Questions & Answers Sessions

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), Nick Parazoo (nicholas.c.parazoo@jpl.nasa.gov), Jackie Ryan (jacqueline.ryan@jpl.nasa.gov) or Karen Yuen (karen.yuen@jpl.nasa.gov)

Question 1: Are there differences in SIF detection in difficult-to-sense landscapes like sagebrush steppe or semi-arid drylands?
Answer 1: Detectability is in principle independent of landscape. However, landscapes with reduced vegetation or less productive vegetation will typically have weaker signals resulting in increased noise in the SIF retrieval.

Question 2: Can Landsat and Sentinel satellites measure SIF?
Answer 2: No for Landsat. Yes for the Sentinel 5 Precursor (S5P). Landsat is a broadband instrument optimized for detecting optical signals in visible and near infrared wavelengths. These are important for constructing vegetation indices, which help us understand plant structural change. However, Landsat cannot resolve solar Fraunhofer lines needed for the SIF retrieval. The S5P satellite mission contains the TROPOsphereic Monitoring Instrument (TROPOMI) which has sufficient spectral resolution within the red and far-red SIF bands needed to retrieve SIF.

Question 3: What is 'PhotoSpec' on slide 16?
Answer 3: PhotoSpec is a tower mounted spectrometer similar to those in space (such as the Orbiting Carbon Observatory) but capable of measuring SIF for individual leaves. Photospec is typically placed a few meters above the top of a plant canopy and designed to scan vertically and horizontally across the canopy. Photospec can also measure the entire SIF spectrum at high spectral resolution. This is perfect for calibrating and validating satellite data, and for better understanding leaf to canopy level photochemistry, and the relationship between SIF and photosynthesis across different ecosystems.

Question 4: What is the overall ability of this data to resolve metal contamination in vegetation?

Answer 4: This is a great research question! The short answer is "I don't know"! The longer answer is that current space-based SIF observers can detect mineral luminescence in non-vegetated areas (e.g., https://doi.org/10.1029/2021GL095227), so in principle, it is possible. It may also be possible to observe metal contamination "indirectly" by using SIF time series to observe the side effects on plant health.

Question 5: Is the current sensor resolution of TROPOMI/OCO-2 & 3 suitable to apply SIF observations for inland aquatic purposes? What would the current limit to those observations be? (i.e. Could I look at algal blooms in the Great Lakes or the Caspian Sea, but not small lakes or rivers?).
Answer 5: Inland aquatic applications require observations of SIF within the red bands of the spectrum around 685 nm. OCO-2 and OCO-3 focus on the far-red bands around 755 nm and 757 nm where SIF is emitted but re-absorbed in aquatic environments and therefore not currently detectable from space. The current TROPOMI instrument includes red and far-red bands and is therefore suitable for inland aquatic purposes (e.g., see Figure 4 of https://doi.org/10.1029/2020GL087541). TROPOMI spatial resolution is 5km x 5km.

Question 6: Are the dataset and software available for free after the training? How different is it from GIS?
Answer 6: All the datasets and code is at no cost. The demo in session 2 will show how to export as netCDF and GeoTIFF that can be used in a GIS. In the notebook we show how to plot in more custom ways. Session 2 will cover exporting GeoTIFFs.

Question 7: Why is it not recommended to use Conda environments?
Answer 7: We selected the standard python based to be more accessible to participants.

Question 8: How rapidly does the SIF signal of a plant vary with changes in its health? Or, how quickly can I detect the existence of stressors in an area?
Answer 8: SIF is highly correlated with absorbed light and activity in Photosystem II and thus can vary rapidly over the course of a day. Tower sensors, which observe continuously in time, can detect changes in SIF from morning to afternoon associated with temperature and/or water stress. A plant's response to external forcing (fires, floods, droughts, etc.) can be detected theoretically as soon as the plant exhibits a physiological response. In practice, OCO-2 and OCO-3 take daily measurements but

have revisit times of ~16 days. The current state of the art publicly available gap-filled products have a temporal resolution of 8 days.

