine if the time frame of interest is within 1998-2021.
- If it is, they will be guided to the Washington University in St. Louis dataset.[5]
- If they answered “No” or “Other” to any of these questions, they will be guided to the “Satellite Data Download” flowchart on page 50. The “Satellite Data Download” flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly averages, they will be guided toward the “Satellite Data Download” flowchart.

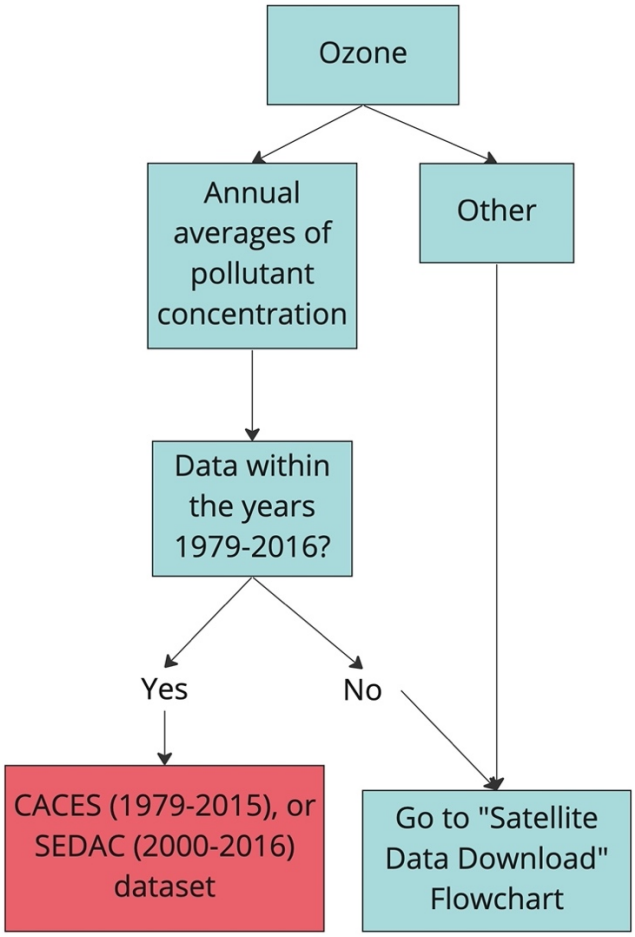
[6] Washington University in St. Louis dataset - https://sites.wustl.edu/acag/datasets/surface-pm2-5/#V5.GL.02
[7] CACES dataset - https://www.caces.us/data
[8] SEDAC dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016



If the user previously indicated they are interested in coarse particulate matter, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages or something else.
- If they are interested in annual averages, they will then determine if the time frame of interest is between 1988 and 2015.
- If it is, they will be guided to the CACES dataset.[9] The CACES website offers publications that have utilized this dataset. It is recommended to explore this website for more information.
- If they answered “No” or “Other” to any of these questions, they will be guided to the “Satellite Data Download” flowchart on page 50. The “Satellite Data Download” flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly or monthly averages, they will be guided toward the “Satellite Data Download” flowchart.

[9] CACES dataset - https://www.caces.us/data

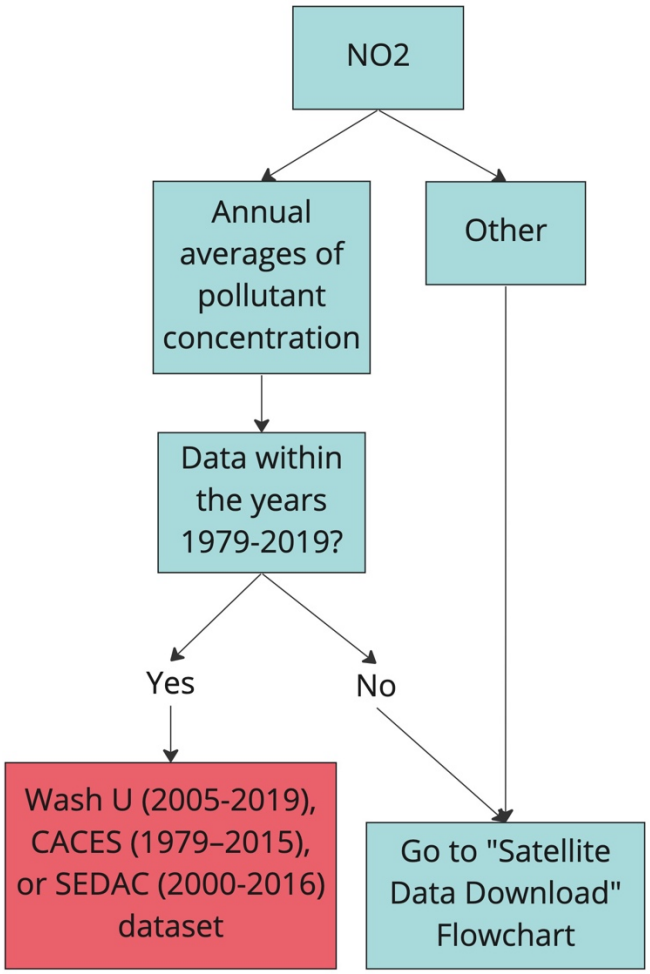


If the user previously indicated they are interested in ozone, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages or something else.
- If they indicate that they are interested in annual averages, they will then determine if the time frame of interest is between 1979 and 2016.
- If it is, they will be guided to the CACES dataset[10] or the SEDAC dataset.[11] The websites of these datasets offer publications that have utilized the datasets. It is recommended to explore these websites for more information.
- If they answered "No" or "Other" to any of these questions, they will be guided to the "Satellite Data Download" flowchart on page 50. The "Satellite Data Download" flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly or monthly averages, they will be guided toward the "Satellite Data Download" flowchart.

[10] CACES dataset - https://www.caces.us/data

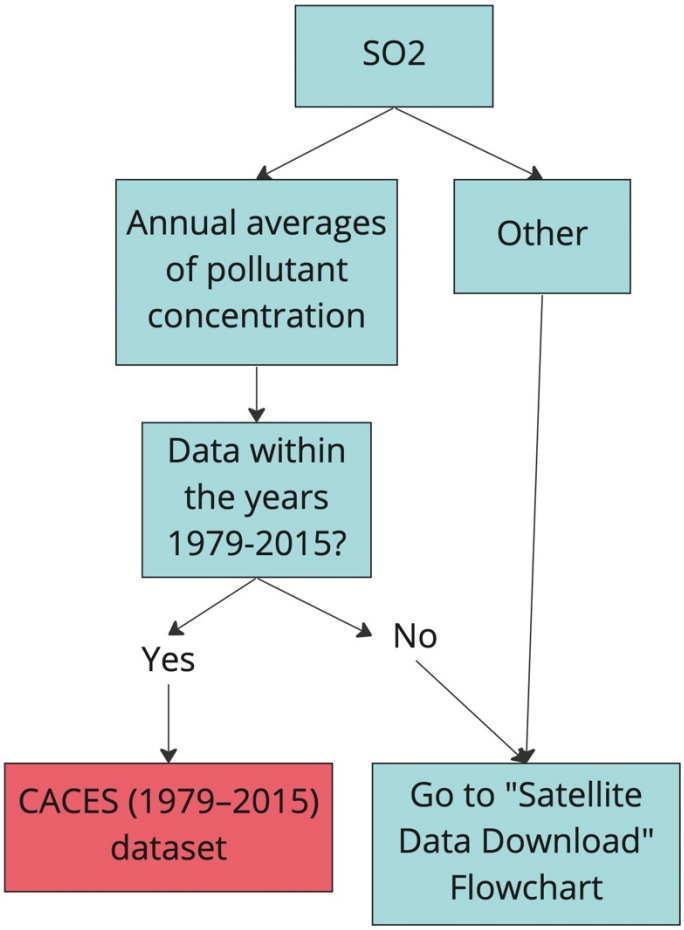
[11] SEDAC dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016



If the user previously indicated they are interested in NO_2, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages or something else.
- If they indicate that they are interested in annual averages, they will then determine if the time frame of interest is within the years 1979-2019.
- If it is, they will be guided to the Washington University in St. Louis dataset,[12] the CACES dataset,[13] or the SEDAC datasets.[14] [15] The websites of these datasets offer publications that have utilized the datasets. It is recommended to explore these websites for more information.
- If they answered "No" or "Other" to any of these questions, they will be guided to the "Satellite Data Download" flowchart on page 50. The "Satellite Data Download" flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly or monthly averages, they will be guided toward the "Satellite Data Download" flowchart.

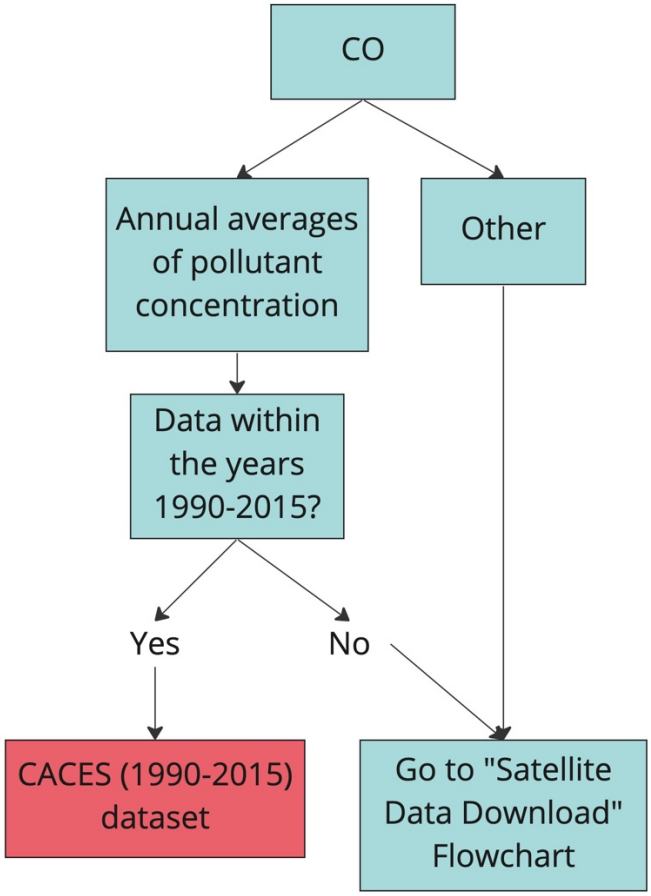
[12] Washington University in St. Louis dataset - https://sites.wustl.edu/acag/datasets/surface-no2/
[13] CACES dataset - https://www.caces.us/data
[14] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016
[15] SEDAC 1 km dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-no2-concentrations-contiguous-us-1-km-2000-2016



If the user previously indicated they are interested in SO_2, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages or something else.
- If they indicate that they are interested in annual averages, they will then determine if the time frame of interest is within the years 1979-2015.
- If it is, they will be guided to the CACES dataset.[16] The website of this dataset offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If they answered “No” or “Other” to any of these questions, they will be guided to the “Satellite Data Download” flowchart on page 50. The “Satellite Data Download” flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly or monthly averages, they will be guided toward the “Satellite Data Download” flowchart.

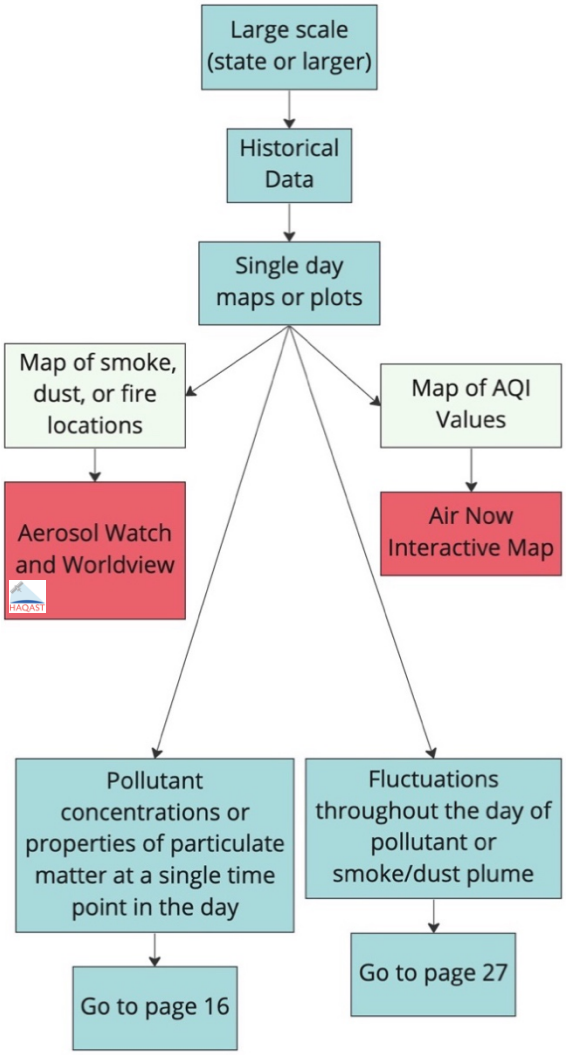
[16] CACES dataset - https://www.caces.us/data



If the user previously indicated they are interested in CO, they will be guided to this flowchart.

- They will then determine if they are interested in annual averages or something else.
- If they indicate that they are interested in annual averages, they will then determine if the time frame of interest is within the years 1990-2015.
- If it is, they will be guided to the CACES dataset.[17] The website of this dataset offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If they answered “No” or “Other” to any of these questions, they will be guided to the “Satellite Data Download” flowchart on page 50. The “Satellite Data Download” flowchart can be utilized for most spatial scales and time scales (starting in 2004 for some cases). For example, if the user is interested in a time scale that is not indicated on this flowchart, such as weekly or monthly averages, they will be guided toward the “Satellite Data Download” flowchart.

