

How to Access and Visualize OCO-2 and OCO-3 Data

Karen Yuen, Sagar Limbu, and Charles Thompson

May 26, 2022

Webinar Agenda

Part 1: An Introduction to XCO₂ with OCO-2 and OCO-3

- EDT (UTC-4:00)
- Tuesday, May 24, 2022
- Trainers: Vivienne Payne (JPL)
- Background of the XCO₂ measurement and how it is measured
- Description of the OCO-2/OCO-3 sensors
- Characteristics, limitations and validation of the measurement
- Q&A

Part 2: A Demonstration on how to Access and Visualize OCO-2/OCO-3 Data

- EDT (UTC-4:00)
- Thursday, May 26, 2022
- Trainers: Karen Yuen (JPL)
- Use of Jupyter Notebook to access, search, filter and display XCO₂ data
- Q&A

Part 3: XCO₂ in Support of Global and Regional Climate-Related Studies

- EDT (UTC-4:00)
- Tuesday, May 31, 2022
- Trainers: Abhishek Chatterjee (JPL)
- Global and regional carbon flux estimation, and carbon cycle response to climate variability and changes in anthropogenic emissions
- Q&A

Part 4: XCO₂ in Support of Local and Regional Climate-Related Studies

- EDT (UTC-4:00)
- Thursday, June 2, 2022
- Trainers: John Lin (University of Utah)
- Climate impacts from localized emissions, air quality, and urban density
- Q&A



Learning Objectives

By the end of this demonstration attendees will be able to:

- Understand the characteristics and limitations of XCO₂ measurements from space
- Understand the type of climate studies that these measurements can support
- Be able to open and visualize XCO₂ data from OCO-2 and OCO-3

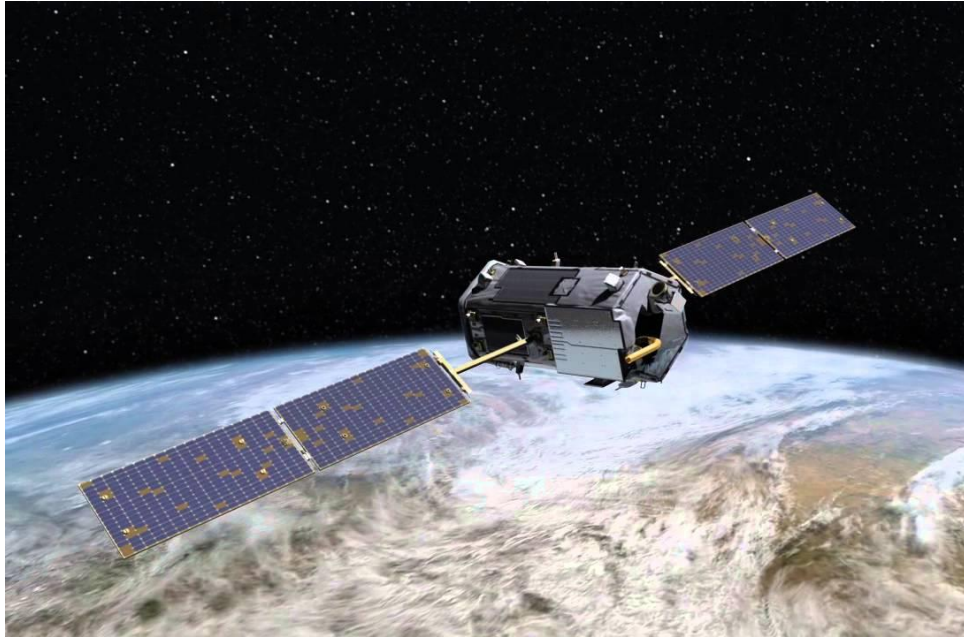


Overview

1. A summary of the characteristics of OCO-2 and OCO-3
2. OCO-2 Measurement Approach
3. OCO-3 Measurement Approach
4. Recap of XCO₂ Measurement
5. Spatial and Temporal Resolution for OCO-2 and OCO-3
6. Timeline of Available XCO₂ data
7. Where to Download Data
8. Product and Naming
9. Documentation for data products (ATBD and User Guide and Link)
10. Demonstration Portion with Jupyter Notebook



OCO-2 and OCO-3



OCO-2 (2014 - Present)