Question 9: I have the Python 3 environment that comes with ArcGIS Pro. It is Anaconda-based. As I understand, I will need to install the "standard" Python environment. Can I assume this will NOT "break" my existing Python environment?
Answer 9: Yes, the installation creates a virtual environment.

Question 10: I am interested in using SIF for detecting algae blooms. Can you share case studies with a specific methodology to follow?
Answer 10: Yes, here are two case studies. The first provides an example of an inland algal bloom in California (https://doi.org/10.1029/2020GL087541). The second is more focused on coastal algal blooms (https://doi.org/10.1029/2022GL101715).

Question 11: Does SIF saturate similar to greenness indices like NDVI? Does the relationship between SIF and photosynthesis remain linear across varying vegetation, densities, etc.?
Answer 11: The SIF emission does not saturate, but the sign of the relationship with photosynthesis changes at different light levels, from strongly linear and positive at low light to negative at high light. Generally speaking, the slope of the relationship (rate of change) is sensitive to vegetation properties (e.g., leaf area, biomass, composition).

Question 12: Can you use a polygon (for example, Iowa state boundaries) as a bounding box? Or would you just need to clip the rasters to the polygon instead?
Answer 12: The helper function only supports rectangular bounding boxes. Unless you are doing spatial averages, it doesn't hurt to have more data.

Question 13: In cell V, what is the difference between variables dataset and local_dataset? Is it something related to downloaded data on a local computer and the other downloaded directly from earthdata?
Answer 13: That is how it is referenced online. Local is by file name.

Question 14: What are granules?
Answer 14: A granule is another name for a file we use for storing Earth Observation data.

Question 15: Is there a relationship (or suggested) between SIF and carbon absorption?
Answer 15: Yes, SIF is positively correlated with photosynthetic carbon absorption, which means that increases in SIF are associated with increases in carbon uptake.

Question 16: Will we be able to easily combine the data from future satellites with the existing satellite data into a single rendering?
Answer 16: In principle, yes. We are combining data streams by harmonizing how the data are gridded in space and time, and by using estimates of SIF at the same wavelength between instruments. Recall that in the discussion of the 740nm, 757nm, and 771nm SIF variables, the observed radiance varies quite substantially depending on the wavelength of the estimate. You need to consider the wavelength (and retrieval method) carefully when combining SIF from multiple instruments.
If you can ensure the retrieval is done in the same way, data fusion and machine learning can be used for downscaling.

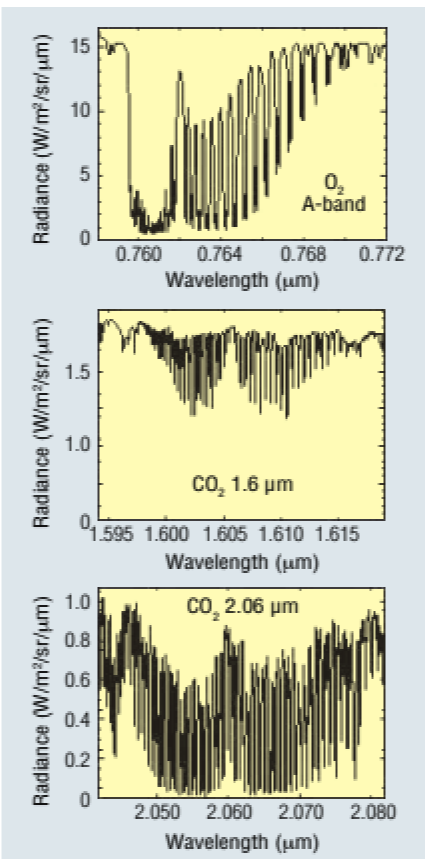
Question 17: What is the maximum spatial resolution that can be obtained for using SIF data in local agriculture? A spatial resolution of 10 to 30 meters would allow local analysis. In Colombia, a 2 km resolution is not useful because there is a high number of small producers.
Answer 17: 3 km^2 is the highest spatial resolution we can get from the sensor. Field scale resolution can be obtained using machine learning techniques or neural network tools can be used to achieve a higher resolution. 10 - 30 m is not currently possible with SIF alone.
Please see these two papers for an example of a model that downscaled SIF data to ~30m resolution: https://doi.org/10.1016/j.compag.2022.107260 and https://doi.org/10.1016/j.rse.2023.113861
Xiaoyan Kang and others at the Chinese Academy of Sciences have conducted research on downscaling SIF to 30m (0.0005°) resolution, but the uncertainty of SIF estimates produced through these techniques is increased as the downscaling is derived from already gap-filled data, the GOSIF dataset we will use in part 3. There is a physical limit to the SNR of SIF measured by instruments in space like OCO-2 and OCO-3 due to the amount of light that can reach the detector from a given area on the ground, giving rise to a tradeoff between spatial resolution and uncertainty.

