Questions & Answers Part 4

Please type your questions in the Question Box. We will try our best to answer all of your questions. If we don't, feel free to email Erika Podest (erika.podest@jpl.nasa.gov) or John Chun-Han Lin (John.Lin@utah.edu).

Question 1: Can you please clarify on slide 21 - the correlation between CO_2 and other pollutants - if the correlation and measurements were done with OCO or ground based tools?

Response 1: Those analyses were done with ground-based measurements.

Question 2: On slide 26, CO, PM2.5, and NOx are listed for observing ecosystem stress. Could you explain this relationship a bit more? What references do you suggest to read more about this?

Response 2: Actually, those bullet points on the left-hand column and the right-hand column do not map one-to-one. I was thinking more of using CO_2 variations to understand ecosystem carbon fluxes and thus ecosystem stress (e.g., reduced photosynthetic uptake), rather than CO/PM2.5/NOx, which would be more relevant for pollution and air quality. Another remote sensing dataset that would be valuable for observing ecosystem stress is satellite-observed Solar-Induced Fluorescence (SIF). If you are interested in the use of SIF, there is a whole ARSET training session focused exclusively on SIF.

ARSET SIF Training:
https://appliedsciences.nasa.gov/join-mission/training/english/arset-use-solar-induced-fluorescence-and-lidar-assess-vegetation

Question 3: Dr. Lin says that city-scale action can deliver 40% of the Paris agreement. Remote sensing CO_2 sometimes does not show the specific sources of these CO_2 emissions. Therefore, how do you use remote sensing atmospheric CO_2 emission trends to convince decision-makers to take real action toward the Paris agreement?

Response 3: This is a valid question! Even if remotely-sensed CO_2 does not show specific sources of CO_2 emissions, even tracking total city emissions over multiple years is valuable in seeing whether the decision-makers' policies help reduce urban carbon emissions over time. That being said, OCO-3 and other satellite instruments being planned in upcoming years have some potential of providing more granularity in emissions across the urban landscape.

Question 4: In slide 49, how do you define a city with heavy power industries?
Response 4: We looked at emission inventory measurements. These are socio-economic estimates - bottom-up estimates (not using the atmosphere). There are detailed numbers for each city in terms of approximate power emissions. We ratioed those values against area emissions. Certain cities had a very high ratio. Dien Wu's paper in Environmental Research Letters has further details: https://doi.org/10.1088/1748-9326/ab68eb

Question 5: Since a city may not be fully captured in a single tile, how do you create a complete atmospheric image of its area (i.e., with Sentinel you would merge adjacent tiles to cover the full city's extent)? Can you please elaborate on this challenge, what tools to use, or any algorithms to consider?
Response 5: Yes–this is a great point. Let's start with OCO-2, which has a narrow track. Sometimes the observation is downwind, upwind or directly over the city. From that track we have to rely on winds for atmospheric transport to carry information from different parts of the city in order to try to piece together a fuller picture of the emissions. One of the tools recommended is an atmospheric model to reconstruct those winds and how the air arrived in your track.

In the case of OCO-3, it has the SAM mode, which is more of a mapping tool that allows you to scan across your targeted urban extent. We are still trying to figure out the use of OCO-3 data to pull emissions from different parts of the city. In the end it will depend on the sensor that you use and how you will use it.

Question 6: In spatial terms - what is a track width, are there exact adjacent tracks, how close are the tracks to each other? In temporal terms - to build a

city's atmospheric image, how many revisits will be needed, how can the revisit gap impact it?
Response 6: These are important things to consider. For OCO-2 the track is on the order of 10 km in terms of width. For a city, with OCO-2 you get a single track. The revisit time is 16 days. There are other considerations. For example, you can have an overpass but there could be cloud coverage and you would not be able to collect data and therefore the gap may be longer. That means that you may not be able to get very detailed variations in time.

Another reality is that it is a day time sampler because you rely on reflected sunlight, which is a fundamental limitation. In terms of how many revisits, as a rule of thumb I would suggest around 5 to beat down the noise and get a more robust number. You need to aggregate 5 for each city to get an adequate number however by doing this you will lose some temporal variation. The SAM mode is different therefore for OCO-3, the adequate number of observations is still a research question. A final consideration is that depending on the city you may have to aggregate multiple years of data to get that sample of 5.

