



Questions & Answers Part 2

Please type your questions in the Question Box. We will try our best to answer all your questions. If we don't, feel free to email Erika Podest (erika.podest@jpl.nasa.gov) or Karen Yuen (karen.yuen@jpl.nasa.gov).

Question 1: Could you please explain how you downloaded the data. The last step after slide 20. Do you just need to download the links to the data?

Answer 1: Yes, you have to download the data. The slide contains instructions and links to do a batch code in order to download all the files together. The files are rather big so if you choose to download the data files, it might take some time.

If you choose not to download the data and this is understandable, the Distributed Active Archive Center (DAAC) suggests that folks work in OPeNDAP. You can read more about it here. We are working on developing a simplified tutorial to help with this - thank you for your patience.

https://oco2.gesdisc.eosdis.nasa.gov/opensdap/OCO2_L2_Lite_FP.10r/contents.html

<https://www.earthdata.nasa.gov/engage/open-data-services-and-software/api/opensdap>

Question 2: I have Python within Anaconda. Will that be sufficient to run this or should it be installed as stand alone?

Answer 2: It should work as is. You would just need to open your prompt and type in "Jupyter Notebook" at the line and a new notebook will open up in your browser of choice (whatever you have set it up to be). Once it is open then you can copy the code that we have made available and start working with it.

Question 3: Can we display the map with other than Mapbox key dependency?

Answer 3: To use the map that we chose to display the data, you need the key dependency. That key is associated with that package. There may be other packages where you won't need a key. It is not clear from this question if the participant wants to



use the data with another map or if they want to use it without the key. The short answer is that you will need the key to use that map.

Question 4: How do you compare the intra day time variations in satellite observations (like one observation at 9 am and another one sometime later)?

Answer 4: If you are looking at just OCO-2, the data is collected at around the same local time (1:30 PM or 13:30). OCO-3 is on the ISS and it therefore has a slightly different orbit as mentioned during the session. There are the ISS descending and ascending nodes and depending upon those orbits you end up collecting data at different times during the day. If you are looking at, for example Los Angeles, you can collect data in the morning as well as in the afternoon. If we try to compare this data against a validation site we look at collocated data in space and time, which means we make a specific bounding box around that site in space and in time. For example, we only look at data ± 30 minutes or ± 2 hours when the satellite passed over that site. We need to do this because we believe that within this short time-frame, we do not expect huge variations in the column CO₂. Now in general, over the course of the day, there is a large variation in CO₂ fluxes, with changes being greatest closer to the surface. These changes become diluted, or dampened, when we look at the total column. Please see the following reference, specifically Figure 2 for an illustration on how CO₂ flux variations translate to CO₂ concentration changes, and then how they relate to XCO₂ concentration changes.

Reference: Olsen, S. C., and J. T. Randerson (2004), Differences between surface and column atmospheric CO₂ and implications for carbon cycle research, *J. Geophys. Res.*, 109, D02301, doi:10.1029/2003JD003968

Question 5: Are there web APIs to download the nc4 files programmatically?

Answer 5: There is not one specific web API we can recall, but this is something we can look into further. Pydap is possible and we were planning on showing this for the Intermediate level training. However, we can make the existing code available to anyone who needs it right away.

Question 6: Is there a way to convert or export netCDF data as GeoTiff for post-processing in GIS softwares?

Answer 6: There is a way and we are working on making it publicly available. Please reach out to Karen Yuen for additional information.



Measuring Atmospheric Carbon Dioxide from Space in Support of Climate Related Studies

May 24 - June 2, 2022

https://colab.research.google.com/drive/1hLEmGSgY_JJpvRNSWsCgUiJppC4q5_Pj?authuser=1

https://colab.research.google.com/drive/1OSYsWtsdvQIJ3ty9CCKX39_uIT0cx5on?authuser=1

Question 7: I have read that basemap is being deprecated in favor of cartopy, but cartopy doesn't have all of the nice features that you demonstrated today. Are you planning on sticking with basemap or switching over to cartopy (or some other module) for your high resolution static maps? Thanks!

Answer 7: We have tested different visualization libraries and we selected basemap. We have tried libraries such as pydeck and kepler. In the future we might use other libraries that have more features.

Question 8: Is there a cloud-native solution, like cloud optimized geotiffs, on the STAC API with Microsoft Planetary Computer? If not, are you working toward a cloud solution?

Answer 8: Not currently. This is something we will look into for OCO future capabilities.

Question 9: Why does the data have gaps within tracks? Is there any way to fill in the gaps?

Answer 9: Gaps exist due to the small footprint of the instrument and as a result, there will be inconsistencies in coverage. Gaps also exist since we cannot obtain retrievals where there is thick cloud cover, or aerosol and smoke plumes. There are ways to fill in the gaps using higher-order products. We call this Level 3 (L3) gap-filled XCO₂ estimates. These gap-filling methods can be based on statistical methods or advanced data assimilation methods. Refer to the next part of this training series where we will briefly discuss L3 products and applications with those products.