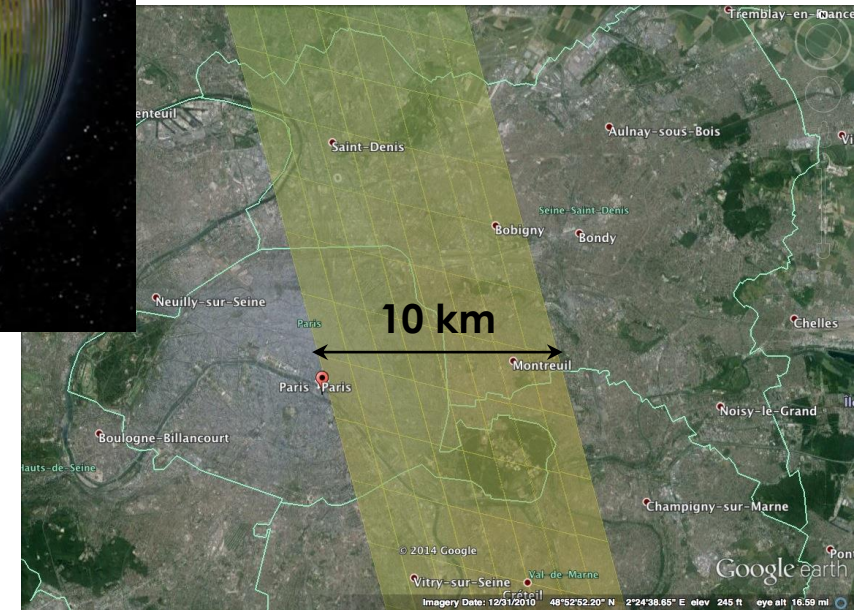
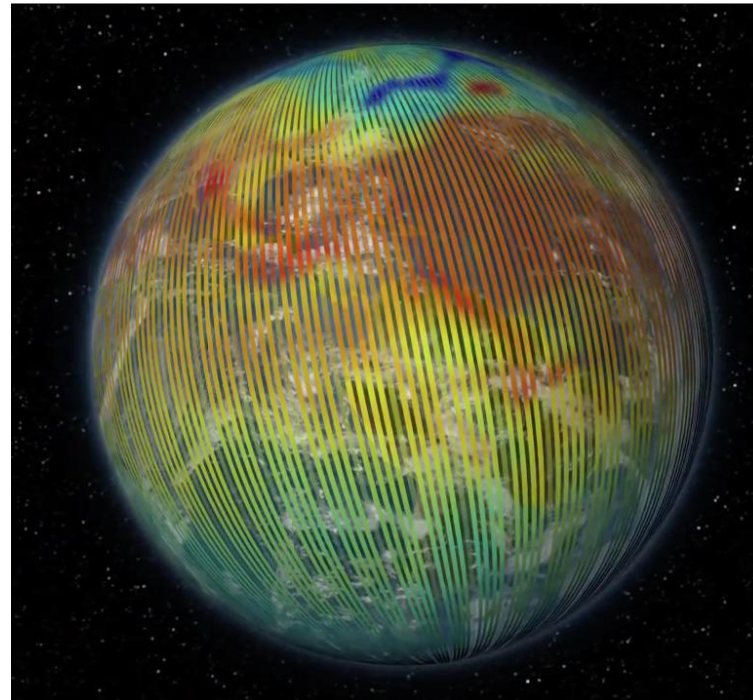
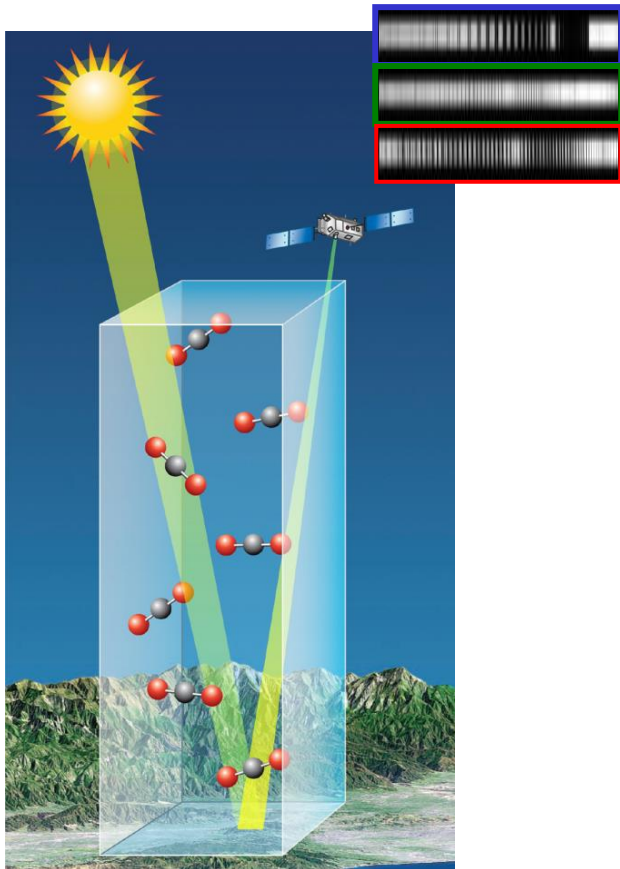


OCO-3 on ISS (2019 - Present)



OCO-2 Measurement Approach

Collect spectra of CO₂ & O₂ absorption in reflected sunlight over the globe

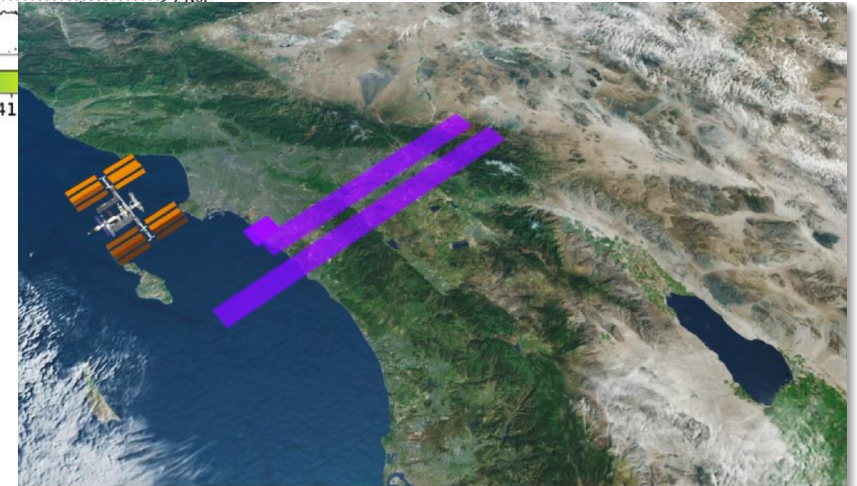
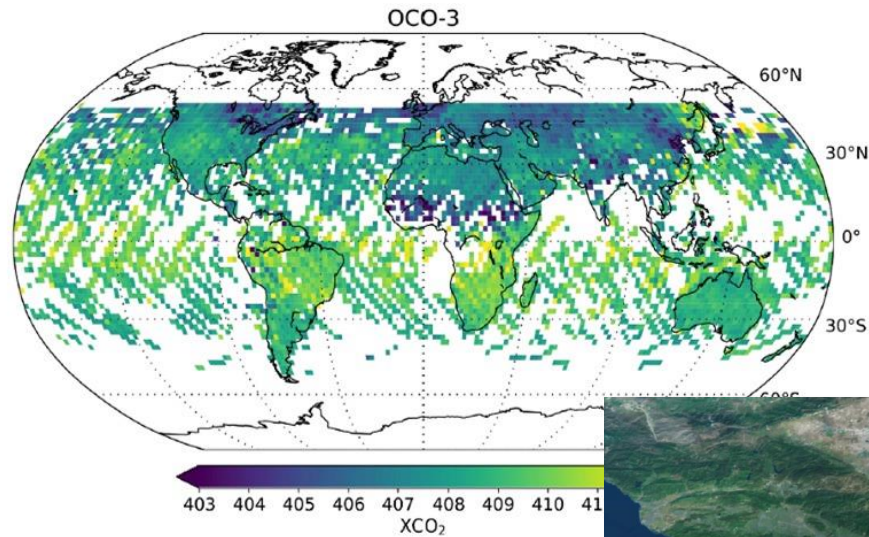
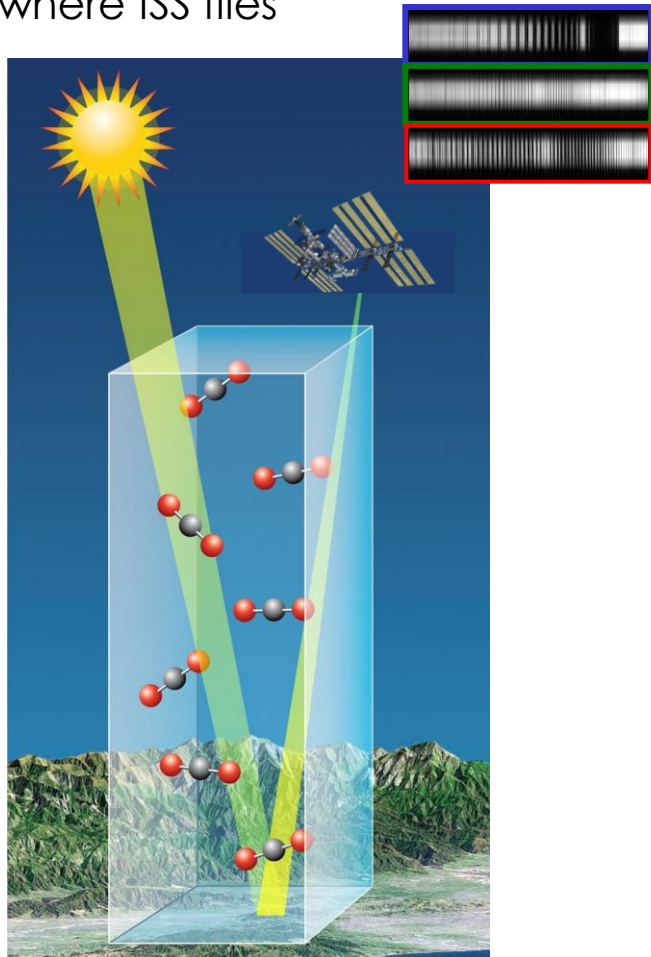