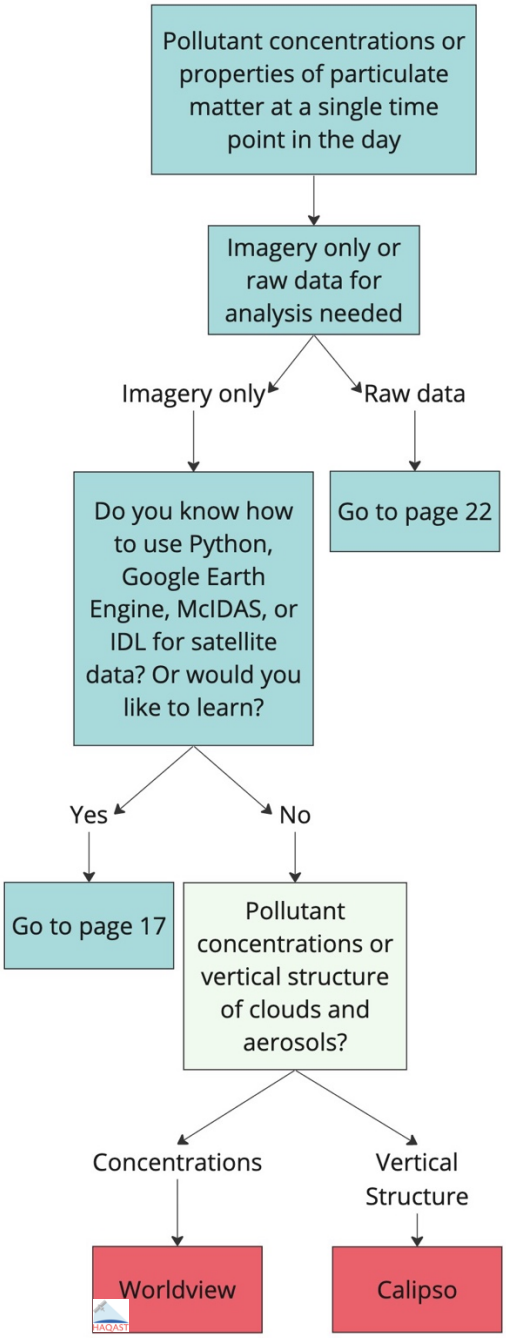
[17] CACES dataset - https://www.caces.us/data



If the user previously determined that they are interested in a large spatial scale, a historical timeframe, and they would like to create single day maps or plots they will be guided to this flowchart. The user will then need to decide if they are interested in (1) a map of smoke, dust, or fire locations, (2) pollutant concentrations or properties of particulate matter at a single time point in the day, (3) fluctuations throughout the day of a pollutant or smoke/dust plume, or (4) a map of AQI values.

- If the user determines they would like a map showing smoke, dust, or fire locations, they will be guided to Aerosol Watch[18] and NASA Worldview.[19] Aerosol Watch is a web-based platform where the user can map satellite imagery and the smoke or dust mask for the day of interest. NASA Worldview is a web-based platform that can show satellite detections of fires for any day the user chooses. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If the user determines they are interested in pollutant concentrations or properties of particulate matter at a single time point in the day, they will be guided to page 16 of this document.
- If the user determines they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will be guided to page 27.
- If the user determines they would like a map showing AQI values, they will be directed to the Air Now Interactive Map.[20] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in North America.

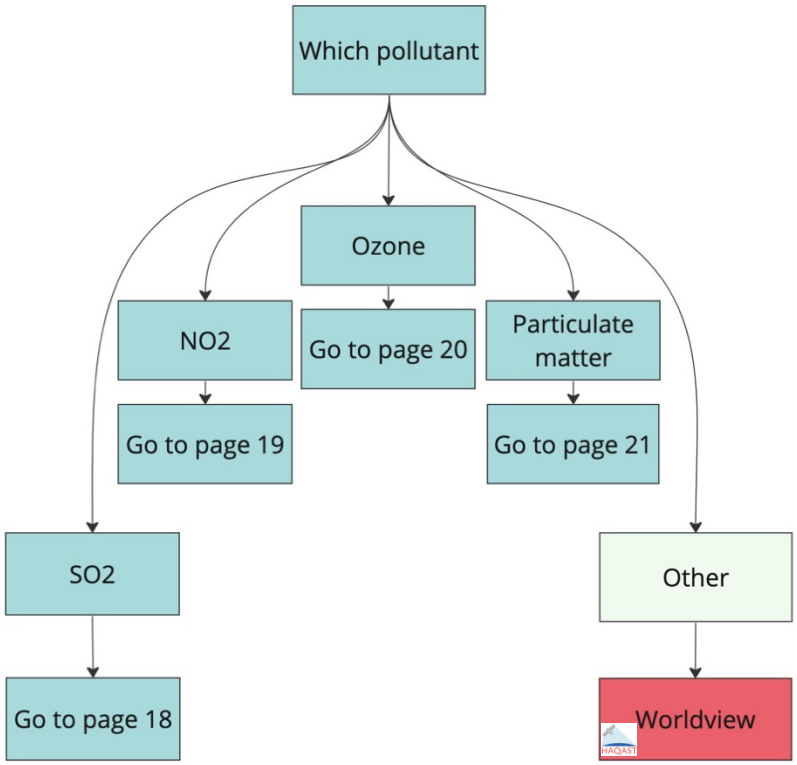
[18] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[19] NASA Worldview - https://worldview.earthdata.nasa.gov/
[20] Air Now Interactive Map - https://gispub.epa.gov/airnow/



If the user previously indicated they are interested in pollutant concentrations or the properties of particulate matter at a single point in the day, they will be guided to this flowchart. They will then determine if they are interested in only the imagery, such as a map of the pollutant concentrations, or if they also need the raw data for analysis.

- If the user determines that they are only interested in the imagery, they will then indicate if they know how to use Python, Google Earth Engine, the Man computer Interactive Data System (McIDAS), or Interactive Data Language (IDL) for satellite data. Or if they would like to learn.
- If they do, they will be guided to page 17 of this document. Downloading the data allows the user to create a wide range of plots and analyze the data in a way that makes the most sense for their research question.
- If the user is not familiar with any satellite-relevant applications, they will then indicate if they are interested in pollutant concentrations or the vertical structure of clouds and aerosols.
- If they are interested in concentrations, they will be guided to NASA Worldview.[21] This platform displays satellite-based data products related to air quality and health such as NO_2. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[22] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If the user determines they need the raw data, they will be guided to page 22.

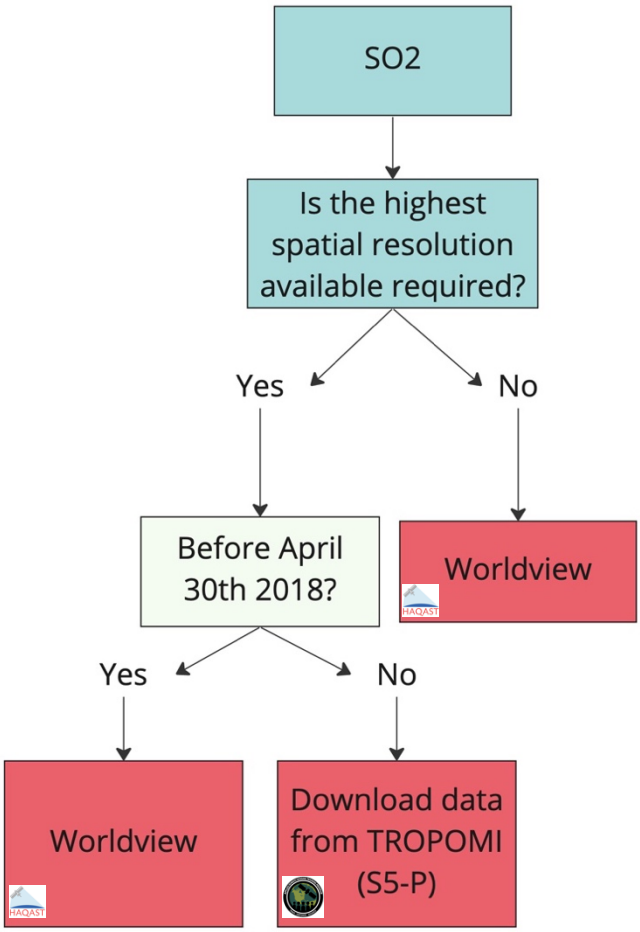
[21] NASA Worldview - https://worldview.earthdata.nasa.gov/
[22] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php



If the user previously indicated they are interested in the imagery of pollutant concentrations from a single day, they will then indicate which pollutant.

- If the pollutant is SO_2, NO_2, ozone, or particulate matter, they will be guided to the corresponding page of this document.
- If it is not one of these pollutants, they will be guided to NASA Worldview.[23] NASA Worldview is an interactive web-based platform where the user can display maps of satellite data pollutant concentrations.
- Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.

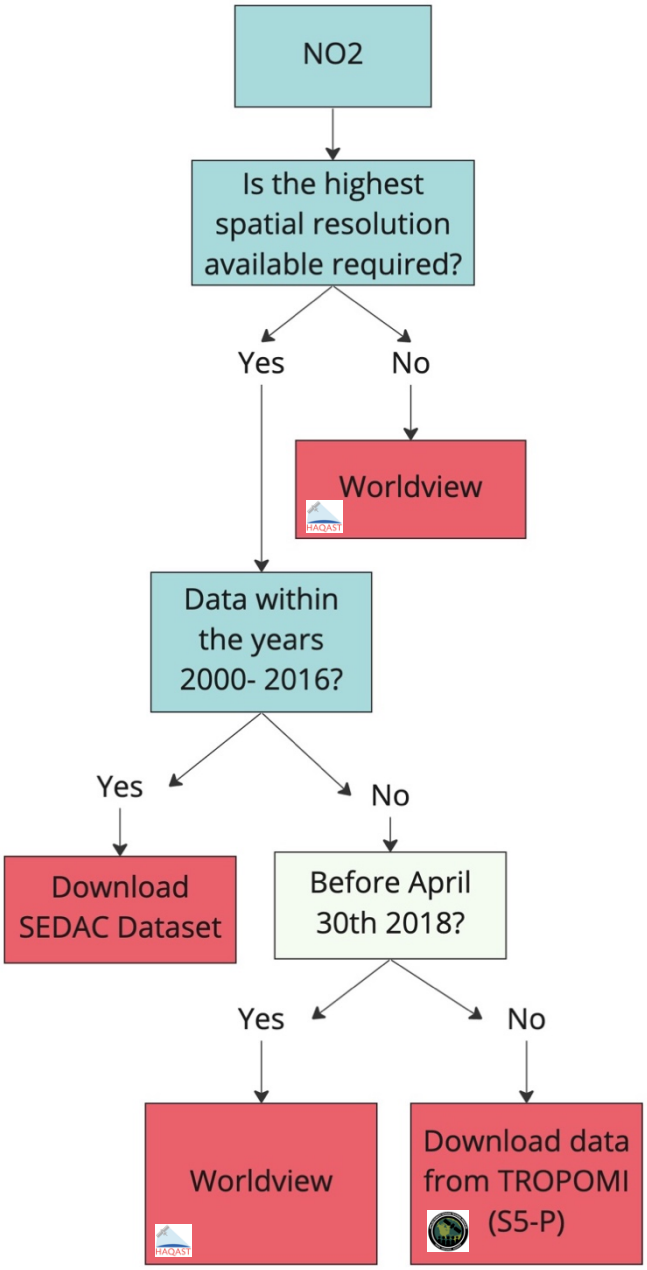
[23] NASA Worldview - https://worldview.earthdata.nasa.gov/



If the user previously indicated they are interested in the imagery of SO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the highest spatial resolution available is required.

- If it is, they will then be asked if the day of interest is before April 30th, 2018.
- If it is, then they will be guided to NASA Worldview.[24]
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution SO_2 data than what is available on NASA Worldview. Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.
- If the highest resolution is not required, the user will be guided to NASA Worldview. For a tutorial on NASA Worldview see (1) on page 53.

[24] NASA Worldview - https://worldview.earthdata.nasa.gov/

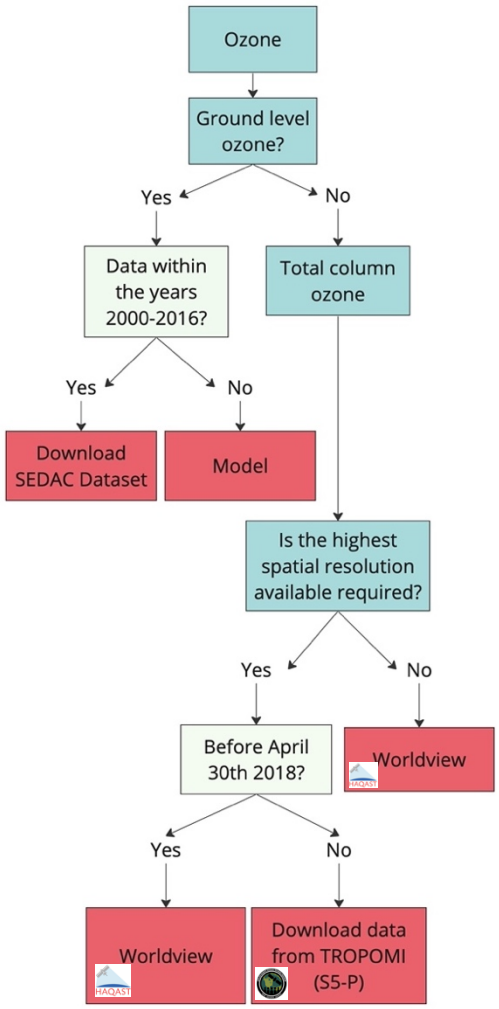


If the user previously indicated they are interested in the imagery of NO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the highest spatial resolution available is required.

- If it is, they will then be asked if the day of interest is within the years 2000-2016.
- If it is, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[25] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If the day of interest is after 2016, they will then indicate if it is before April 30th, 2018. If it is, they will be guided to NASA Worldview.[26] For a tutorial on NASA Worldview see (1) on page 53.
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution NO_2 data than what is available on NASA Worldview. Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.
- If the highest resolution is not required, the user will be guided to NASA Worldview. For a tutorial on NASA Worldview see (1) on page 53.

[25] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016

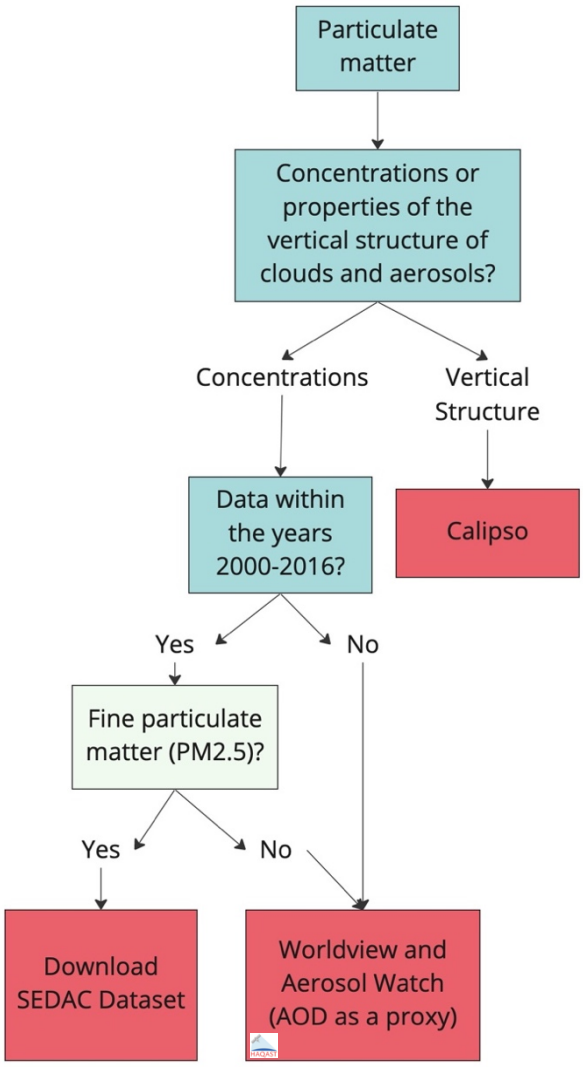
[26] NASA Worldview - https://worldview.earthdata.nasa.gov/



If the user previously indicated they are interested in ozone pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in ground level ozone. This distinction between ground level ozone and total column ozone is made because the ozone layer in the atmosphere makes it difficult to estimate trends and concentrations of ground level ozone.

