Observations of Solar-Induced Fluorescence from the Orbiting Carbon Observatory 2&3 Missions

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Overview

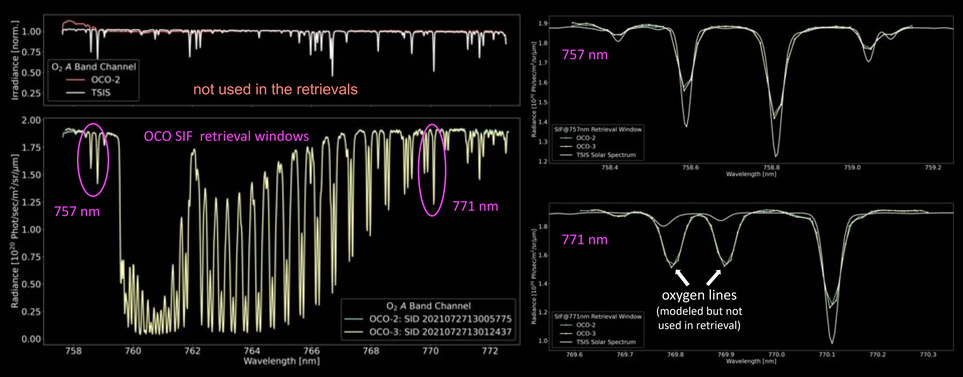
The Orbiting Carbon Observatory (OCO) 2 and 3 instruments have been making continuous measurements of CO_2 and far-red Solar-Induced Fluorescence (SIF) since 09/2014 (OCO-2) and 09/2019 (OCO-3). OCO-2 operates from a dedicated space craft in a sun-synchronous orbit with a fixed 1330h equator crossing time and observes at all latitudes. OCO-3 is installed on the International Space Station (ISS). This limits measurements to within a latitude band of about 52°S-52°N due to the ISS orbit inclination but allows observations to be made at different local times between sunrise and sunset. All OCO-2&3 data products are publicly available on the NASA GES-DISCs.

The two OCO instruments have a similarly-sized swath width of 12-15 km across-track subdivided into 8 footprints, with ground pixels sizes between 3.5 km² and 4.5 km². OCO-2 measurements consist of three distinct observation modes: nadir over land, glint over ocean, and a target mode over select locations primarily for CO_2 and SIF validation purposes. In addition to these three modes, OCO-3 also includes a Snapshot Area Mapping (SAM) mode, a spatially extended target mode where areas between 50x50 km² and 80x80 km² are covered continuously. SAM observations are mainly performed over cities to monitor urban CO_2 emissions, but the list of locations includes several sites dedicated to SIF validation.

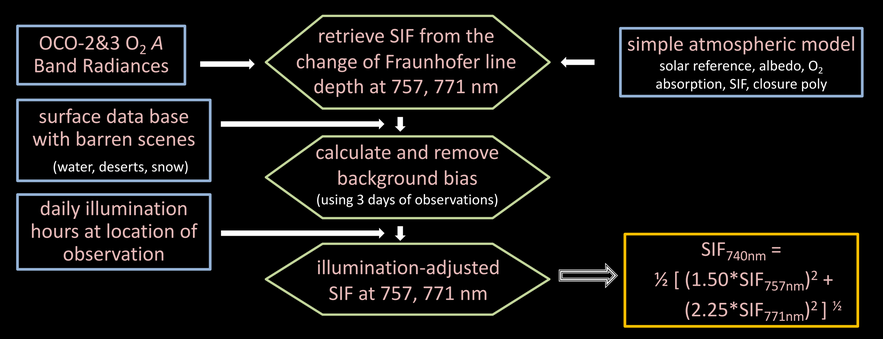
Both CO_2 and SIF retrievals are performed on all observation modes and at all locations. SIF retrievals are performed in two narrow wavelength regions around the O_2 A band, centered at 757 nm and 771 nm. The raw retrievals are subject to a background correction and are also scaled at the time of overpass with a daily average using solar illumination calculations within ±12 hours for each location. The publicly distributed SIF data product consists of daily files of single-footprint SIF observations, including the fully adjusted and background-corrected SIF values as well as the raw retrievals.