OCO-2 Measurements:

- Global
- Precise
- Small Footprints

OCO-3 Measurement Approach

Collect spectra of CO₂ & O₂ absorption in reflected sunlight over where ISS flies

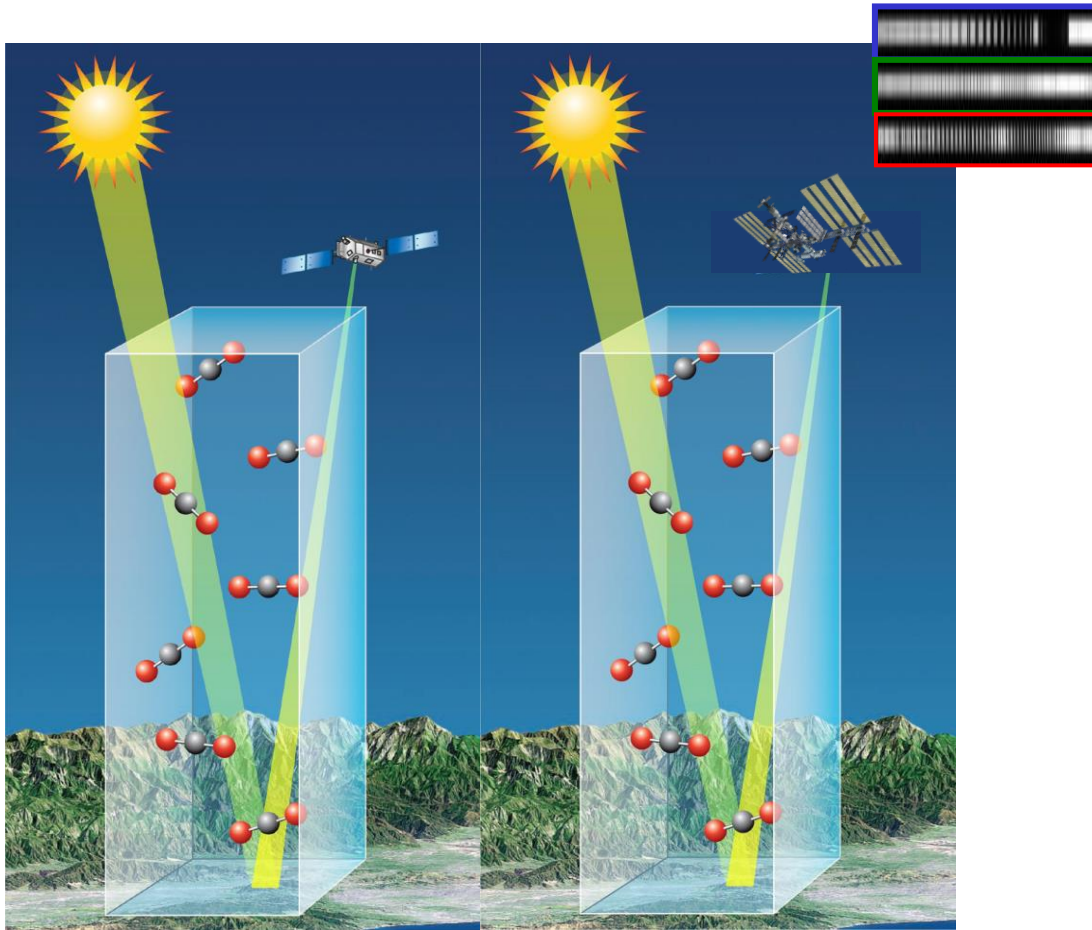


OCO-3 Measurements:

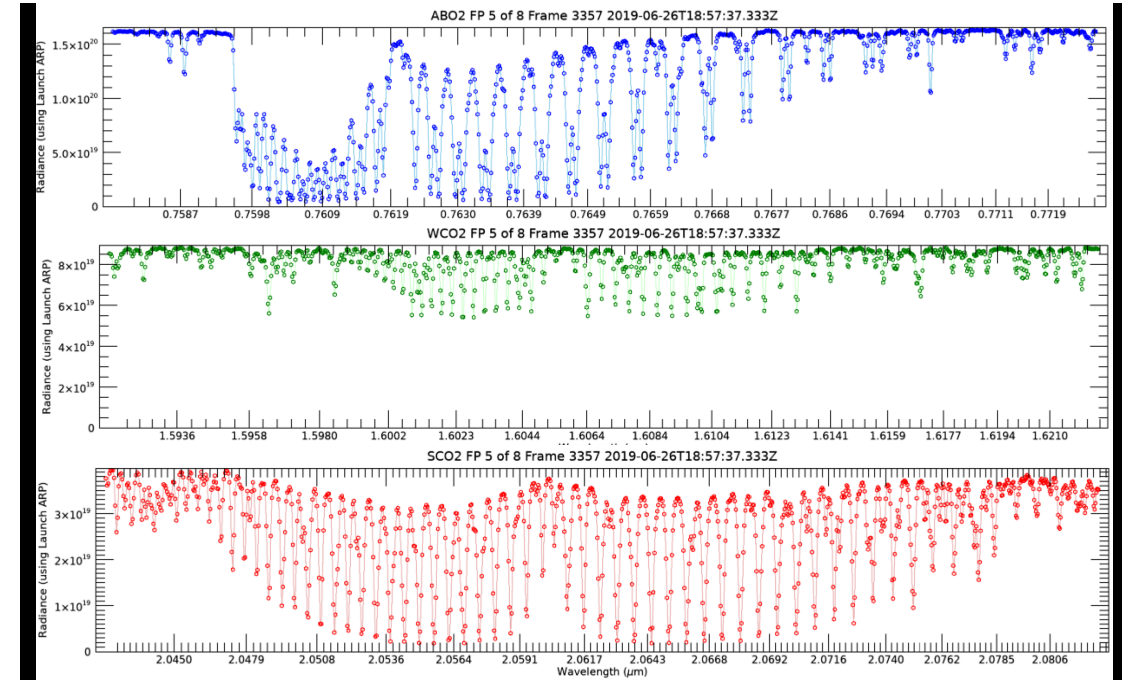
- 52 Degrees North/South Latitude
- More Precise and Denser Footprint than OCO-2
- Mapping Capability of 80 x 80 km