- If yes, they will then indicate if the day of interest is within the years 2000-2016.
- If it is, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[27] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If it is not, they will be guided towards using a model. See (20) on page 54 for a publication related to ground level ozone and modeling.
- If they are interested in total column ozone, they will then indicate if the highest spatial resolution available is required.
- If it is, they will then be asked if the day of interest is before April 30th, 2018.
- If it is, then they will be guided to NASA Worldview.[28]
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution ozone data than what is available on NASA Worldview. Data from the TROPOMI instrument is available at NASA Earthdata Search.[29] Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.
- If the highest resolution is not required, the user will be guided to NASA Worldview. For a tutorial on NASA Worldview see (1) on page 53.

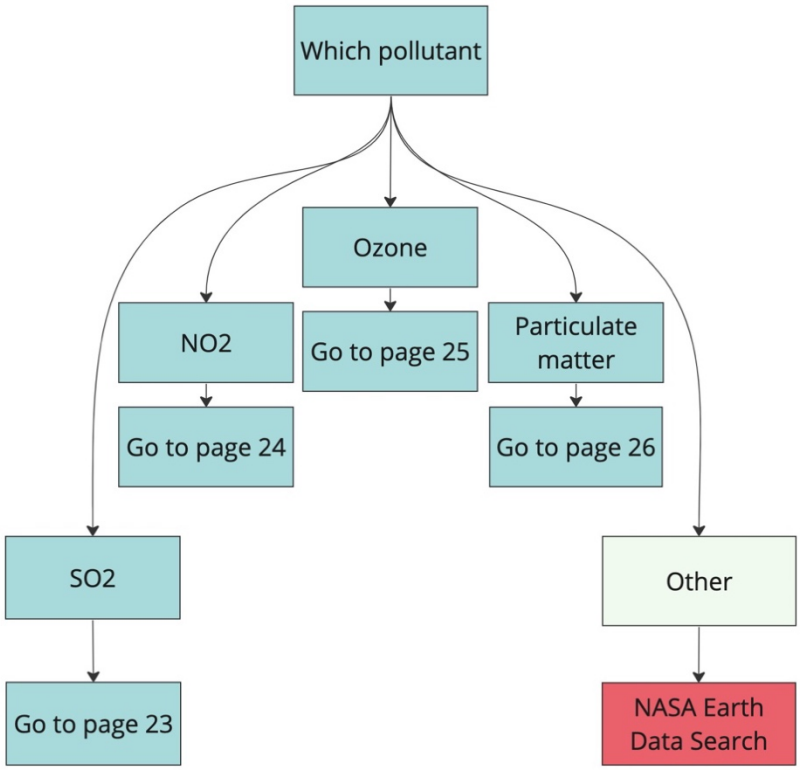
[27] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016
[28] NASA Worldview - https://worldview.earthdata.nasa.gov/
[29] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the imagery of particulate matter pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in pollutant concentrations or the vertical structure of clouds and aerosols.

- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[30] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If they are interested in concentrations, they will then indicate if the day of interest is within 2000-2016.
- If it is, they will then be asked if they are interested in fine particulate matter ($PM_{2.5}$).
- If they are, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[31] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more info %rmation.
- If the day of interest is after 2016 or they are not interested in fine particulate matter, the user will be guided to NASA Worldview[32] and Aerosol Watch.[33] Both of these web-based platforms have aerosol optical depth (AOD) data products that can be used as a proxy for particulate matter. For a tutorial on NASA Worldview see (1) on page 53.

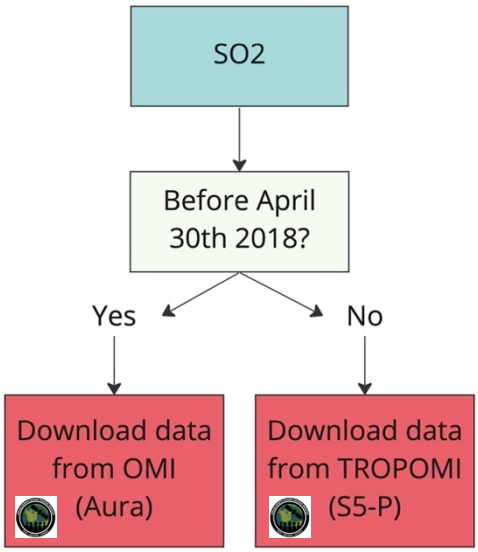
[30] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php
[31] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016
[32] NASA Worldview - https://worldview.earthdata.nasa.gov/
[33] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/



If the user previously indicated they are interested in the raw data of pollutant concentrations, they will then indicate which pollutant.

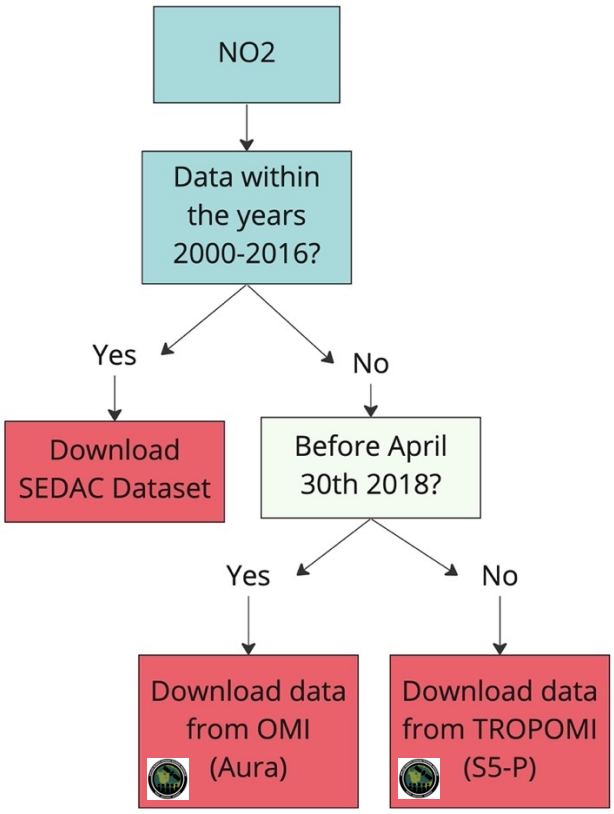
- If the pollutant is SO_2, NO_2, ozone, or particulate matter, they will be guided to the corresponding page of this document.
- If it is not one of these pollutants, they will be guided to NASA Earth Data Search[34] where the user can explore pollutants measured by satellite data. NASA Earth Data Search is a website where the user can filter through keywords and data formats to find certain data products.

[34] NASA Earth Data Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the raw data of SO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the day of interest is before April 30th, 2018.

- If it is, then they will be guided to downloading data from OMI. Additionally, there are Applied Remote Sensing Training (ARSET) tutorials available for using OMI data. For these tutorials see (16) and (21) on page 54.
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution SO_2 data than the OMI satellite. Additionally, there is an ARSET tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.

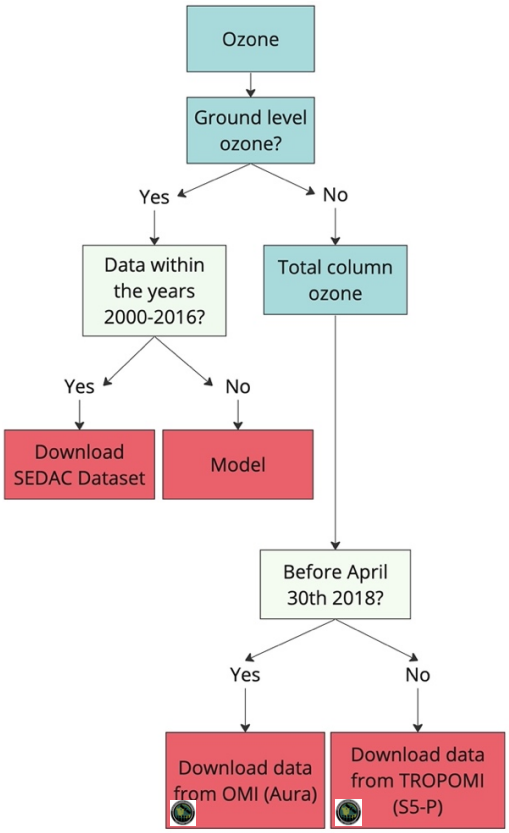


If the user previously indicated they are interested in the raw data of NO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the day of interest is within the years 2000-2016.

- If it is, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[35] and 1km[36] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If the day of interest is after 2016, they will then indicate if it is before April 30th, 2018.
- If it is, then they will be guided to downloading data from OMI. Additionally, there are Applied Remote Sensing Training (ARSET) tutorials available for using OMI data. For these tutorials see (16) and (21) on page 54.
- If the day of interest is after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution NO_2 than the OMI satellite. Additionally, there is an ARSET tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.

[35] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016

[36] SEDAC 1km - https://sedac.ciesin.columbia.edu/data/set/aqdh-no2-concentrations-contiguous-us-1-km-2000-2016

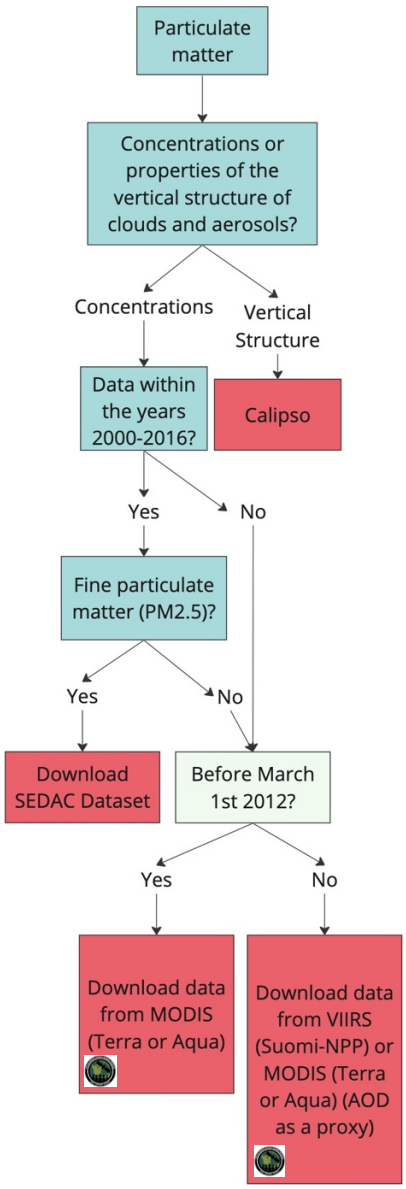


If the user previously indicated they are interested in the raw data of ozone pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in ground level ozone. This distinction between ground level ozone and total column ozone is made because the ozone layer in the atmosphere makes it difficult to estimate trends and concentrations of ground level ozone.

- If yes, they will then indicate if the day of interest is within the years 2000-2016.
- If it is, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[37] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If it is not, they will be guided towards using a model. See (20) on page 54 for a publication related to ground level ozone and modeling.
- If they are interested in total column ozone, they will then be asked if the day of interest is before April 30th, 2018.
- If the day of interest is before April 30th, 2018, they will be guided to the OMI instrument aboard to Aura satellite. OMI has data from 2004-present but has a coarser spatial resolution compared to TROPOMI. Data from the OMI instrument is available at NASA Earthdata Search.[38] If the user has yet to work with OMI data, it is recommended to complete tutorial (8) on page 53 of this document. For more information about the capabilities of OMI, see publications (9) and (10) on page 53 of this document.
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. There is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.

[37] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016

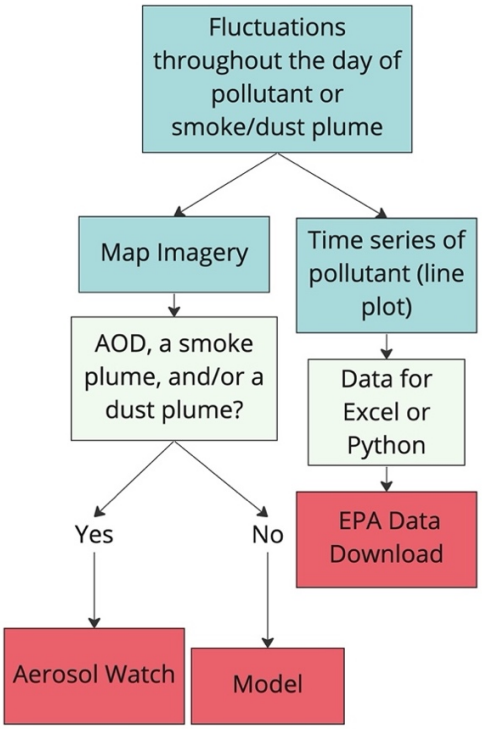
[38] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the raw data of particulate matter pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in pollutant concentrations or the vertical structure of clouds and aerosols.

- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[39] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If they are interested in concentrations, they will then indicate if the day of interest is within 2000-2016.
- If it is, they will then be asked if they are interested in fine particulate matter ($PM_{2.5}$).
- If they are, they will be guided to the SEDAC datasets. These datasets provide daily concentrations at the zip code[40] spatial resolution. The SEDAC website offers publications that have utilized the dataset. It is recommended to explore this website for more information.
- If the day of interest is after 2016 or they are not interested in fine particulate matter, they will then indicate if the day of interest is before March 1st, 2012.
- If it is, the user will be guided towards downloading satellite data from the MODIS sensor aboard the Terra and Aqua satellites. Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using MODIS data. For this tutorial see (16) on page 53. For a publication using MODIS data, see (17) on page 53.
- If it is not, the user will be guided towards downloading satellite data from the VIIRS sensor aboard the Suomi-NPP satellite or the MODIS sensor. Additionally, there is an ARSET tutorial available comparing MODIS and VIIRS data to help the user learn more about the two sensors and choose between the two. For this tutorial see (18) on page 53. For a publication using VIIRS data, see (19) on page 53.
- Both sensors measure aerosol optical depth (AOD) that can be used as a proxy for particulate matter.