Question 7: To better understand how cities report their CO_2 emissions - can you please point to a few cities' official CO_2 reports published, either with\out OCO data, and possibly in C40 resources?
Response 7: One example is the one we discussed today in Salt Lake City in Utah, USA. Many cities have official reports about their emissions but most of them do not use OCO-2 data in their reports. This can be for several reasons. These reports are compiled using socio-economic data, staffing is limited and people do not have the expertise to use OCO-2 data. These reports follow established models based on the number and dimensions of buildings, for example. Those models are the dominant ones used by cities for reporting their emissions. There is no single reporting platform. There are several different types and sometimes you can get very different results. Satellites provide an independent source of information to try to help nail down the numbers and see whether trends and goals are met.

Question 8: Can you please clarify, for monitoring cities, if we should use OCO-2 and/or OCO-3?

Response 8: Both! OCO-2 has a narrow track and it does not have frequent coverage. However, it provides a decent handle on what is happening over the city as a whole using atmospheric modeling tools. If you wanted to zoom into parts of a city then that is where OCO-3 can be of great benefit through its SAM mode, which scans the whole city. For a large city like Los Angeles, you can identify what is happening in different parts of the city such as the port area, the downtown area, the eastern part, etc. That is the benefit in combining these two satellite sensors.

Question 9: What are the advantages of using SIF in comparison to NDVI for mapping the vegetation in a city?

Response 9: NDVI is the go to ecosystem monitoring greenness vegetation index. In comparison, SIF is a direct byproduct of the photosynthetic mechanism. Research over the past decade has shown that SIF is more closely related to photosynthesis. Therefore, SIF has an advantage in mapping vegetation. The key disadvantage is that SIF has a shorter time series. NDVI goes back decades while SIF is available for the past decade.

NDVI is a greenness index and it runs into serious problems with coniferous vegetation, which is green throughout the year. You do not get a good seasonal NDVI signal with photosynthesis turning off during the winter and then turning on during the growing season. That is a specific example of the advantage of SIF over NDVI. SIF is being observed by Earth EO sensors and is therefore collocated with XCO2.

Question 10: How available are the data for the tropical region in Africa? What are the processing tools?

Response 10: The first slides of part 2 of today's session show figures with large data gaps in tropical regions. That is primarily because of cloud cover. There is a lot of convection and weather there that affects the retrieval. Unfortunately there is just not a lot of data in tropical regions.

Processing is dependent on sampling if you are just relying on the OCO missions. You need to determine what conditions you are sampling. However, even though there are gaps in tropical regions, there is enough high density data over these regions to constrain seasonal and interannual variations in fluxes. There are several publications that have used the data from OCO-2 to look at changes over the tropics. Some are referenced in part 3 of this training. It is true that if you want to address changes that are happening within a week or a day then there might be enough gaps in the data that make it hard to address processes occurring in such short time scales.

SIF is less sensitive to cloudiness and you can get pretty good coverage in the tropics. If you are interested in the vegetation you will want to combine SIF and XCO2.

Question 11: In Session 1 it was said that OCO-2 records at wavelengths of 1600 nm. Landsat 8 also has a SWIR band of about 1600 nm. Is it possible to use Landsat 8 to measure CO_2 in the atmosphere?
Response 11: No–due to the fact that Landsat measurements are broadband measurements. What allows us to use OCO-2 and OCO-3 observations to measure atmospheric CO2 is that they have high spectral resolution.

Question 12: What is the height range (min and max height) of the air column measured by OCO-2 and -3?
Response 12: The air column extends from the ground to the stratosphere. The averaging kernel is relatively evenly weighted.

Question 13: How do you verify/validate the results of OCO (2 and 3) estimate accuracy, because in this method satellite data is used with very low resolution, one a pixel will include many other gas objects, even the value of OCO (2-3) recorded in a pixel will not have the same value?
Response 13: You will want to combine the satellite measurement with a different measurement as a potential independent check. Examples include estimates from ground based data that can serve as a check to the satellite data. It is something that will become more common in terms of published work.