Recap of the XCO₂ Measurement



XCO₂ is the column average volume mixing ratio. This is a measure of the amount of carbon dioxide in the atmosphere within the column.

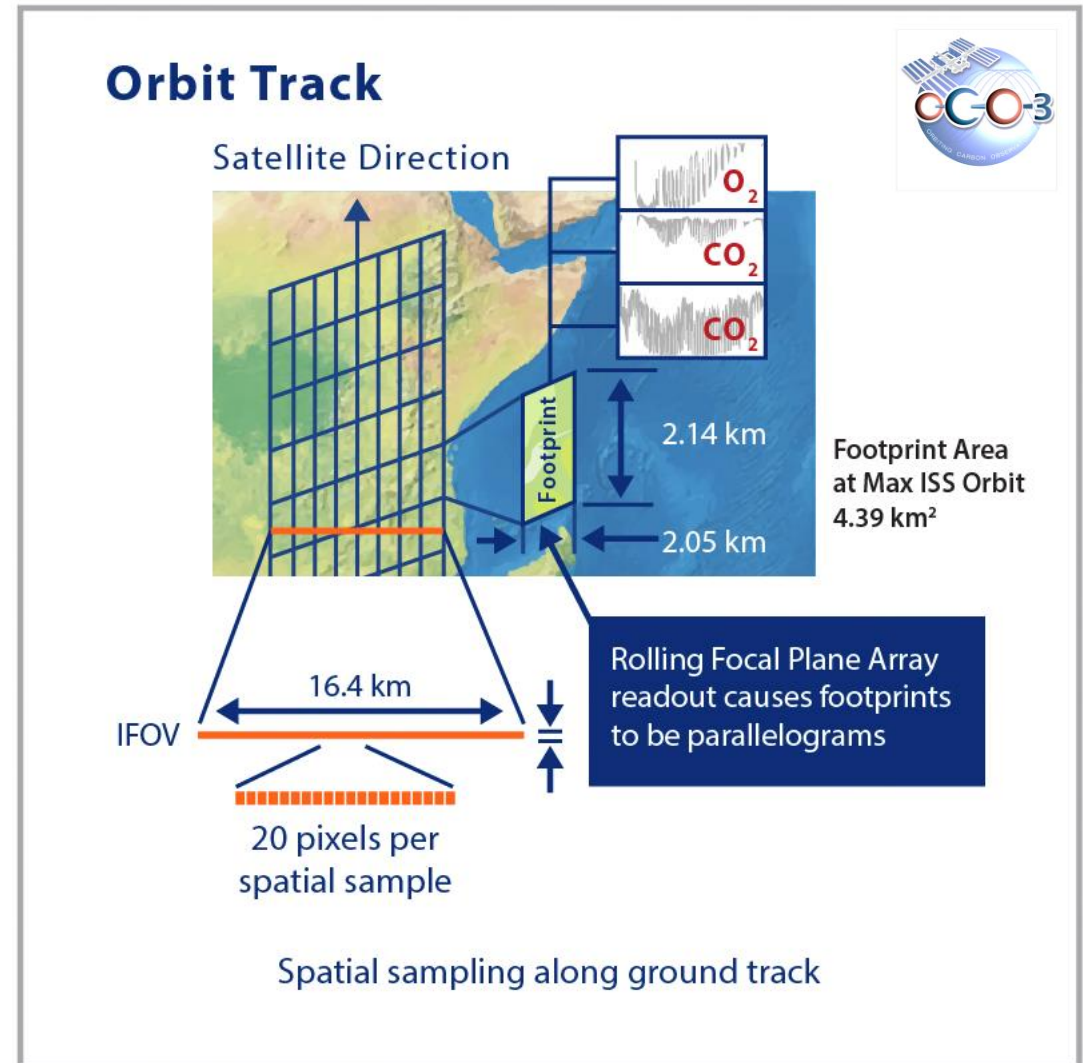
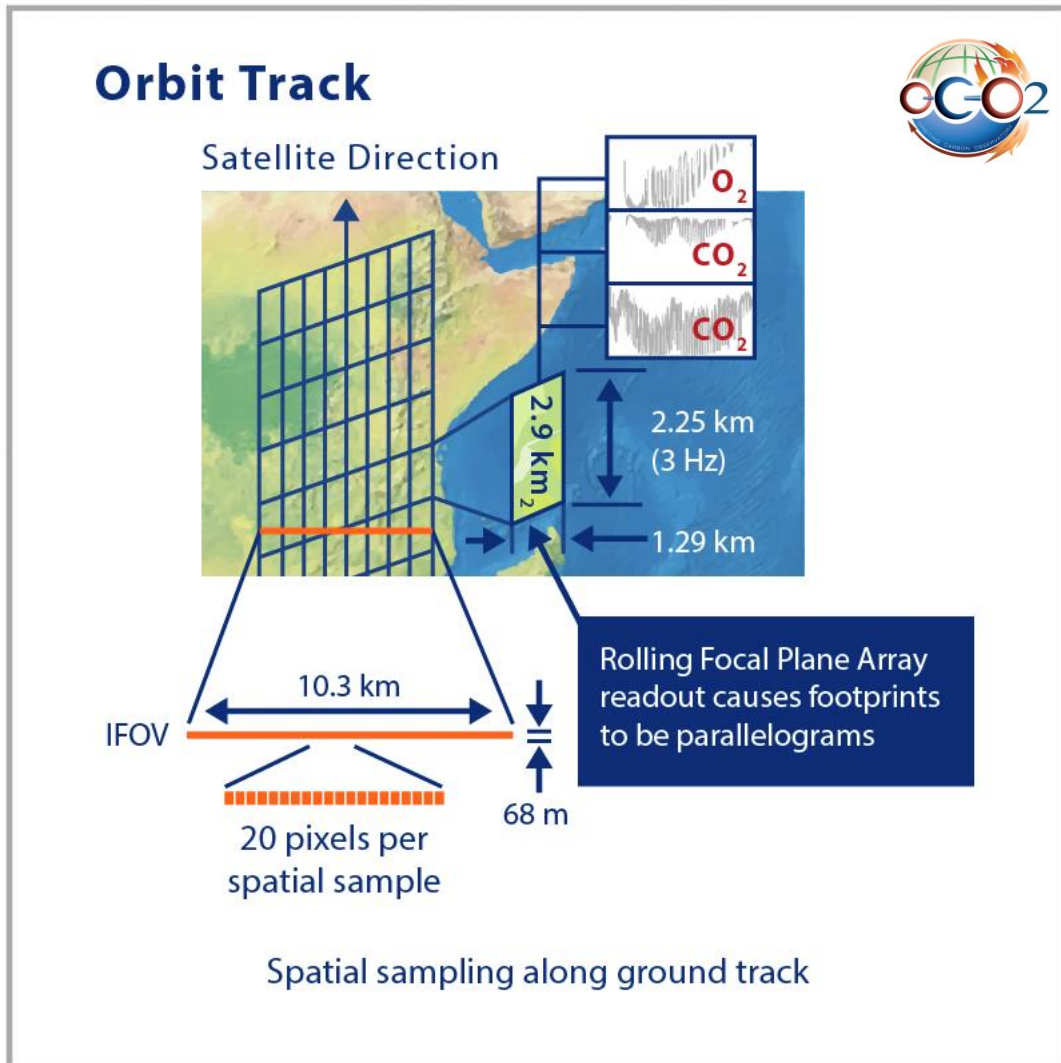