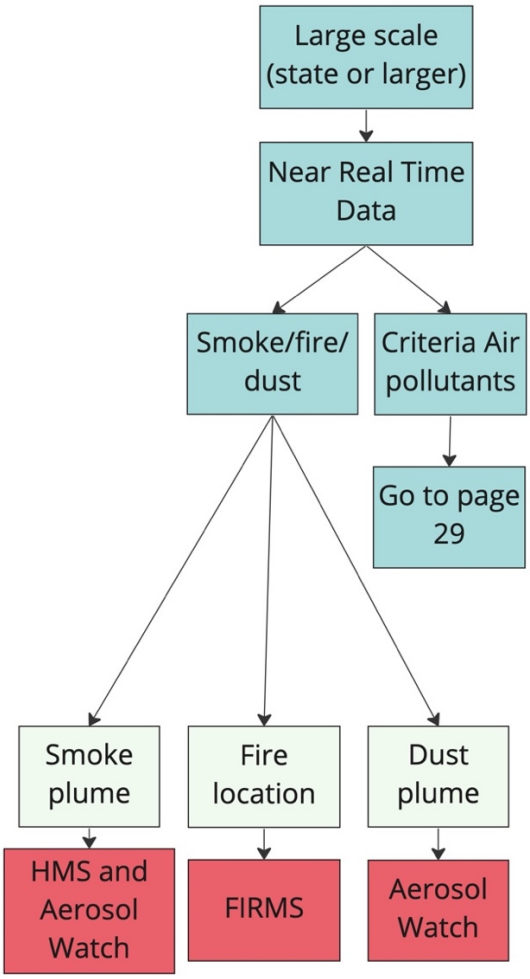
[39] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php
[40] SEDAC zip code dataset - https://sedac.ciesin.columbia.edu/data/set/aqdh-pm2-5-o3-no2-concentrations-zipcode-contiguous-us-2000-2016



If the user previously determined that they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will then identify if they are interested in map imagery (such as an animation) or a times series of the pollutant (such as a line plot).

- If the user determines they would like a map showing fluctuations throughout the day, they will then be asked if they are interested in aerosol optical depth (AOD), a smoke plume, and/or a dust plume. AOD can be used as a proxy for particulate matter. Examples of particulate matter include smoke, dust, sulfate, or nitrate.
- If yes, they will be guided to Aerosol Watch.[41] Aerosol Watch is an interactive website where the user can view satellite data from the GOES-16 and GOES-17 geostationary satellites. A geostationary satellite takes multiple measurements per day of the same area, so it can track changes throughout one day. Both GOES-16 and GOES-17 provide true color imagery (useful for trying to see a smoke or dust plume) and AOD.
- If they are not interested in AOD, a smoke plume, or a dust plume, they will be guided towards a model. This is because there is not currently a satellite that monitors one area multiple times a day for anything other than AOD or true color imagery. To learn more about modeling, see (2), (3), and (4) on page 53 of this document.
- If the user determines they would like a time series such as a line plot showing fluctuations throughout the day, they will be guided to downloading data from the EPA[42] to use in excel or Python. The EPA offers hourly data, daily data, and pre-generated data files for criteria air pollutants, speciation data, hazardous air pollutants and more. For more information and a related publication, see (5), (6), and (7) on page 53 of this document.

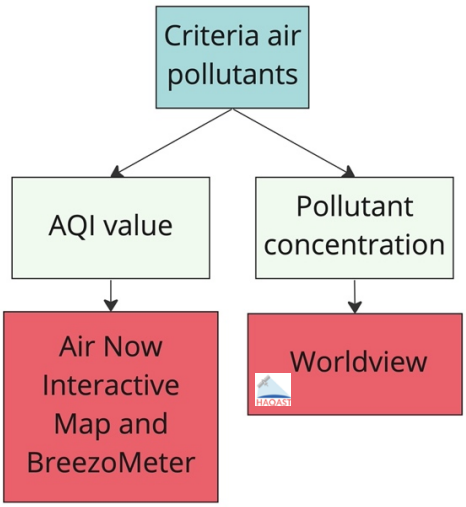
[41] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[42] EPA Data - https://aqs.epa.gov/aqsweb/airdata/download_files.html



If the user previously determined that they are interested in a large spatial scale and near real time data, they will be guided to this flowchart. The user will then determine if they are interested in smoke/fire/dust or criteria air pollutants. Criteria air pollutants are the 6 air pollutants that are regulated by the EPA. These pollutants include ozone, particulate matter, nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead.

- If they indicate that they are interested in smoke/fire/dust, they will then specify if they are interested in smoke plumes, dust plumes, or fire locations.
- If the user is interested in smoke plumes, they will be directed towards the NOAA Hazard Mapping System (HMS)[43] and Aerosol Watch.[44] HMS uses satellite data to show where there are smoke plumes and fire points. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a smoke mask. Both tools are useful when identifying a smoke plume.
- If the user is looking for real time fire locations, then NASA FIRMS[45] is recommended. NASA FIRMS is an interactive website that uses data from the Landsat satellite, the VIIRS sensors (aboard the S-NPP and NOAA-20 satellites), and the MODIS sensors (aboard the Aqua and Terra satellites) to indicate the locations of fires and hotspots.
- If the user is interested in dust plumes, they will be guided to Aerosol Watch. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a dust mask. Both tools are useful when identifying a dust plume.
- If they indicate that they are interested in criteria air pollutants, they will be guided to page 29.

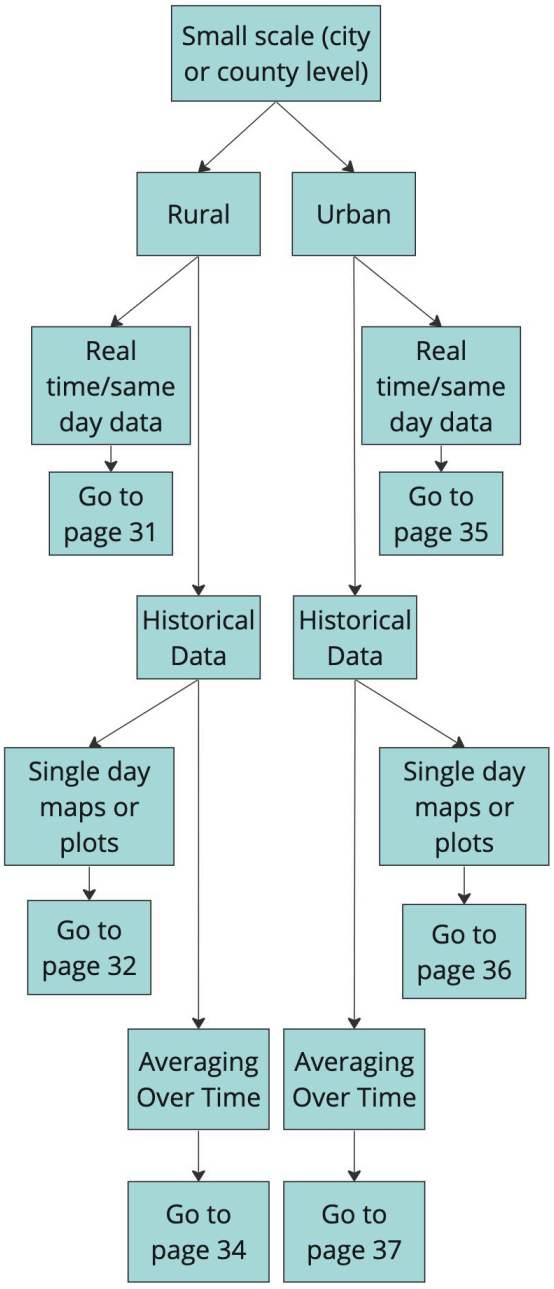
[43] NOAA HMS - https://www.ospo.noaa.gov/Products/land/hms.html#maps
[44] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[45] NASA FIRMS - https://firms.modaps.eosdis.nasa.gov/map/



If the user previously indicated they are interested in criteria air pollutants, they will then specify if they are interested in the AQI value or the pollutant concentration. The AQI value is the numerical value assigned to communicate air quality and possible health concerns to the public.

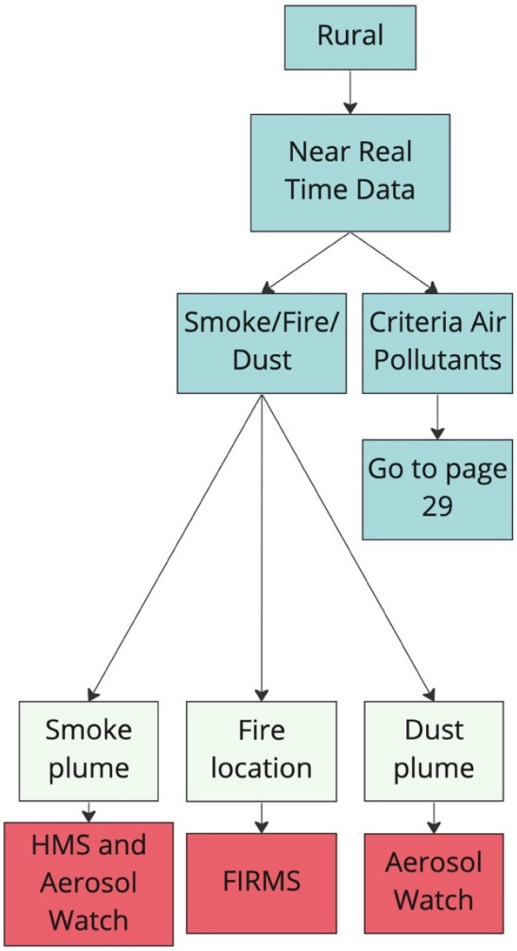
- If the user is interested in the AQI value, they will be guided to the Air Now Interactive Map[46] and BreezoMeter.[47] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in the United States. BreezoMeter shows the overall AQI across the world using ground-based measurements from monitors and satellite data from all 6 of the criteria air pollutants.
- If the user is interested in pollutant concentration, they will be guided to NASA Worldview.[48] NASA Worldview displays satellite-based data products providing the pollutant concentration.

[46] Air Now Interactive Map - https://gispub.epa.gov/airnow/
[47] BreezoMeter - https://www.breezometer.com/air-quality-map/
[48] NASA Worldview - https://worldview.earthdata.nasa.gov/



If the user previously determined they are interested in a small spatial scale, they will be guided this this flowchart where they will indicate if the area is rural or urban.

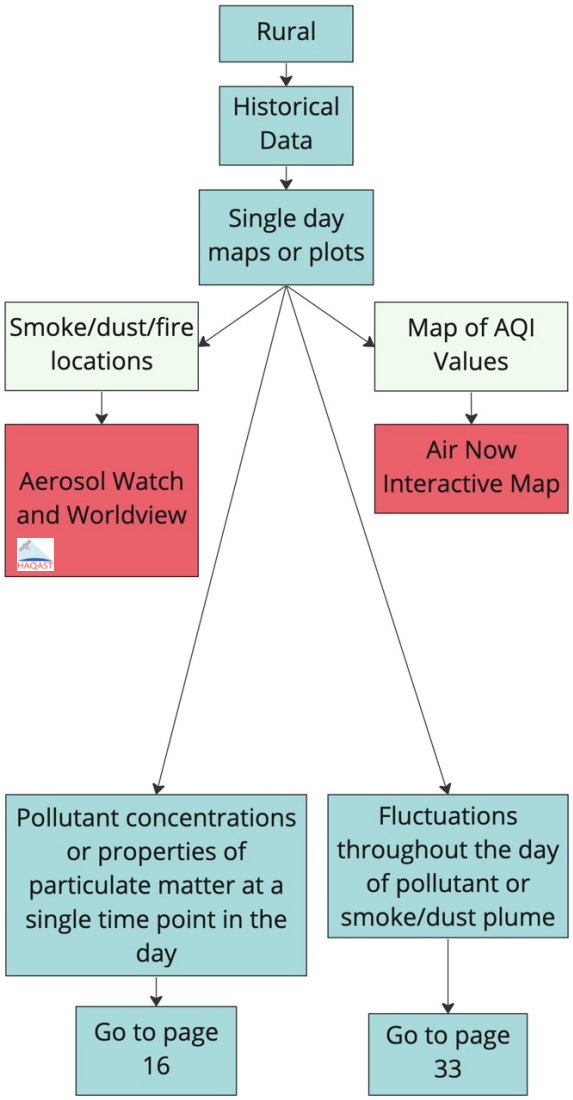
- If the user determines they are interested in a rural area, they will then indicate if they are interested in real time/same day data or historical data.
- If they are interested in real time/same day data, they will be guided to page 31.
- If the user chooses historical data, they will then choose between single day maps/plots or averaging over time.
- If they indicate that they would like single day maps or plots, they will be guided to page 32.
- If they indicate that they would like to average data over time, they will be guided to page 34.
- If the user determines they are interested in an urban area, they then need to indicate if they are interested in real time/same day data or historical data.
- If they are interested in real time/same day data, they will be guided to page 35.
- If the user chooses historical data, they will then choose between single day maps/plots or averaging over time.
- If they indicate that they would like single day maps or plots, they will be guided to page 36.
- If they indicate that they would like to average data over time, they will be guided to page 37.



If the user previously determined that they are interested in a small, rural spatial scale and near real time data, they will be guided to this flowchart. The user will then determine if they are interested in smoke/fire/dust or criteria air pollutants. Criteria air pollutants are the 6 air pollutants that are regulated by the EPA. These pollutants include ozone, particulate matter, nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead.

- If they indicate that they are interested in smoke/fire/dust, they will then specify if they are interested in smoke plumes, dust plumes, or fire locations.
- If the user is interested in smoke plumes, they will be directed towards the NOAA Hazard Mapping System (HMS)[49] and Aerosol Watch.[50] The HMS uses satellite data to show where there are smoke plumes and fire points. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a smoke mask. Both tools are useful when identifying a smoke plume.
- If the user is looking for real time fire locations, then NASA FIRMS[51] is recommended. NASA FIRMS is an interactive website that uses data from the Landsat satellite, the VIIRS sensors (aboard the S-NPP and NOAA-20 satellites), and the MODIS sensors (aboard the Aqua and Terra satellites) to indicate the locations of fires and hotspots.
- If the user is interested in dust plumes, they will be guided to Aerosol Watch. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a dust mask. Both tools are useful when identifying a dust plume.
- If they indicate that they are interested in criteria air pollutants, they will be guided to page 29.