References:

- (1) Statistical approaches for gap-filling: Hammerling, D. M., A. M. Michalak, and S. R. Kawa (2012), Mapping of CO₂ at high spatiotemporal resolution using satellite observations: Global distributions from OCO-2, *J. Geophys. Res.*, 117, D06306, doi:10.1029/2011JD017015
- (2) Using data-assimilation methods: Chatterjee, A., R. J. Engelen, S. R. Kawa, C. Sweeney, and A. M. Michalak (2013), Background error covariance estimation for atmospheric CO₂ data assimilation, *J. Geophys. Res. Atmos.*, 118, 10,140–10,154, doi:10.1002/jgrd.50654



Question 10: Is there a timestamp in the nc4 files indicating the ingestion date\upload date\processed date?

Answer 10: The nomenclature includes the date that the product was acquired as well as the version and when it was produced.

Question 11: Is there any quota on downloading nc4 files? Is all the data freely available?

Answer 11: There is no quota and the files are freely available (NASA policy). It is NASA data policy that all its data is made freely available without any quotas.

Question 12: Is it possible to obtain an x-y plot with the data?

Answer 12: Yes! This was the first example covered during the demonstration.

Question 13: Is it possible to export this data to GIS (QGIS or ArcGIS) or to some vectorial program?

Answer 13: Not directly. You will have to convert the file to be compatible in a GIS software. This is something that we are exploring.

Question 14: What data is in the different product levels e.g., L1A, L2A etc.?

Answer 14: The data products mentioned today were the Level 2 Lite products. That is the lowest level data that we recommend for people to use. The Level-1A is the raw spacecraft data. The Level-1B contains the geolocated and calibrated radiances. We don't recommend that you use the L1-A or L1B data. We recommend that you use the Level-2 Lite products, which contain the XCO₂ information.

Question 15: Can you do vectorial processing with any library for this?

Answer 15: We are not aware of any libraries that can do this directly.

Question 16: I asked the question on the Mapbox key dependency. MapBox acts as a base map. Can we export the data and plot and display the data simply in QGIS with a base map?

Answer 16: With QGIS, you need to create the base layer. Right now the OCO data does not translate directly into the base layer that you need to feed into QGIS. There



are some additional steps involved to help you with this process. We are working on a solution for this to make it easier.

Question 17: Are there any Python libraries *specific* to working with OCO (e.g., not matplotlib but ones implemented by NASA or OSS that work directly with OCO and nc4 files)?

Answer 17: Panoply is a software that can open the netcdf files and export that allows you to export them in a different format.

Question 18: Any notable Open Source Software (OSS) projects related to OCO that you can recommend?

Answer 18: Great question and the answer is not immediately. We will have to consider this for the next training and be exploring.

Question 19: Can the OCO-2 data files be imported in Google Earth Engine? If yes, can you share any reference for that?

Answer 19: Eventually yes, but it takes a few steps to export the XCO2 data in a format that can be imported by GEE. We will write that up and make it available in Fall. Right now you can open the files with Panoply and export them in a format that is compatible with GEE.

Question 20: Have you considered staging your data on a public ERDDAP server? This would allow users to programmatically access data using the consistent URLs.

Answer 20: No, we have not. Our data is made freely available through the Data Archive Center (DAAC). Because the data is data freely available there are security protocols to consider when making the data available through direct access.

Question 21: How can we do anomaly detection or deviation from long term mean like standardized Z Score?

Answer 21: There are some examples of work in the literature where people have been doing anomaly detection.



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Weir et al., 2021, Science Advances, vol 7 (45), [DOI: 10.1126/sciadv.abf9415](https://doi.org/10.1126/sciadv.abf9415)

Torres et al., 2019. J. Geophys. Res., vol 124, pp 9773-9795,
<https://doi.org/10.1029/2018JD029933>

Question 22: Can you provide data on OCO-2/OCO-3 and monitoring data for each different country at different times? for example for countries that have signed agreements at COP26. Thanks!

Answer 22: Yes and we will talk about this application during the next session of this training series. The way we use the OCO-2 and OCO-3 data for this application is that we do not directly use the concentrations. Instead, we use the concentrations through an inverse modeling framework to estimate the net flux exchange that is happening between the surface and the atmosphere. We then bring in information about fossil fuel emissions as well as information about other bottom-up inventories such as the movement of wood products, crop products, and other flux exchanges that happen. We then put all that information together to deliver a net carbon exchange (NCE) term. That term we can then be divided up by country totals. In fact we are providing that NCE estimate to the global stocktake process. We recently had an ARSET training on the global stocktake titled “Atmospheric CO₂ and CH₄ Budgets to Support the Global Stocktake” <https://appliedsciences.nasa.gov/join-mission/training/english/arset-atmospheric-co2-and-ch4-budgets-support-global-stocktake>