OCO-2&3 SIF Retrieval Spectral Windows

OCO SIF retrievals are performed in two narrow spectral bands around the O_2 *A* band centered at 758.5 and 769.9 nm ("757" and "771", for historic reasons) and exploit the change of depth in solar Fraunhofer lines due to the fluorescence emitted from plants. The graphs show O_2 A band spectra from OCO-2 (blue) and OCO-3 (yellow) plus the TSIS solar spectrum (white [1] not used in the retrievals) from two footprints taken over the same location about 25 seconds apart. The OCO-2 and OCO-3 spectra indicate excellent cross-sensor radiometric calibration.

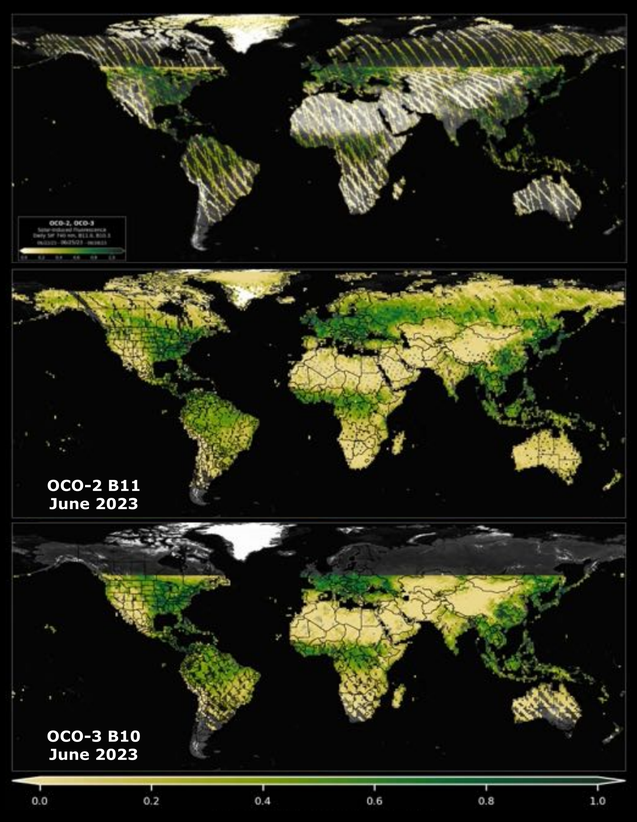


OCO SIF Retrieval Flowchart



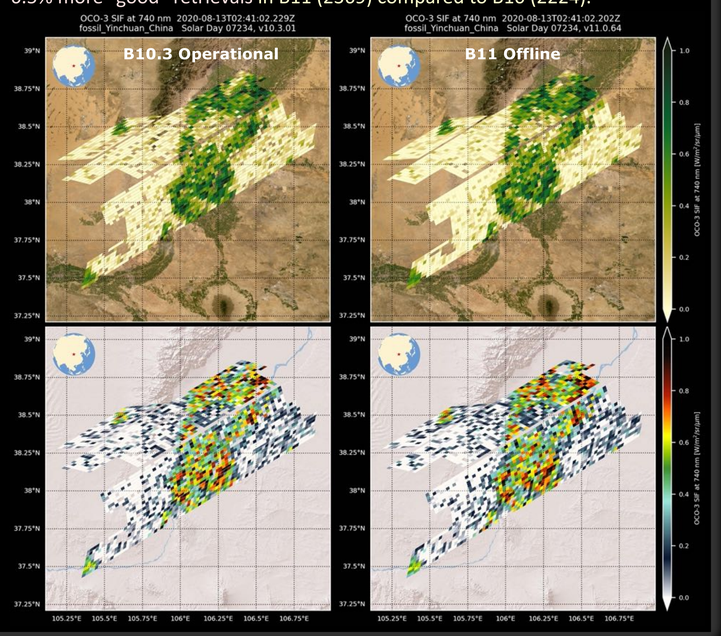
OCO-2 and OCO-3 Spatial Sampling Patterns

OCO-2 operates from a dedicated space craft in a sun-synchronous orbit with a fixed 1330h equator crossing time and observes at all latitudes. OCO-3 is installed on the International Space Station (ISS). This limits measurements to within a latitude band of about 52°S-52°N due to the ISS orbit inclination but allows observations to be made at different local times between sunrise and sunset. The latitudinal coverage of OCO-3 within this band depends on local overpass time and thus changes with time of year. ISS ground tracks describe a type of sine wave pattern on the Earth's surface. The top image shows a three-day composite of OCO-2 and OCO-3 SIF@740nm data for 24-26 June 2023, the middle and lower plots show the June 2023 monthly average from OCO-2 and OCO-3.