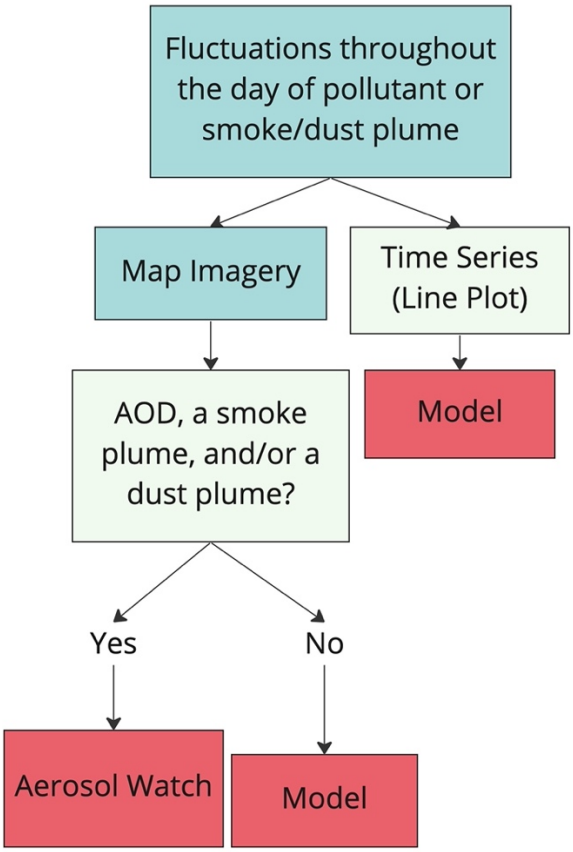
[49] NOAA HMS - https://www.ospo.noaa.gov/Products/land/hms.html#maps
[50] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[51] NASA FIRMS - https://firms.modaps.eosdis.nasa.gov/map/



If the user previously determined that they are interested in a small and rural area, a historical timeframe, and they would like to create single day maps or plots they will be guided to this flowchart. The user will then determine if they are interested in (1) a map of smoke, dust, or fire locations, (2) pollutant concentrations or properties of particulate matter at a single time point in the day, (3) fluctuations throughout the day of a pollutant or smoke/dust plume, or (4) a map of AQI values.

- If the user determines they would like a map showing smoke, dust, or fire locations, they will be guided to Aerosol Watch[52] and NASA Worldview.[53] Aerosol Watch is a web-based platform where the user can map satellite imagery and the smoke or dust mask for the day of interest. NASA Worldview is a web-based platform that can show satellite detections of fires or true color imagery for any day the user chooses. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If the user determines they are interested in pollutant concentrations or properties of particulate matter at a single time point in the day, they will be guided to page 16 of this document.
- If the user determines they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will be guided to page 33.
- If the user determines they would like a map showing AQI values, they will be directed to the Air Now Interactive Map.[54] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in the United States.

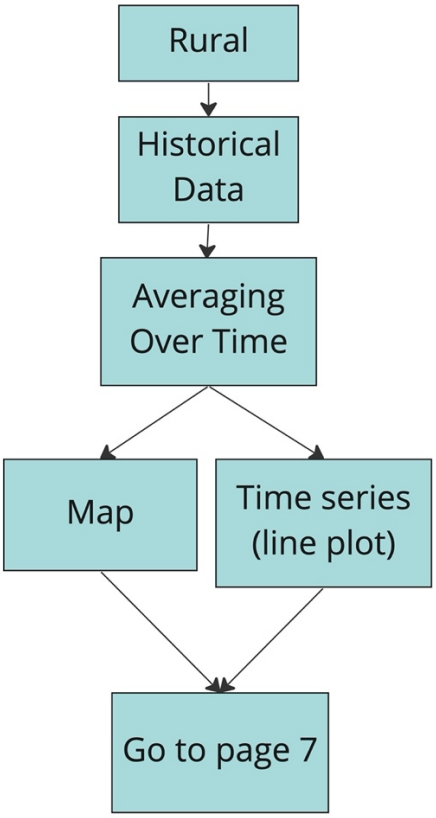
[52] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[53] NASA Worldview - https://worldview.earthdata.nasa.gov/
[54] Air Now Interactive Map - https://gispub.epa.gov/airnow/



If the user previously determined that they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will then identify if they are interested in map imagery (such as an animation) or a times series of the pollutant (such as a line plot).

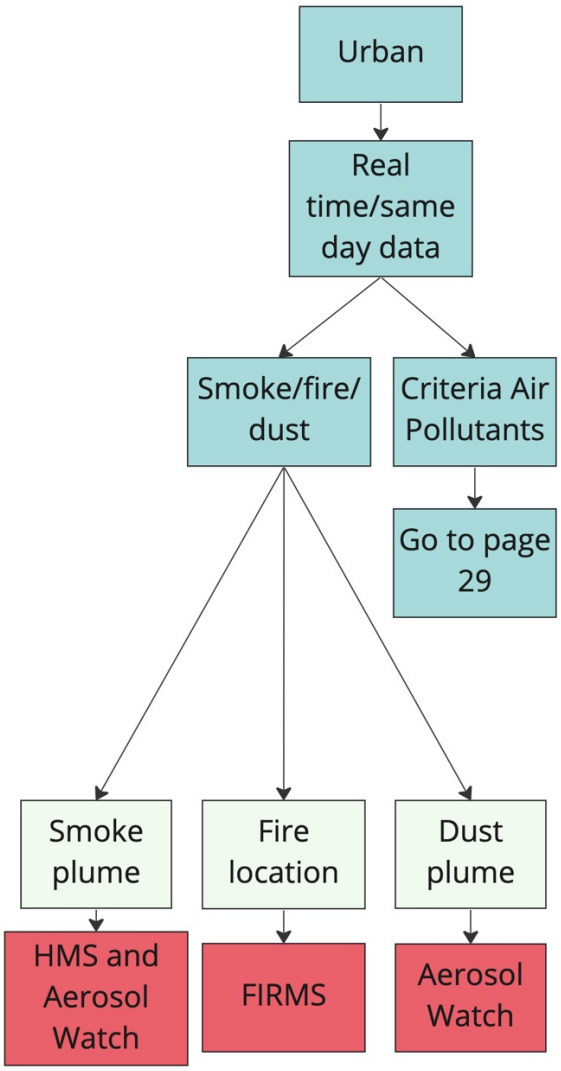
- If the user determines they would like a map showing fluctuations throughout the day, they will then indicate if they are interested in AOD, a smoke plume, and/or a dust plume.
- If yes, they will be guided to Aerosol Watch.[55] Aerosol Watch is an interactive website where the user can view satellite data from the GOES-16 and GOES-17 geostationary satellites. A geostationary satellite takes multiple measurements per day of the same area, so it can track changes throughout one day.
- If they are not interested in AOD, a smoke plume, or a dust plume, they will be guided towards a model. This is because there is not currently a satellite that monitors one area multiple times a day for anything other than AOD or true color imagery. To learn more about modeling, see (2), (3), and (4) on page 53 of this document.
- If the user determines they would like a time series such as a line plot showing fluctuations throughout the day, they will be guided towards a model. This is because it is unlikely that there is a ground monitor in the area of interest. To learn more about modeling, see (2), (3), and (4) on page 53 of this document.

[55] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/



If the user previously determined that they are looking at a small and rural spatial scale, a historical timeframe, and they would like to average satellite data over time, they will then determine if they would like to create a map or a time series (line plot).

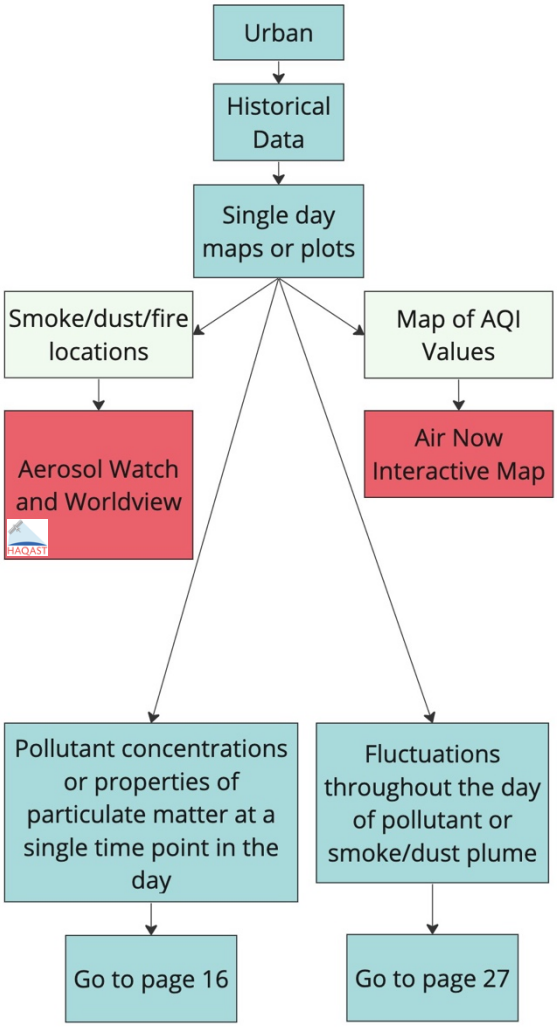
- In both cases, the user will be guided to page 7 of this document.



If the user previously determined that they are interested in a small, urban area and near real time data, they will be guided to this flowchart. The user will then determine if they are interested in smoke/fire/dust or criteria air pollutants.

- If they indicate that they are interested in smoke/fire/dust, they will then specify if they are interested in smoke plumes, dust plumes, or fire locations.
- If the user is interested in smoke plumes, they will be directed towards the NOAA Hazard Mapping System (HMS)[56] and Aerosol Watch.[57] The HMS uses satellite data to show where there are smoke plumes and fire points. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a smoke mask.
- If the user is looking for real time fire locations, then NASA FIRMS[58] is recommended. NASA FIRMS is an interactive website that uses data from the Landsat satellite, the VIIRS sensors (aboard the S-NPP and NOAA-20 satellites), and the MODIS sensors (aboard the Aqua and Terra satellites) to indicate the locations of fires and hotspots.
- If the user is interested in dust plumes, they will be guided to Aerosol Watch. Aerosol Watch plots true color imagery from the GOES-16 and GOES-17 geostationary satellites as well as a dust mask. Both tools are useful when identifying a dust plume.
- If they indicate that they are interested in criteria air pollutants, they will be guided to page 29.

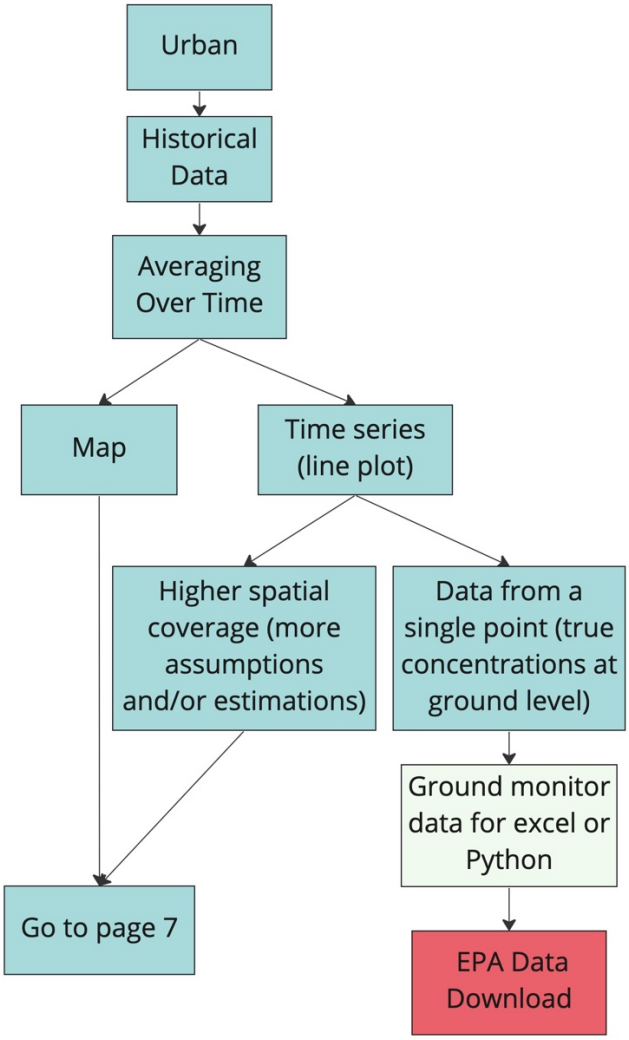
[56] NOAA HMS - https://www.ospo.noaa.gov/Products/land/hms.html#maps
[57] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[58] NASA FIRMS - https://firms.modaps.eosdis.nasa.gov/map/



If the user previously determined that they are interested in a small and urban spatial scale, a historical timeframe, and they would like to create single day maps or plots they will be guided to this flowchart. The user will then need to decide if they are interested in (1) a map of smoke, dust, or fire locations, (2) pollutant concentrations or properties of particulate matter at a single time point in the day, (3) fluctuations throughout the day of a pollutant or smoke/dust plume, or (4) a map of AQI values.

- If the user determines they would like a map showing smoke, dust, or fire locations, they will be guided to Aerosol Watch[59] and NASA Worldview.[60] Aerosol Watch is a web-based platform where the user can map satellite imagery and the smoke or dust mask for the day of interest. NASA Worldview is a web-based platform that can show satellite detections of fires for any day the user chooses. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If the user determines they are interested in pollutant concentrations or properties of particulate matter at a single time point in the day, they will be guided to page 16 of this document.
- If the user determines they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will be guided to page 27.
- If the user determines they would like a map showing AQI values, they will be directed to the Air Now Interactive Map.[61] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in North America.

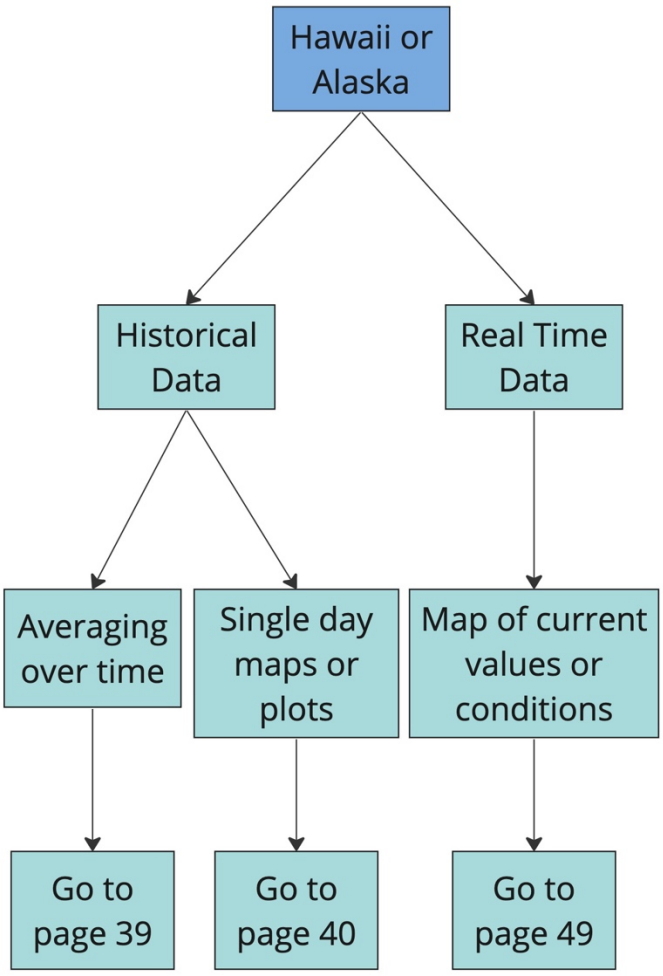
[59] Aerosol Watch - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
[60] NASA Worldview - https://worldview.earthdata.nasa.gov/
[61] Air Now Interactive Map - https://gispub.epa.gov/airnow/



If the user previously determined they are looking at a small and urban spatial scale, a historical timeframe, and they would like to average satellite data over time, they will then determine if they would like to create a map or a time series (line plot).