Question 18: Can the layers be resampled to a higher spatial resolution? What are the maximum and minimum resolutions in latitude and longitude?

Answer 18: Neural network tools can be used for this. Low earth observation satellites can see pole to pole. ISS is 52 degrees North to south.

Question 19: Do these satellite platforms provide continuous or complete coverage, like Sentinel 1/2?
Answer 19: This depends on how long the mission has been operating.

Question 20: How many spectral bands does the sensor have?
Answer 20: OCO-2 and 3 have 195 bands per channel, and there are 3 channels on the instrument. SIF retrievals rely on the O2 A-band channel centered at 765nm. The bands are very narrow (min Δλ of ~0.04 nm on the SIF-sensing O2 channel!). This image from the OCO-2 Mission Brochure gives example spectra from the three channels to give you a sense of the resolution:



Question 21: What is the minimum area that can be analyzed?
Answer 21: An individual footprint is 2.25 km x 1.29 km for both OCO-2 and OCO-3. Although the two instruments orbit on different spacecraft at slightly different altitudes,

the data are processed to the same footprint resolution. As we will see with SAM processing, these footprints have vertices in the granule that allow more strict georeferencing than what we used in the first notebook.

Question 22: Is it possible to obtain SIF or a similar index using other satellite programs?
Answer 22: GOME,SCIAMACHY, GOME 2 (2007 -2022), GoSAT (2009-2020), TROPOMI, CO2M, FLEX all measure SIF.
In Session 3 we will review this information in more detail.

Question 23: How do you address the issue of signal anisotropy in the case of tower data?
Answer 23: Tower data receives a lot of information from different angles. Averaging data over space and time is one way, normalizing the SIF data.

Question 24: Has this data been used to look at macro algae/kelp forests?
Answer 24: Please see the answer to Question 10

Question 25: During the winter, we can observe a very weak photosynthesis signal. What is the smallest signal that OCO-2 and OCO-3 are able to detect? We saw some negative values during the demonstration, should those values be set to zero or removed?
Answer 25: We observe weak photosynthesis in the winter, especially in evergreen biomes, such as needleleaf forests. As SIF is an radiated signal from the chloroplasts of plants, the absence of SIF signal (the lowest physical value) would correspond to 0 $W/m^2/sr/\mu m$. Negative values are not physical, but you do not want to remove them due to the uncertainty in the measurements. The estimated value plus the uncertainty for that point (remember that uncertainty is a variable in the granule with a value at each point) provides an upper limit to the possible “true” radiance from SIF over that footprint.

Question 26: Is there any other method to increase spatial resolution without resampling, downscaling and machine learning techniques?
Answer 26: No, you must alter the data to increase spatial resolution. Spatial overlap can be used for multiple observations in the same area.

Question 27: To what extent does tower-based SIF data measure photosynthesis in different species or parts of a plant? Could you provide examples (papers) if any?

Answer 27: A network of towers are global. Location and instrument type come into play here. Some towers will be downward looking. Other instruments can scan across a canopy - top of the canopy to under canopy. Tower based SIF measurements will be discussed at a biome level in session 2.

Question 28: Can we use Colab instead of installing Python3?

Answer 28: Google Colab was considered for this training. Storage limitations for free accounts is why we chose the installation method covered in this part. Jackie indicated that she can add conda support as soon as possible.