Gas molecules in the Earth's atmosphere absorb the sunlight at specific wavelengths, creating "fingerprints" that can be detected by a spectrometer.

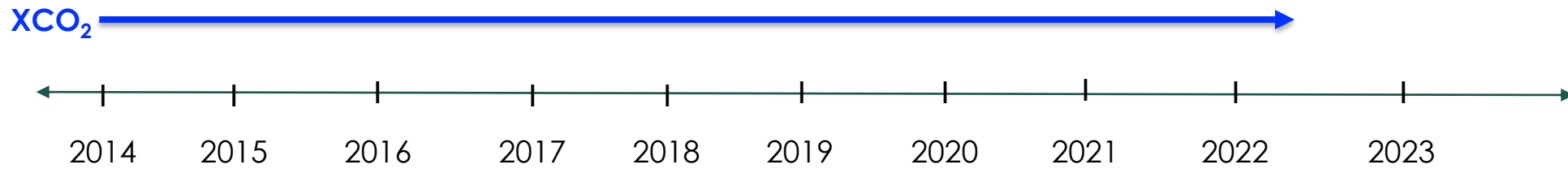
A spectrometer creates spectra, or photos of these "fingerprints". Then the absorption levels shown in these spectra, like a captured image, tells us how many molecules were in the region where the instrument measured.



Spatial Resolution for OCO-2 and OCO-3



Timeline of Available XCO₂ Data



Combined Global Measurements
with Targeted Mapping



Where to Download Data

<https://daac.gsfc.nasa.gov/datasets?keywords=OCO-2&page=1>

<https://co2.jpl.nasa.gov/>

Image	Dataset ↕	Source ↕	Version ↕	Time Res. ↕	Spatial Res. ↕	Process Level ↕	Begin Date ↕	End Date ↕
	OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r (OCO2_L2_Lite_FP 10r) Subset / Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01
	OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V9r (OCO2_L2_Lite_FP 9r) Subset / Get Data	Earth Observation Satellites OCO-2	9r	16 days	2.25 km x 1.29 km	2	2014-09-06	2020-01-22
	OCO-2 Level 2 bias-corrected solar-induced fluorescence and other select fields from the IMAP-DOAS algorithm aggregated as daily files, Retrospective processing V10r (OCO2_L2_Lite_SIF 10r) Subset / Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-02-28
	ACOS GOSAT/TANSO-FTS Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files V9r (ACOS_L2_Lite_FP 9r) Subset / Get Data	GOSAT TANSO-FTS	9r		10.5 km x 10.5 km	2	2009-04-20	2020-01-01
	OCO-2 Level 2 geolocated XCO2 retrievals results, physical model, Retrospective Processing V10r (OCO2_L2_Standard 10r) Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01
	OCO-2 Level 2 geolocated XCO2 retrieval results and algorithm diagnostic information, Retrospective Processing V10r (OCO2_L2_Diagnostic 10r) Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-02-28
	OCO-2 Level 2 spatially ordered geolocated retrievals screened using the IMAP-DOAS Preprocessor (IDP), Retrospective Processing V10r (OCO2_L2_IMAPDOAS 10r) Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01



Product & Naming from OCO-2

Image	Dataset ↕	Source ↕	Version ↕	Time Res. ↕	Spatial Res. ↕	Process Level ↕	Begin Date ↕	End Date ↕
 Hover	OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r (OCO2_L2_Lite_FP 10r) Subset / Get Data	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01

OCO-2 LiteXCO2 File Naming Convention:

oco2_LtCO2_[AcquisitionDate]_{ShortBuildID}_[ProductionDateTime][Source].nc4

oco2_LtCO2_191018_B10_v0.nc4



ATBD and User Guide

https://docserver.gesdisc.eosdis.nasa.gov/public/project/OCO/OCO_L2_ATBD.pdf

OCO D-55207

Orbiting Carbon Observatory-2 & 3 (OCO-2 & OCO-3)