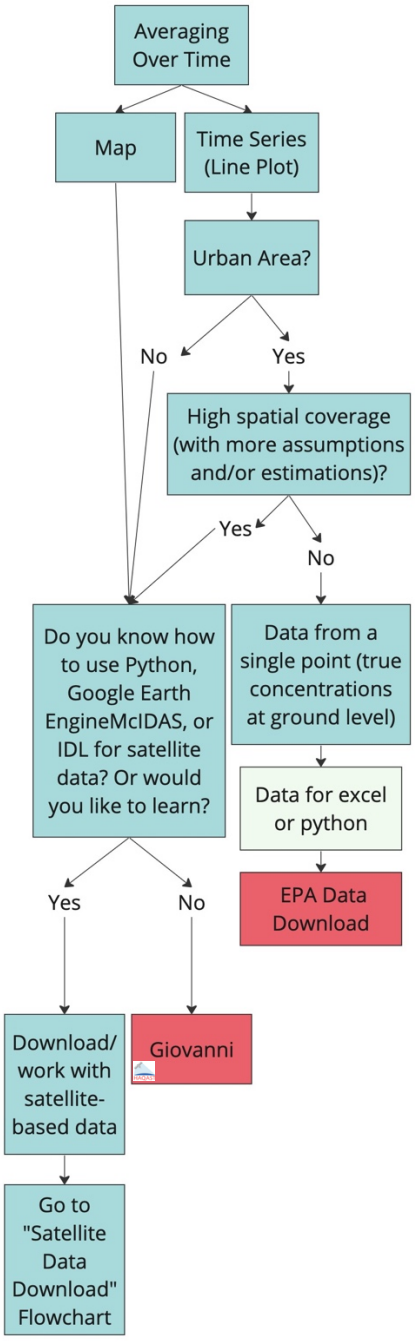
- If the user determines they would like a map, they will be guided to page 7.
- If the user determines they are interested in a time series, they will then identify if they would prefer a high spatial coverage or data from a single point. The higher spatial coverage tends to have more assumptions and/or estimations. Data from a single point will be the true concentrations at ground level.
- If the user determines they would prefer a higher spatial coverage, they will be guided to page 7.
- If the user determines they would rather have the true concentrations from a single point, they will be guided to ground monitor data to manipulate in excel or python. This data can be downloaded from the Environmental Protection (EPA) website.[62]

[62] EPA Data - https://aqs.epa.gov/aqsweb/airdata/download_files.html



If the user previously determined they are interested in Hawaii or Alaska, they will be guided to this flowchart. They will then need to indicate the time frame they are interested in, historical or real time data.

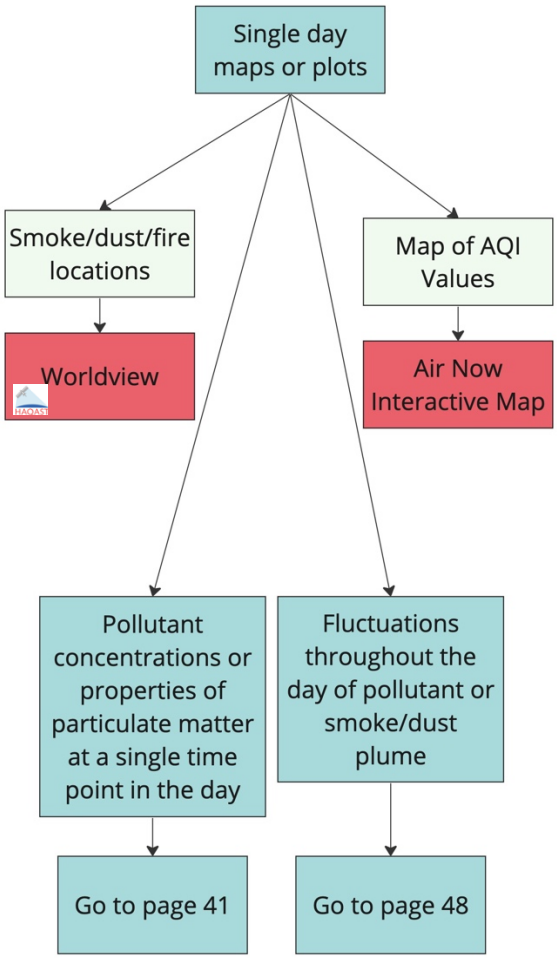
- If the user chooses historical data, they will then determine if they are interested in averaging over time or single day maps or plots.
- If the user is interested in averaging over time, they will be guided to page 39 where they will continue the flowchart.
- If the user is interested in single day maps or plots, they will be guided to page 40 where they will continue the flowchart.
- If the user is interested in real time data, it is assumed they would like a map of the current values or conditions and they will be guided to page 49 to continue the flowchart.



If the user previously determined they are interested in averaging values over time, they will then indicate if they are interested in a map or a time series (line plot).

- If the user determines they would like a map, they will then indicate if they know how to use Python, Google Earth Engine, the Man computer Interactive Data System (McIDAS), or Interactive Data Language (IDL) for satellite data, or if they would like to learn.
- If they do, they will be guided to download or work with satellite data. Downloading the data allows the user to create a wide range of maps and analyze the data in a way that makes the most sense for their research question. To determine which satellite and sensor the user should download data from, the user will then be guided to the "Satellite Data Download" flowchart on page 50 of this document.
- If the user is not familiar with any satellite-relevant applications, they will be guided to Giovanni.[63] Giovanni has the capabilities to create a variety of maps to display satellite imagery without coding skills. Some examples available include a time averaged map or an animation. For a tutorial for Giovanni, please see (1) on page 53.
- If the user determines they would prefer a time series (line plot), they will then determine if the area of interest is an urban area.
- If it is, they will then indicate if they are interested in a high spatial coverage, knowing that there will be more assumptions and/or estimations with these data products.
- If they would rather have data from a single point, they will then be guided to download data from the EPA[64] to use in excel or Python. The EPA offers daily data and pre-generated data files for criteria air pollutants, speciation data, hazardous air pollutants and more. For more information and a related publication, see (5), (6), and (7) on page 53.
- If the area is not urban or they are interested in a high spatial coverage, they will then follow the corresponding steps in the flowchart that are detailed above. Satellite data is the best option for this situation because there usually are no ground monitors in rural areas.

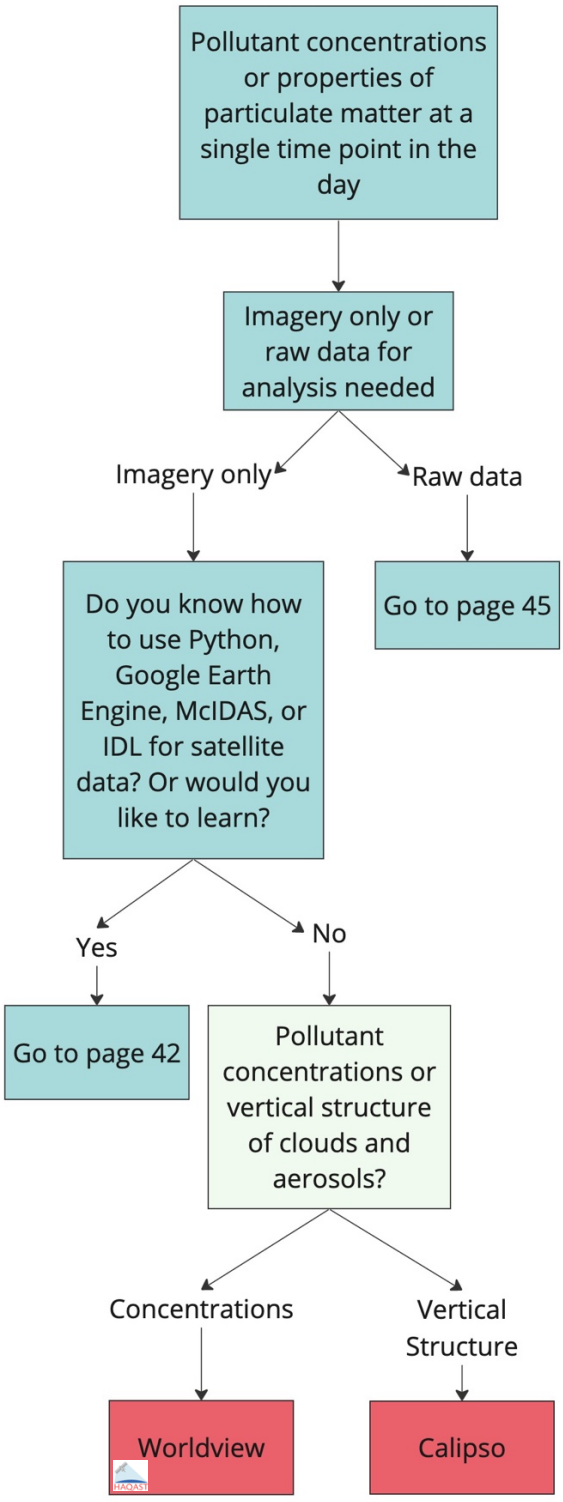
[63] NASA Giovanni - https://giovanni.gsfc.nasa.gov/giovanni/
[64] EPA Data - https://aqs.epa.gov/aqsweb/airdata/download_files.html



If the user previously determined that they are interested in a historical timeframe, and they would like to create single day maps or plots they will be guided to this flowchart. The user will then indicate if they are interested in (1) smoke, dust, or fire locations, (2) pollutant concentrations or properties of particulate matter at a single time point in the day, (3) fluctuations throughout the day of a pollutant or smoke/dust plume, or (4) a map of AQI values.

- If the user determines they would like a map showing smoke, dust, or fire locations, they will be guided to NASA Worldview.[65] NASA Worldview is a web-based platform that can show satellite detections of fires for any day the user chooses. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If the user determines they are interested in pollutant concentrations or properties of particulate matter at a single time point in the day, they will be guided to page 41 of this document.
- If the user determines they are interested in the fluctuations throughout the day of a pollutant or smoke/dust plume they will be guided to page 48.
- If the user determines they would like a map showing AQI values, they will be directed to the Air Now Interactive Map.[66] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in North America.

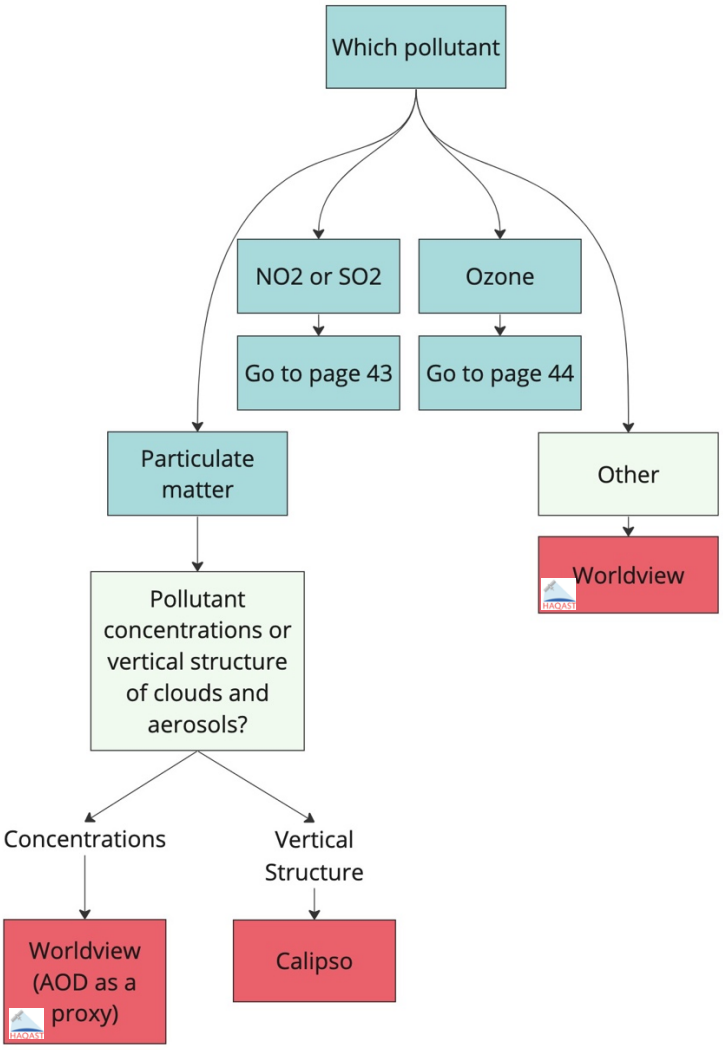
[65] NASA Worldview - https://worldview.earthdata.nasa.gov/
[66] Air Now Interactive Map - https://gispub.epa.gov/airnow/



If the user previously indicated are interested in pollutant concentrations, they will then determine if they are interested in only the imagery, such as a map of the pollutant concentrations, or if they need the raw data.

- If the user determines that they are only interested in the imagery, they will indicate if they know how to use Python, Google Earth Engine, the Man computer Interactive Data System (McIDAS), or Interactive Data Language (IDL) for satellite data. Or if they would like to learn.
- If they do, they will be guided to page 42 of this document. Downloading the data allows the user to create a wide range of plots and analyze the data in a way that makes the most sense for their research question.
- If the user is not familiar with any satellite-relevant applications, they will then indicate if they are interested in pollutant concentrations or the vertical structure of clouds and aerosols.
- If they are interested in concentrations, they will be guided to NASA Worldview.[67] This platform displays satellite-based data products related to air quality and health such as NO_2. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[68] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If the user determines they need the raw data, they will be guided to page 45.