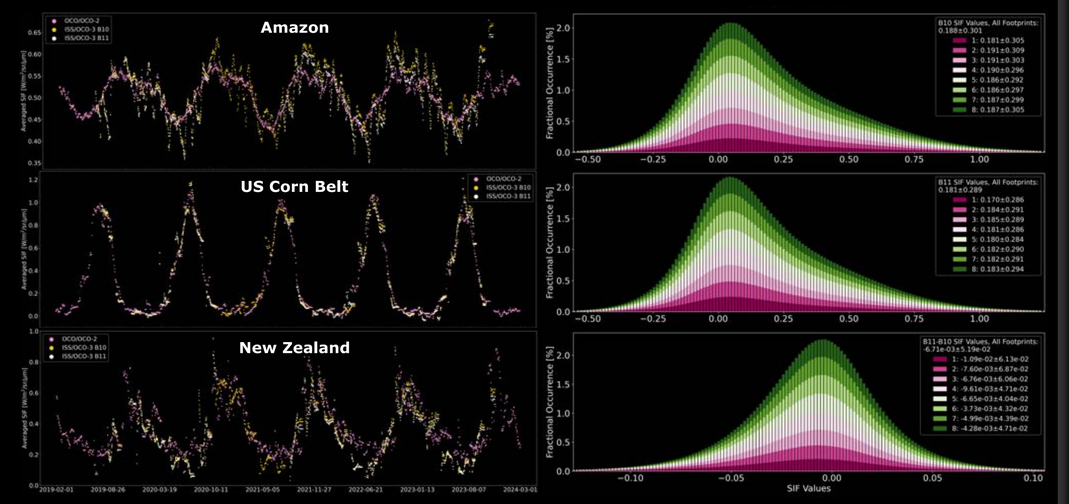
OCO-3 SIF B10 vs B11 – Snapshot Area Map Example

An example of SIF@740nm from a Snapshot Area Map taken over Yinchuan, China on 2020-08-13, B10 in the left column, B11 on the right. The bottom row shows the same data with a higher-contrast color scale for better visual comparison (ask the presenter for a loupe). In this particular SAM, there are 6.5% more "good" retrievals in B11 (2369) compared to B10 (2224).



OCO-2 B11 and OCO-3 B10&11 Time Series; OCO-3 B10&11 Histogram

With the reprocessing of the OCO-3 data record for Build 11 currently under way, an offline version of the official LtSIF PGE was applied to the available B11 data and that output subjected to global spatial resampling (see the MEaSUREs Multi-Sensor SIF Data Record box). The time series on the left show light-corrected SIF@740 nm from OCO-2 B11, OCO-3 B10, and the partial OCO-3 B11 over three geographic regions: Amazon (53-75W, 8°S-2°N), a portion of the central US Corn Belt (90-96°W, 40-44°N), and New Zealand (166-179°E, 34-48°S, land surfaces only). Each data point represents a 15-day running average for all data within the geographic region, and no adjustment of SIF values between records has been performed. OCO-2 and OCO-3 are generally consistent, and OCO-3 B11 closely follows B10, with B11 values being slightly smaller than B10. The histograms of SIF@740nm on the left are compiled from the common set of 2022 OCO-3 B10 (top) and B11 (middle) data, and their differences (bottom), about 32 million quality-screened observations.