Level 2 Full Physics Retrieval Algorithm Theoretical Basis

Version 2.0 Rev 3
December 1, 2020

National Aeronautics and
Space Administration

JPL

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California



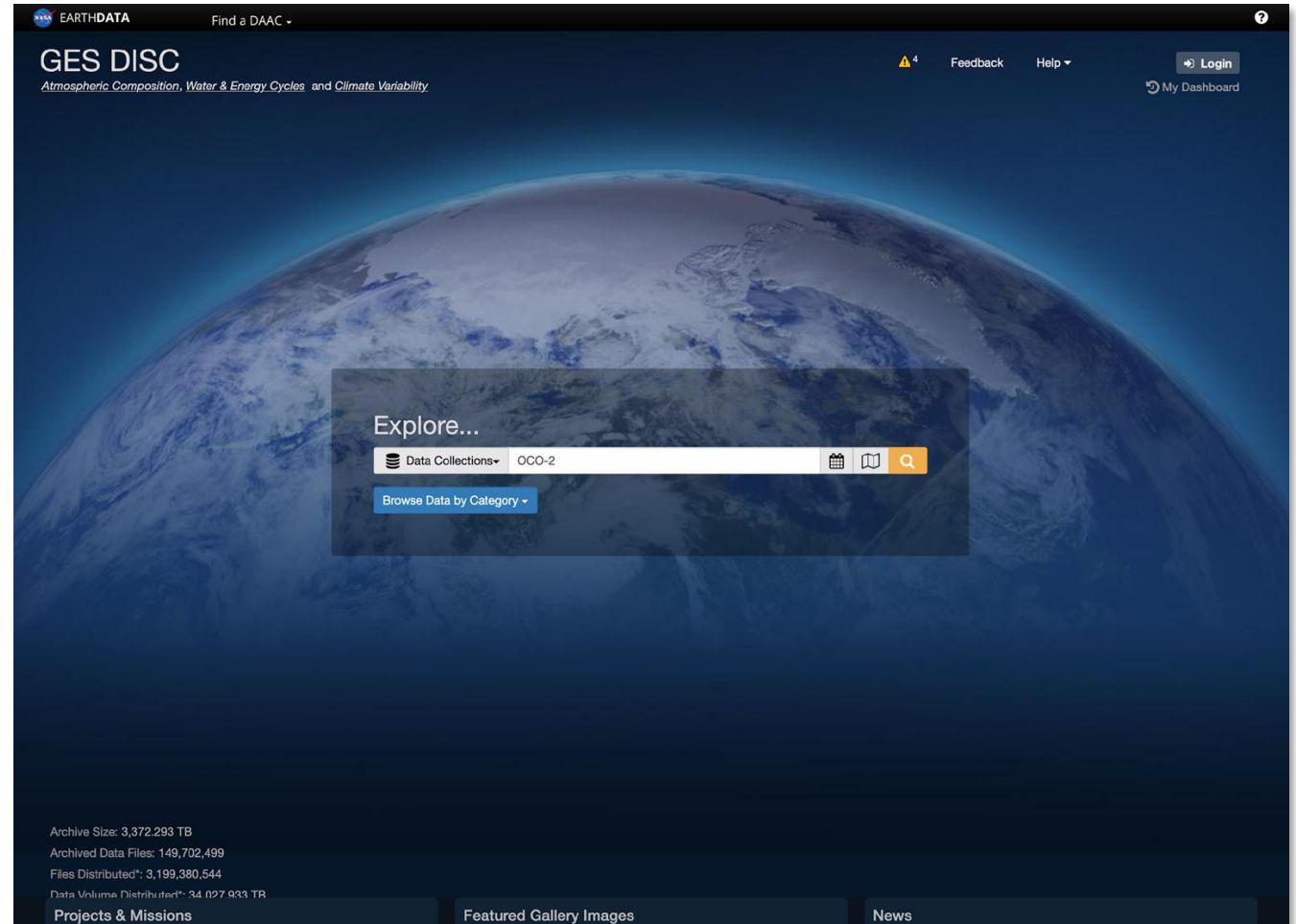
Getting Started

OCO-2 and OCO-3 data are stored at the [GES DISC](#)!

Be sure to register for a profile. It's free!

You can browse and look without a login, but you will need one to download data files.

You can always find the data or data collections by entering "OCO-2" or "OCO-3" in the search bar.



Getting Started

You will get a list of products.

We are only focusing on the XCO2 Lite product, which happens to be the top one.

The screenshot shows the NASA EarthData GES DISC interface. The page title is "Data Collections" and it shows 1 - 25 of 61 datasets associated with OCO-2. The interface includes a search bar, a "Refine By" sidebar, and a main table of data collections. The top row of the table is highlighted with a red box.

Image	Dataset	Source	Version	Time Res.	Spatial Res.	Process Level	Begin Date	End Date
	OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r (OCO2_L2_Lite_FP 10r)	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01
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	OCO-2 Level 2 bias-corrected solar-induced fluorescence and other select fields from the IMAP-DOAS algorithm aggregated as daily files, Retrospective processing V10r (OCO2_L2_Lite_SIF 10r)	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-02-28
	ACOS GOSAT/TANSO-FTS Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files V9r (ACOS_L2_Lite_FP 9r)	GOSAT TANSO-FTS	9r		10.5 km x 10.5 km	2	2009-04-20	2020-01-01
	OCO-2 Level 2 geolocated XCO2 retrievals results, physical model, Retrospective Processing V10r (OCO2_L2_Standard 10r)	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-03-01
	OCO-2 Level 2 geolocated XCO2 retrieval results and algorithm diagnostic information, Retrospective Processing V10r (OCO2_L2_Diagnostic 10r)	OCO-2 OCO-2	10r	16 days	2.25 km x 1.29 km	2	2014-09-06	2022-02-28



Getting Started

Get OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r data

Estimated size of results

2,734 days, 2,777 links, 147.42 GB

Download Method

Download Method: Get Original Files

Method Options

Refine Date Range: 2014-09-06 to 2022-03-01

NOTE: All dates and times are in UTC.

From:

2014-09-06

To:

2022-03-01

Available Range: 2014-09-06 to 2022-03-01

January 2017						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	01	02	03	04
05	06	07	08	09	10	11

January 2018						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
31	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	01	02	03
04	05	06	07	08	09	10

Refine Region: -180, -90, 180, 90

Output format

File Format: netCDF

Reset All

Get Data

Get OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r data

Estimated size of results

366 days, 372 links, 19.75 GB

Download Method

Download Method: Get Original Files

Method Options

Refine Date Range: 2017-01-01 to 2018-01-01

NOTE: All dates and times are in UTC.

From:

2017-01-01

To:

2018-01-01

Available Range: 2014-09-06 to 2022-03-01

January 2017						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	01	02	03	04
05	06	07	08	09	10	11

January 2018						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
31	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	01	02	03
04	05	06	07	08	09	10

Refine Region: -180, -90, 180, 90

Output format

File Format: netCDF

Reset All

Get Data

Getting Started

Download Method ?

- ▼ **Download Method:** ✓ Get File Subsets using the GES DISC Subsetter Reset
- Get [Original Files](#)
Generate unmodified file links directly from the archive.
- Get File Subsets using the GES DISC Subsetter 🗺️
Generate file links supporting geo-spatial search and crop, selection of variables and dimensions, selection of time of day, and data presentation, in netCDF format.

Method Options ?

▼ **Refine Date Range:** ✓ 2017-01-01 00:00:00 to 2018-01-01 23:59:59 Reset

NOTE: All dates and times are in **UTC**.