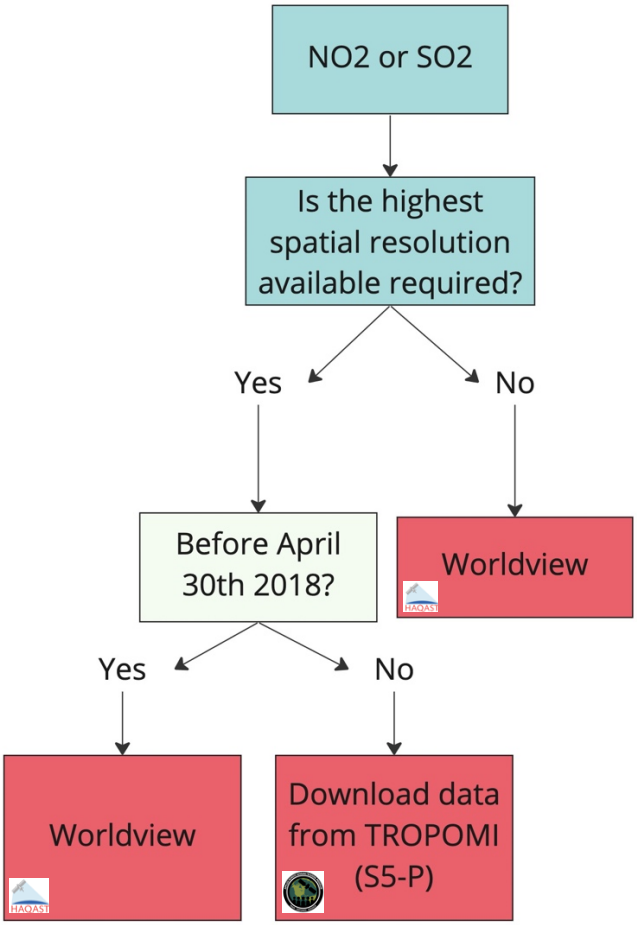
[67] NASA Worldview - https://worldview.earthdata.nasa.gov/
[68] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php



If the user previously determined that they are interested in pollutant concentrations from a single day, they will then indicate which pollutant.

- If the pollutant is particulate matter, they will then indicate if they are interested in pollutant concentrations or the vertical structure of clouds and aerosols.
- If they are interested in concentrations of particulate matter, they will be guided towards NASA Worldview.[69] In this platform, the user can plot aerosol optical depth (AOD) as a proxy for particulate matter. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[70] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If the pollutant is SO_2, NO_2, ozone, or they will be guided to the corresponding page of this document.
- If it is not one of these pollutants, they will be guided to NASA Worldview.

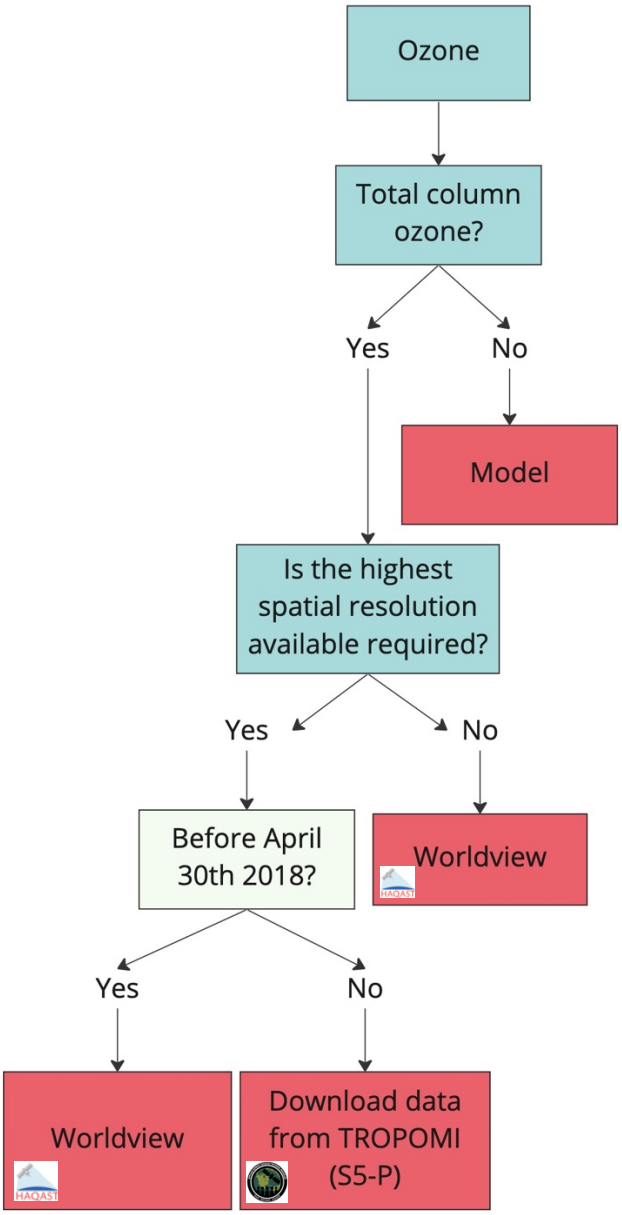
[69] NASA Worldview - https://worldview.earthdata.nasa.gov/
[70] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php



If the user previously indicated they are interested in NO_2 or SO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the highest spatial resolution available is required.

- If it is, they will then be asked if the day of interest is before April 30th, 2018.
- If it is, then they will be guided to NASA Worldview.[71]
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution NO_2 and SO_2 data than what is available on NASA Worldview. Data from the TROPOMI instrument is available at NASA Earthdata Search.[72] Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.
- If the highest resolution is not required, the user will be guided to NASA Worldview. For a tutorial on NASA Worldview see (1) on page 53.

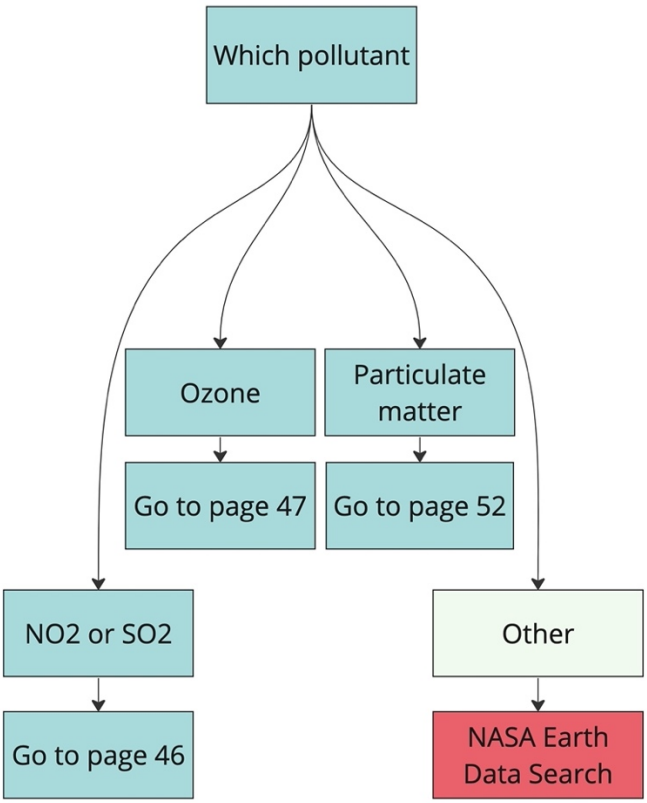
[71] NASA Worldview - https://worldview.earthdata.nasa.gov/
[72] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in ozone pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in total column ozone.

- If no, they will be guided towards using a model. This is because currently, there are no single day estimates of ground level ozone over Hawaii or Alaska. See (20) on page 54 for a publication related to ground level ozone and modeling.
- If yes, they will then indicate if the highest spatial resolution available is required.
- If it is, they will then be asked if the day of interest is before April 30th, 2018.
- If it is, then they will be guided to NASA Worldview.[73]
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution ozone data than what is available on NASA Worldview. Data from the TROPOMI instrument is available at NASA Earthdata Search.[74] Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53.
- If the highest resolution is not required, the user will be guided to NASA Worldview. For a tutorial on NASA Worldview see (1) on page 53.

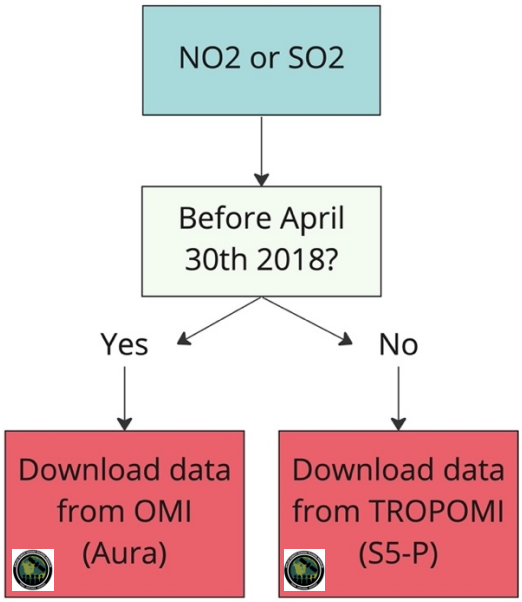
[73] NASA Worldview - https://worldview.earthdata.nasa.gov/
[74] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the raw data of pollutant concentrations, they will then indicate which pollutant.

- If the pollutant is SO_2, NO_2, ozone, or particulate matter, they will be guided to the corresponding page of this document.
- If it is not one of these pollutants, they will be guided to NASA Earth Data Search[75] where the user can explore pollutants measured by satellite data.

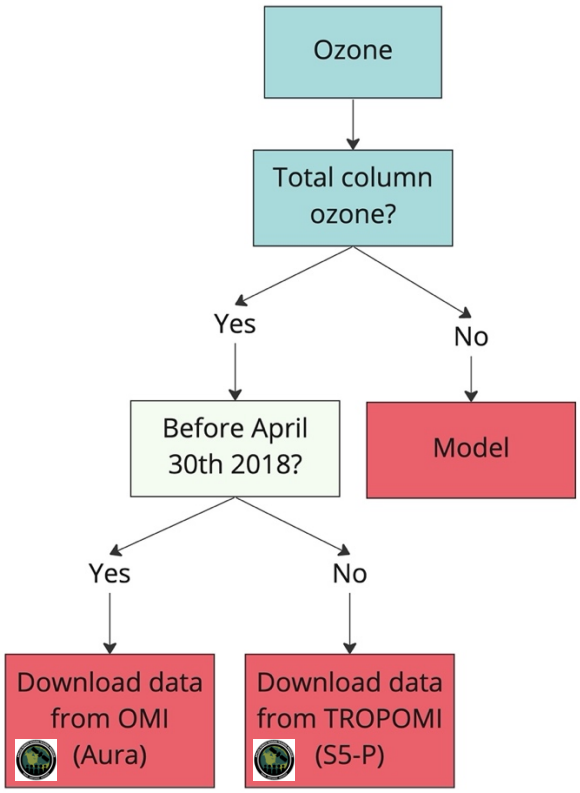
[75] NASA Earth Data Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the raw data of NO_2 or SO_2 pollutant concentrations, they will be guided to this flowchart. They will then indicate if the day of interest is before April 30th, 2018.

- If the day of interest is before April 30th, 2018, they will be guided to the OMI instrument aboard to Aura satellite. OMI has data from 2004-present but has a coarser spatial resolution compared to TROPOMI. Data from the OMI instrument is available at NASA Earthdata Search.[76] If the user has yet to work with OMI data, it is recommended to complete tutorial (8) on page 53 of this document. For more information about the capabilities of OMI, see publications (9) and (10) on page 53 of this document.
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution NO_2 and SO_2 data than what is available on NASA Worldview. Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53. For more information about the capabilities of TROPOMI, see publications (11), (12), and (13) on page 53 of this document.

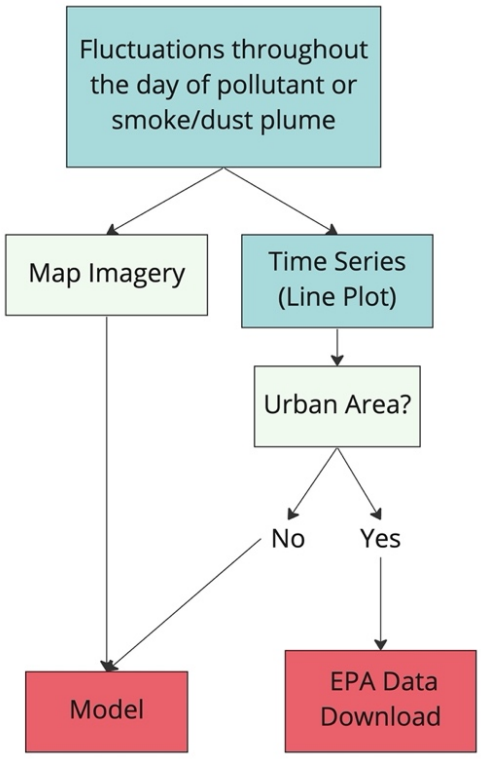
[76] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated they are interested in the raw data of ozone pollutant concentrations, they will be guided to this flowchart. They will then indicate if they are interested in total column ozone.

- If they are not, they will be guided towards using a model. This is because currently, there are no single day estimates of ground level ozone over Hawaii or Alaska. See (20) on page 54 for a publication related to ground level ozone and modeling.
- If they are, they will then indicate if the day of interest is before April 30th, 2018.
- If it is, then they will be guided to download data from OMI. Data from the OMI instrument is available at NASA Earthdata Search.[77] If the user has yet to work with OMI data, it is recommended to complete tutorial (8) on page 53 of this document. For more information about the capabilities of OMI, see publications (9) and (10) on page 53 of this document.
- If the day of interest is April 30th, 2018, or after April 30th, 2018, they will be guided to downloading data from TROPOMI. TROPOMI offers higher resolution ozone data than OMI. Additionally, there is an Applied Remote Sensing Training (ARSET) tutorial available for using TROPOMI data. For this tutorial see (8) on page 53. For more information about the capabilities of TROPOMI, see publications (11), (12), and (13) on page 53 of this document.

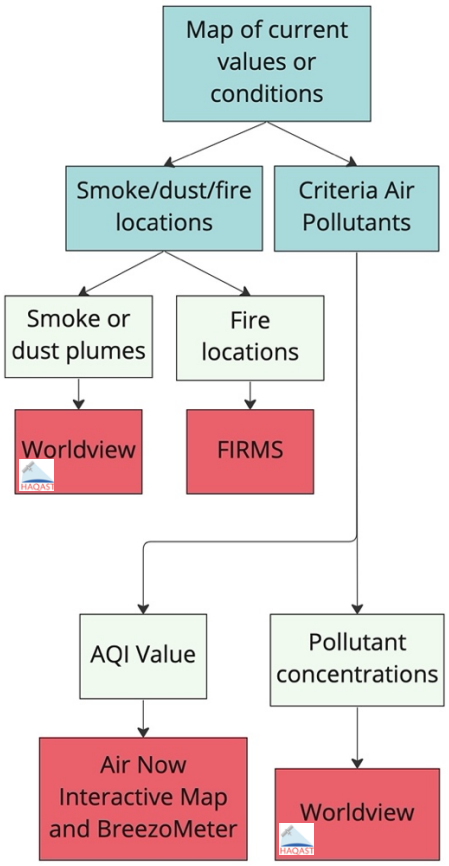
[77] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously indicated that they are interested in fluctuations throughout the day of a pollutant or a smoke/dust plume they will be guided to this flowchart. They will then identify if they are interested in map imagery (such as an animation) or a times series of the pollutant (such as a line plot).