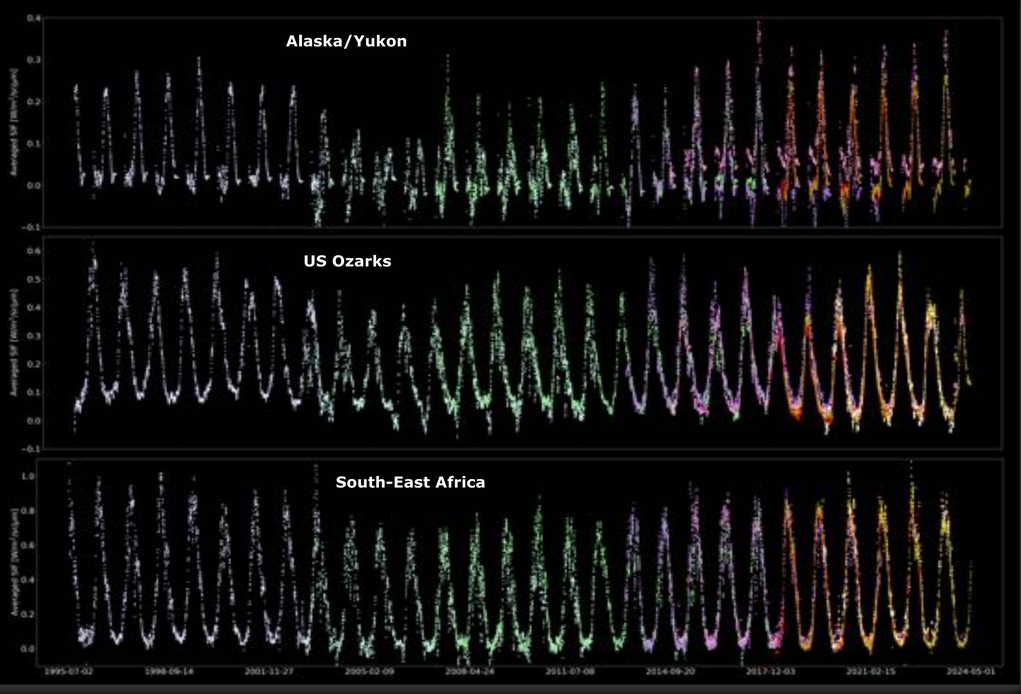


MEaSUREs Multi-Sensor SIF Data Record

In the framework of the NASA/JPL MEaSUREs "Multi-decadal Time Series of Vegetation Chlorophyll Fluorescence and Derived Gross Primary Production" project [2], SIF records from a range of UV/Vis instruments have been collected and spatially resampled onto a common global grid of 1°×1° for daily global averages.

The sensors currently included are ERS-2/GOME [3], Envisat/SCIAMACHY [4], MetOp-A&B GOME-2 [5,6], OCO-2&3 [7] (including available OCO-3 B11 data), and two versions of SIF from S5P/TROPOMI [8,9], collectively spanning a 29-year data record. The spatial averaging is based on a tessellation approach that calculates fractional overlap of instrument ground footprints with the destination grid cells that readily accommodates finer resolution grids without loss of spatial information.

The images show concatenated time series light-corrected SIF@740 nm from all sensors over three regions of the globe: Alaska/Yukon (166-115°W, 64-72°N; *no OCO-3!*), a portion of the US Ozarks (90-95°W, 35-38°N), and South-East Africa (22-32°E, 15-23°S). Each data point represents a 15-day running average for all data within the geographic region. No adjustment of SIF values between sensors has been performed. Cross-sensor agreement varies between regions, which indicates that harmonization efforts are required to create a consistent long-term data record of Solar-Induced Fluorescence.



OCO-3 – ECOSTRESS Data Colocation

Photosynthetic activity, and hence SIF as its byproduct, is intricately linked to the amount of heat- and water-stress the plants experience. The ECOSTRESS instrument on the ISS observes surface temperature (LST) and emissivity, from which it derives evapotranspiration (ET) as well as higher-level data products like evaporative stress index (ESI) and water use efficiency (WUE). SIF and ET/ESI/WUE provide synergistic information on plant photosynthetic activity and its relation to GPP.

From the ISS, OCO-3 and ECOSTRESS frequently observe the same geographic area at the same time. An effort is under way to provide a co-located data product "ECOCO3" (working title) of OCO-3 SAMs taken over sites of ground-based SIF towers and ECOSTRESS validation sites. ECOCO3 will contain selected SIF, ET, and LST data fields from their L2 product files in both native and spatially averaged form. The initial record will comprise the period of 08/2019-11/2023. After operations of OCO-3 restart (expected for 07/2024), ECOCO3 production will be automated and follow the release cycle of OCO-3 LtSIF.

The ECOCO3 product is expected to be publicly released on the NASA DISCs in the time frame of 09/2024.

References

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