From:

2017-01-01 00:00:00

To:

2018-01-01 23:59:59

Available Range: 2014-09-06 00:00:00 to 2022-03-01 23:59:59

< January 2017 >

Sun	Mon	Tue	Wed	Thu	Fri	Sat
01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	01	02	03	04
05	06	07	08	09	10	11

< January 2018 >

Sun	Mon	Tue	Wed	Thu	Fri	Sat
31	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	01	02	03
04	05	06	07	08	09	10

▼ **Refine Region:** ✓ -125.42, 32.44, -114.521, 42.46 Reset

-125.42,32.44,-114.521,42.46




Getting Started

29	30	31	01	02	03	04
05	06	07	08	09	10	11

28	29	30	31	01	02	03
04	05	06	07	08	09	10

▼ **Refine Region:** ✓ -125.42, 32.44, -114.521, 42.46 Reset

-125.42,32.44,-114.521,42.46



Available Range: -180, -90, 180, 90 Cursor Coordinates: 23.827, -76.025

✂ Use 'Refine Region' for geo-spatial subsetting ?

▼ **Variables:** ✓ 1 variable(s) selected Reset

Expand Tree

- Meteorology
- Preprocessors



Getting Started

Data Collections

Refine By

Subject Sort ▾

- Atmospheric Chemistry (55)
- Infrared Wavelengths (12)
- Platform Characteristics (6)
- Vegetation (1)

Measurement Sort ▾

- Atmospheric Carbon Dioxide (55)
- Attitude Characteristics (3)
- Infrared Radiance (12)
- Orbital Characteristics (3)
- Solar Induced Fluorescence (1)

Source Sort ▾

- Earth Observation Satellites OCO SPECTROMETERS (1)
- Earth Observation Satellites OCO-2 (32)
- Earth Observation Satellites TANSO-FTS (2)
- GOSAT TANSO-FTS (2)
- ISS OCO-3 (6)

More...

Processing Level Sort ▾

- 0 (6)
- 1A (6)
- 1B (6)
- 2 (40)
- 3 (2)
- 4 (1)

Project Sort ▾

- MEaSUREs (1)
- OCO (4)
- OCO-2 (42)
- OCO-3 (14)

Temporal Resolution Sort ▾

- 1 day (1)
- 16 days (54)
- 1 month (1)

Spatial Resolution Sort ▾

- 2.25 km x 1.29 km (54)
- 10.5 km x 10.5 km (4)
- 0.5° x 0.625° (2)
- 1° x 1° (1)

Expand Tree

- Meteorology
- Preprocessors
- Retrieval
- Sounding
- co2_profile_apriori
- date
- file_index
- pressure_levels
- pressure_weight
- sensor_zenith_angle
- solar_zenith_angle
- vertex_latitude
- vertex_longitude
- xco2
- xco2_apriori
- xco2_averaging_kernel
- xco2_qf_bitflag
- xco2_qf_simple_bitflag
- xco2_quality_flag
- xco2_uncertainty

Dimensions: Get all dimensions Reset

Time of Day: Get complete time span Reset

NOTE: By default, COMPLETE time of day span is sent in the subset request. All dates and times are in UTC.

From: **To:**

Data Presentation: CROP Reset

Output format ?

File Format: netCDF

Reset All Get Data

Process Level	Begin Date	End Date
2	2014-09-06	2022-03-01
2	2014-09-06	2020-01-22
2	2014-09-06	2022-02-28
2	2009-04-20	2020-01-01
2	2014-09-06	2022-03-01
2	2014-09-06	2022-02-28
2	2014-09-06	2022-03-01
2	2014-09-06	2022-02-28

OCO-2 Level 2 spatially ordered geolocated retrievals screened using the IMAP-DOAS Preprocessor (IDP), Retrospective Processing V10r (OCO2_L2_IMAPDOAS 10r)

Get Data

OCO-2 Level 2 spatially ordered geolocated retrievals

Earth 11 16 days 2.25 km x 1.29 km 2 2022-03-01 2022-05-05



Getting Started

📄 Data File Links for [OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files, Retrospective processing V10r](#)

Results (found 309 links in range from 2017-01-01 to 2018-01-02):

[Download as txt files](#)

[Download links list](#) (This list is valid for 2 days) | [Instructions for downloading](#)

[User's Guide](#)

[OCO_L2_ATBD.pdf](#)

[README document](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170101_B10206Ar_200730053044s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170102_B10206Ar_200730053400s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170103_B10206Ar_200730053434s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170104_B10206Ar_200730053446s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170105_B10206Ar_200730053447s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170106_B10206Ar_200730053548s.nc4](#)

[OCO2_L2_Lite_FP.10r:oco2_LtCO2_170107_B10206Ar_200730053719s.nc4](#)

▶ Selected Parameters

Job ID: [627546322bb51434b1de7cf0](#) ?



Jupyter Notebook Portion

Before following along, you will need to download some software packages for this portion of the training. This is also what you will need in order to work with the data.

We have found the easiest and most straightforward way to work/display the data is to use Conda.

We will be working in Python 3, and Python and Jupyter notebook are packaged within Conda. Please follow the install directions listed for your operating system (Windows, Mac OS, Linux).

<https://docs.conda.io/projects/conda/en/latest/user-guide/install/index.html>

The libraries that you will need to use and import in the code below should be included in Conda. We have made some files available for download. OCO-2 Data files are large so it will take some time to download! This is just a sample. You can always download more files to check things out.

Please remember which directory you download your files, and we recommend creating a folder for the data.

Jupyter Notebook Installation Guide (if you would prefer to just load this without Conda)

From this list of websites, you can follow instructions to setup Jupyter Notebook:

- <https://jupyter.org/install>
- <https://www.geeksforgeeks.org/how-to-install-jupyter-notebook-in-windows/>
- <https://test-jupyter.readthedocs.io/en/latest/install.html>