- If the user determines they would like a map showing fluctuations throughout the day, they will be guided to a model. There currently are not any geostationary satellites that offer coverage over Alaska and Hawaii, so a model is the only option. To learn more about modeling, see (2), (3), and (4) on page 53 of this document.
- If the user determines they would like a time series such as a line plot showing fluctuations throughout the day, they will determine if they are interested in an urban area.
- If yes, they will be guided towards downloading ground monitor data from the EPA.[78] The EPA offers hourly data, daily data, and pre-generated data files for criteria air pollutants, speciation data, hazardous air pollutants and more. For more information and a related publication, see (5), (6), and (7) on page 53 of this document.
- If the area is not urban, they will be guided towards a model. This is because it is unlikely that there is a ground monitor in the area of interest. To learn more about modeling, see (2), (3), and (4) on page 53 of this document.

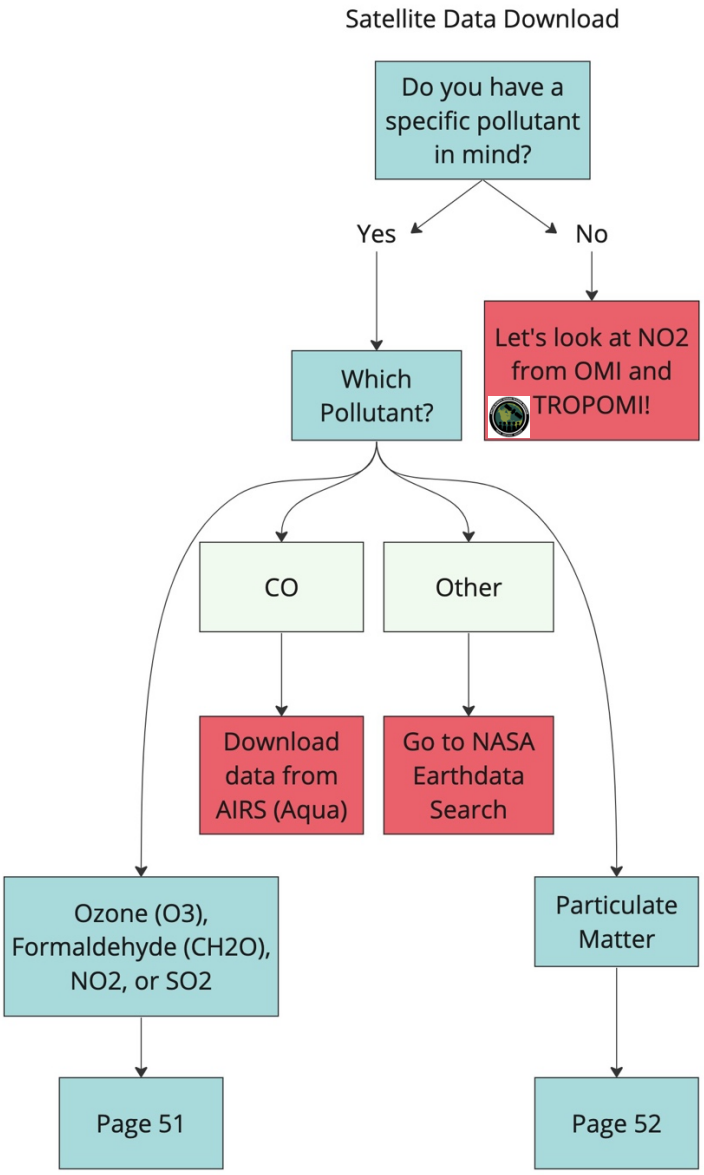
[78] EPA Data - https://aqs.epa.gov/aqsweb/airdata/download_files.html



If the user previously indicated they are interested in a small, rural spatial scale and near real time data, they will be guided to this flowchart. The user will then determine if they are interested in smoke/fire/dust or criteria air pollutants.

- If the user is interested in smoke/fire/dust, they will then specify if they are interested in smoke plumes, dust plumes, or fire locations.
- If the user is interested in smoke or dust plumes, they will be guided towards NASA Worldview.[79] NASA Worldview is an interactive web-based platform that can show true color satellite imagery that is useful for identifying smoke or dust plumes. Additionally, there is a tutorial for Worldview on the HAQAST website. For this tutorial see (1) on page 53.
- If the user is looking for real time fire locations, then NASA FIRMS[80] is recommended. NASA FIRMS is an interactive website that uses data from the Landsat satellite, the VIIRS sensors (aboard the S-NPP and NOAA-20 satellites), and the MODIS sensors (aboard the Aqua and Terra satellites) to indicate the locations of fires and hotspots.
- If they indicate they are interested in criteria air pollutants, they will then decide between the AQI value or pollutant concentration.
- If the user is interested in the AQI value, they will be guided to the Air Now Interactive Map[81] and BreezoMeter.[82] The Air Now Interactive Map shows AQI values for ozone and particulate matter using data from monitors in the United States. BreezoMeter shows the overall AQI across the world using ground-based measurements from monitors and satellite data from all 6 of the criteria air pollutants.
- If the user determines they would like a map of pollutant concentrations, they will be guided to NASA Worldview. This platform displays satellite-based data products related to air quality and health such as NO_2.

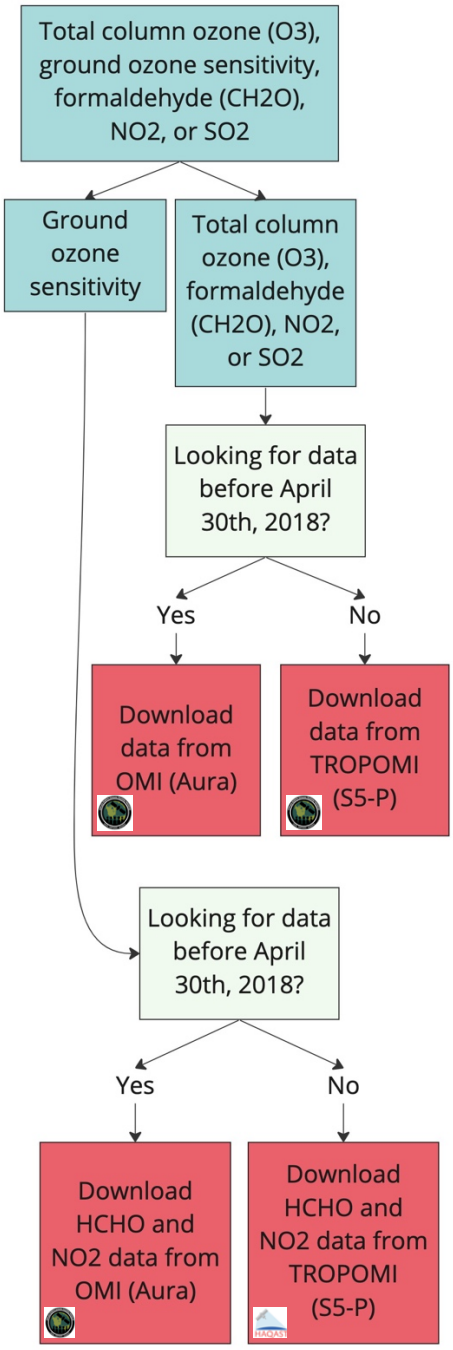
[79] NASA Worldview - https://worldview.earthdata.nasa.gov/
[80] NASA FIRMS - https://firms.modaps.eosdis.nasa.gov/map/
[81] Air Now Interactive Map - https://gispub.epa.gov/airnow/
[82] BreezoMeter - https://www.breezometer.com/air-quality-map/



If the user previously determined to download satellite data, they will be guided to this flowchart. The user will then indicate if they have a specific pollutant in mind.

- If they do not, they will be guided to look at NO_2 data from the satellite instruments OMI and TROPOMI. These instruments measure various air pollutants such as NO_2 which is a great place to start. Data from these instruments are available through NASA Earthdata Search.[83] To get started, there is an Applied Remote Sensing Training Program (ARSET) tutorial. For this tutorial see (8) on page 53 of this document.
- If the user is interested in CO, they will be guided towards downloading data from the AIRS sensor. For a tutorial about using satellite data, see (25) on page 54. For a related article see (26) on page 54.
- If the user is interested in ozone, formaldehyde, NO_2, or SO_2, they will be guided to page 51 of this flowchart.
- If the user is interested in particulate matter, they will be guided to the flowchart on page 52.
- If the user is interested in a different pollutant, they will be guided to NASA Earthdata Search where they can explore what pollutants are measured by satellites.

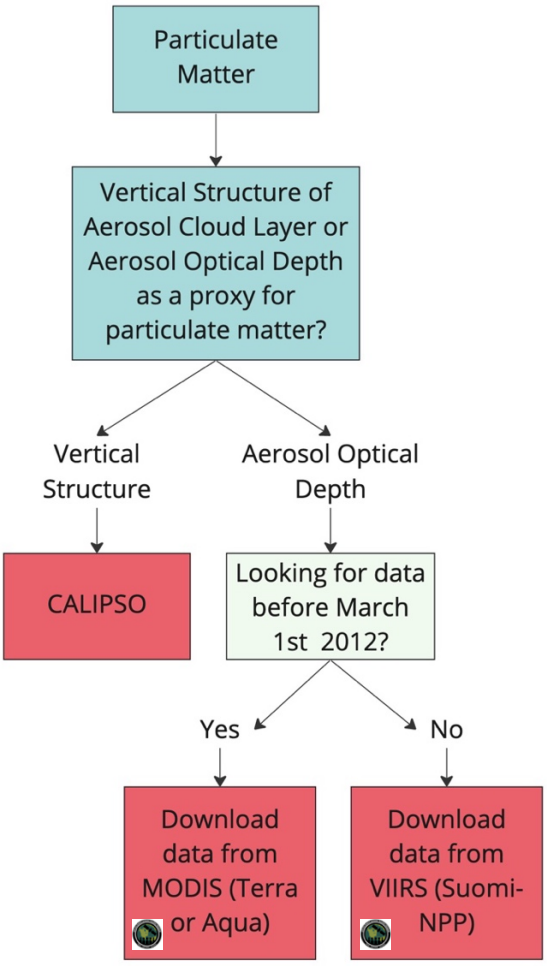
[83] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user has indicated they would like to look at total ozone, ground ozone sensitivity, formaldehyde, NO_2, or SO_2, they will be asked to specify if they are interested in 1) ground ozone sensitivity or 2) total ozone, formaldehyde, NO_2, or SO_2.

- If they are interested in ground ozone sensitivity, they will indicate if they are interested in data before April 30th, 2018.
- If they are looking for data before April 30th, 2018, they will be guided towards downloading HCHO and NO_2 data from the OMI instrument. OMI has data from 2004-present but has a coarser spatial resolution compared to TROPOMI. Data from the OMI instrument is available at NASA Earthdata Search.[84] If the user has yet to work with OMI data, it is recommended to complete tutorial (8) on page 53 of this document. For more information about ozone sensitivity see (22) and (23) on page 54 for related publications.
- If the user is looking for data after April 30th, 2018, the user will be guided towards using TROPOMI data. A tutorial for ozone sensitivity using HCHO and NO_2 is coming soon to the HAQAST website. See (23) and (24) on page 54 for related publications.
- If the user is interested in total ozone, formaldehyde, NO_2, or SO_2, they will then indicate if they are interested in data before April 30th, 2018.
- If it is, they will be guided to the OMI instrument aboard to Aura satellite. For more information about the capabilities of OMI, see publications (9) and (10) on page 53 of this document.
- If the user is not looking for data before 2018, they will be guided to download data from the TROPOMI instrument aboard the Sentinel-5 Precursor (S5-P) satellite. TROPOMI has data from mid 2018-present with a higher spatial resolution than OMI and is available for download at NASA Earthdata Search.[11] If the user has yet to work with TROPOMI data, it is recommended to complete tutorial (8) on page 11 of this document. For more information about the capabilities of TROPOMI, see publications (11), (12), and (13) on page 53 of this document.

[84] NASA Earthdata Search - https://search.earthdata.nasa.gov/search



If the user previously determined they are interested in particulate matter, they will be guided to this flowchart. They will then indicate if they are looking for the vertical structure of the aerosol cloud layer or aerosol optical depth (AOD). AOD is related to the amount of light that is scattered by aerosols, or particulate matter, and can be used to determine trends in particulate matter or estimate ground level concentrations.[85]

- If they are interested in the vertical structure, they will be guided towards the Calipso satellite. The Calipso website[86] offers profile observation images from the year 2013-present. For information about Calipso, downloading the data, and visualizing the data see (14) and (15) on page 53.
- If the user determines they are looking for AOD, they will then be asked if they are looking for data before 2012.
- Data from the MODIS instrument is available at NASA Earthdata Search.[87] For a tutorial about using MODIS data, see (16) on page 53. Additionally, see (17) for a publication using MODIS data.
- If they are looking for data after 2012, they will be guided to download data provided by the VIIRS instrument aboard Suomi-NPP which has a higher spatial resolution than the MODIS instrument. Data from the VIIRS instrument is available at NASA Earthdata Search.[88] For a tutorial about using VIIRS data, see (18) on page 54. Additionally, see (19) for a publication using VIIRS data.

[85] NASA Earth Sciences - https://earth.gsfc.nasa.gov/climate/data/deep-blue/science
[86] Calipso - https://www-calipso.larc.nasa.gov/products/lidar/browse_images/exp_index.php
[87] NASA Earthdata Search - https://search.earthdata.nasa.gov/search
[88] NASA Earthdata Search - https://search.earthdata.nasa.gov/search

Tutorials and Suggested Readings

1) https://haqast.org/data-and-tools/
2) https://www.epa.gov/scram/air-quality-models
3) https://www.epa.gov/air-research/air-quality-modeling
4) Russell, M., Allen, D. T., Collins, D. R., & Fraser, M. P. (2004). Daily, Seasonal, and Spatial Trends in PM $_{2.5}$ Mass and Composition in Southeast Texas Special Issue of *Aerosol Science and Technology* on Findings from the Fine Particulate Matter Supersites Program. *Aerosol Science and Technology*, *38*(sup1), 14–26. https://doi.org/10.1080/02786820390229318
5) https://www.epa.gov/outdoor-air-quality-data/download-daily-data
6) https://aqs.epa.gov/aqsweb/airdata/download_files.html
7) Manning, M. I., Martin, R. V., Hasenkopf, C., Flasher, J., & Li, C. (2018). Diurnal Patterns in Global Fine Particulate Matter Concentration. *Environmental Science & Technology Letters*, *5*(11), 687–691. https://doi.org/10.1021/acs.estlett.8b00573
8) https://appliedsciences.nasa.gov/join-mission/training/english/arset-high-resolution-no2-monitoring-space-tropomi
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