Next Step

The libraries you need should be installed with Conda. To verify, open a terminal and type Conda List. Scroll to check that what you need is there. If not, do pip install.

```
kyuen 1 — jupyter-notebook • python — 223x72
Last login: Mon May 9 21:27:06 on ttys000
(base) kyuen@MT-200995 ~ % conda ls

CommandNotFoundError: No command 'conda ls'.
Did you mean 'conda list'?

(base) kyuen@MT-200995 ~ % conda list
# packages in environment at /Users/kyuen/anaconda3:
#
# Name                    Version            Build             Channel
_ipyw_jlab_nb_ext_conf    0.1.0              py39hced8cb5_0
alabaster                  0.7.12             pyhd3eb1b0_0
anaconda                   2021.11            py39_0
anaconda-client            1.9.0              py39hced8cb5_0
anaconda-navigator         2.1.1              py39_0
anaconda-project           0.10.1             pyhd3eb1b0_0
anyio                      2.2.0              py39hced8cb5_1
appdirs                    1.4.4              pyhd3eb1b0_0
applaunchservices          0.2.1              pyhd3eb1b0_0
appnope                    0.1.2              py39hced8cb5_1001
appscript                   1.1.2              py39h9ed2024_0
argh                        0.26.2             py39hced8cb5_0
argon2-cffi                 20.1.0             py39h9ed2024_1
arrow                       0.13.1             py39hced8cb5_0
asn1crypto                  1.4.0              py_0
astroid                     2.6.6              py39hced8cb5_0
astropy                     4.3.1              py39hf9932de_0
async_generator             1.10               pyhd3eb1b0_0
atomicwrites                1.4.0              py_0
attrs                       21.2.0             pyhd3eb1b0_0
autopep8                    1.5.7              pyhd3eb1b0_0
babel                       2.9.1              pyhd3eb1b0_0
backcall                    0.2.0              pyhd3eb1b0_0
backports                   1.0                pyhd3eb1b0_2
backports.functools_lru_cache 1.6.4              pyhd3eb1b0_0
backports.shutil_get_terminal_size 1.0.0             pyhd3eb1b0_3
backports.tempfile          1.0                pyhd3eb1b0_1
backports.weakref           1.0.post1          py_1
basemap                     1.2.2              py39h1ed8f73_2  anaconda
beautifulsoup4              4.10.0             pyh06a4308_0
binaryornot                 0.4.4              pyhd3eb1b0_1
bitarray                    2.3.0              py39h9ed2024_1
bkcharts                    0.2                py39hced8cb5_0
black                       19.10b0            py_0
blas                        1.0                mkl
bleach                       4.0.0              pyhd3eb1b0_0
```

```
127 KB
Download
Anaconda Powershell Prompt (Anaconda3)
(base) PS C:\Users\sagar1> pip install pandas numpy matplotlib xarray netCDF4 plotly
```



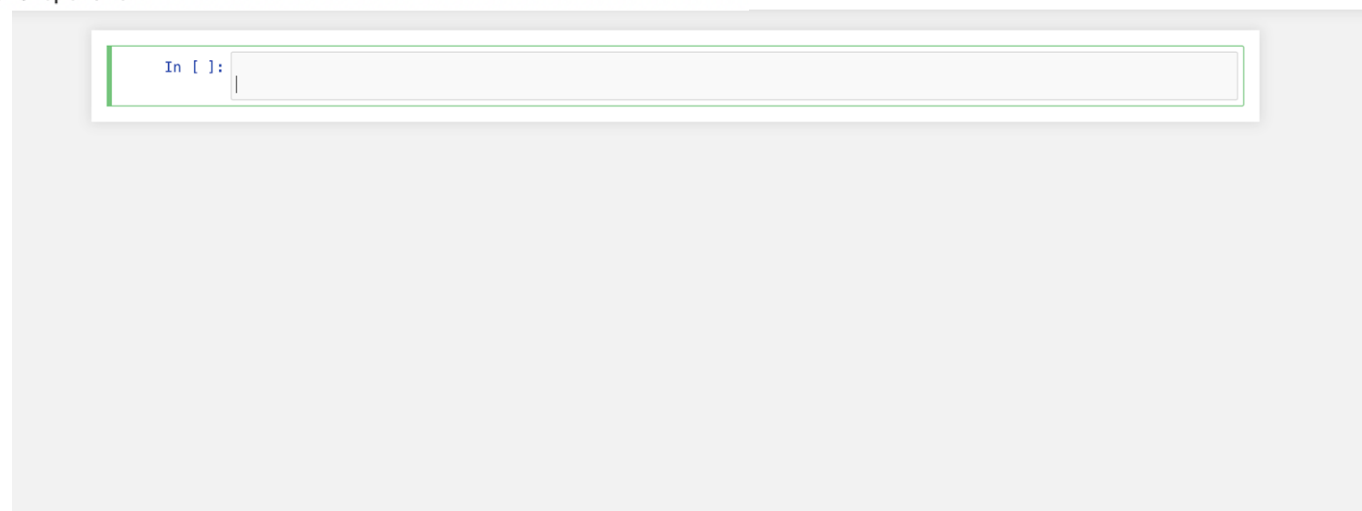
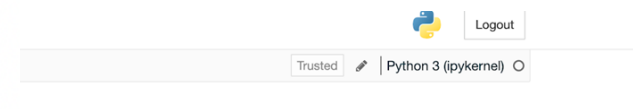
Final Step

To open up Jupyter notebook, you simply type Jupyter notebook in terminal and prompt and it will open up a new notebook in your chosen browser.

```
Last login: Mon May  9 21:29:44 on ttys001
(base) kyuen@MT-200995 ~ % jupyter notebook
[I 2022-05-12 19:39:01.808 LabApp] JupyterLab extension loaded from /Users/kyuen/anaconda3/lib/python3.9/site-packages/jupyterlab
[I 2022-05-12 19:39:01.808 LabApp] JupyterLab application directory is /Users/kyuen/anaconda3/share/jupyter/lab
[I 19:39:01.813 NotebookApp] The port 8888 is already in use, trying another port.
[I 19:39:01.813 NotebookApp] The port 8889 is already in use, trying another port.
[I 19:39:01.814 NotebookApp] Serving notebooks from local directory: /Users/kyuen 1
[I 19:39:01.814 NotebookApp] Jupyter Notebook 6.4.5 is running at:
[I 19:39:01.814 NotebookApp] http://localhost:8890/?token=8d904a1bab00dd06d19f4c44d22cae9bd1cc91121be9e98b
[I 19:39:01.814 NotebookApp] or http://127.0.0.1:8890/?token=8d904a1bab00dd06d19f4c44d22cae9bd1cc91121be9e98b
[I 19:39:01.814 NotebookApp] Use Control-C to stop this server and shut down all kernels (twice to skip confirmation).
[C 19:39:01.818 NotebookApp]
```

To access the notebook, open this file in a browser:

file:///Users/kyuen/Library/Jupyter/runtime/nbserver-29346-open.html



References

Get Data:

<https://daac.gsfc.nasa.gov/datasets?keywords=OCO-2&page=1>

<https://co2.jpl.nasa.gov/>

Github/Collab for Code:

<https://github.com/sagarlimbu0/OCO2-OCO3>

https://github.com/kyuenjpl/ARSET_XCO2

<https://colab.research.google.com/drive/13KC3vPt6DXj8bQAyc7MHjimNjJDdMfK?authuser=1>

Contacts

- Trainers:
 - Karen Yuen: karen.yuen@jpl.nasa.gov
- Training Webpage:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/arset-measuring-atmospheric-carbon-dioxide-space-support-climate>

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Thank You!

