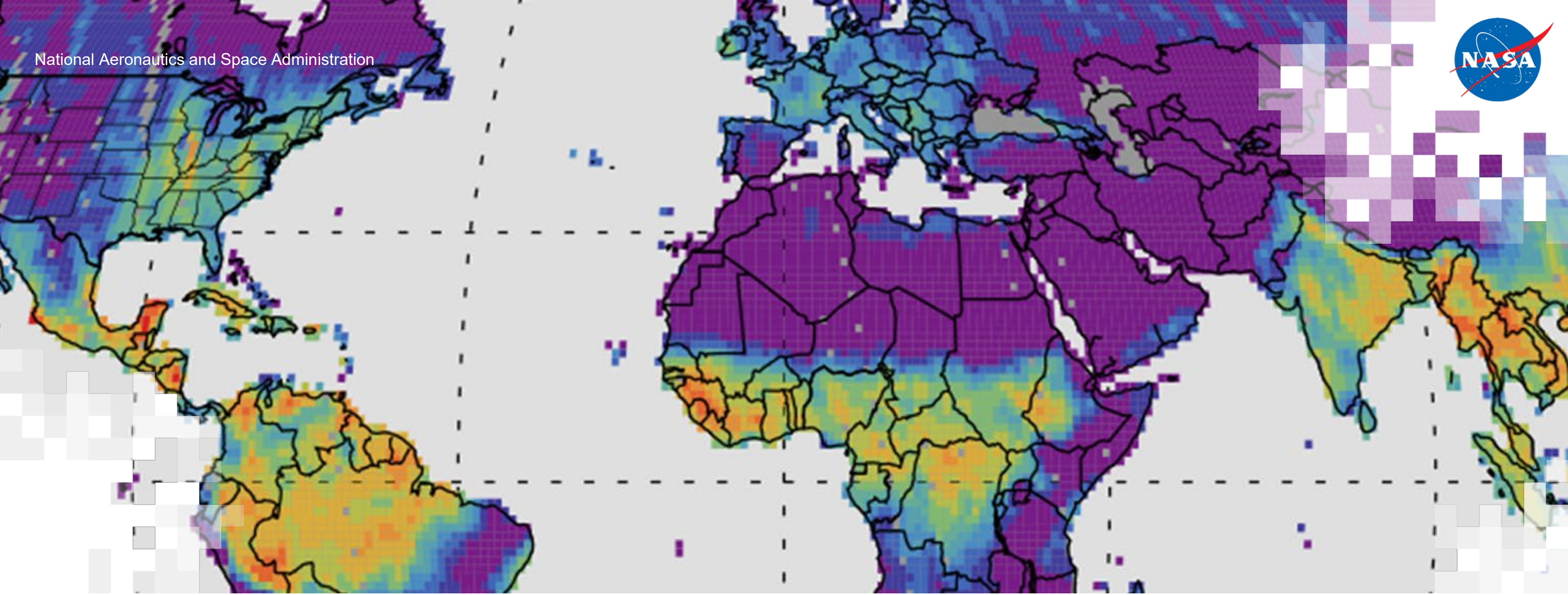
National Aeronautics and Space Administration



Use of Solar Induced Chlorophyll Fluorescence and LIDAR to Assess Vegetation Change and Vulnerability

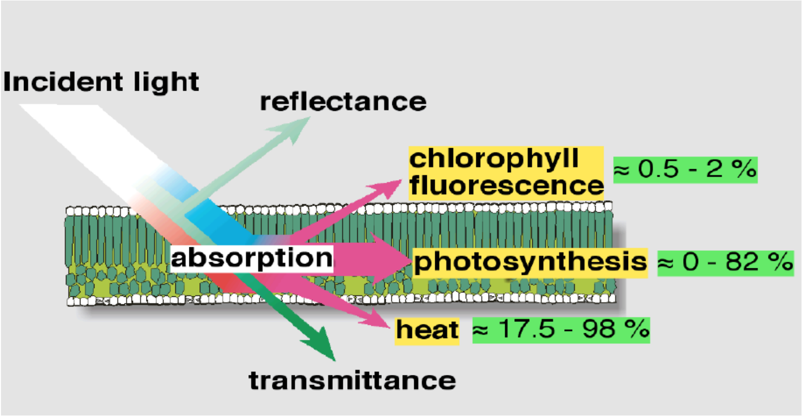
Philipp Koehler, Christian Frankenberg, and Karen Yuen

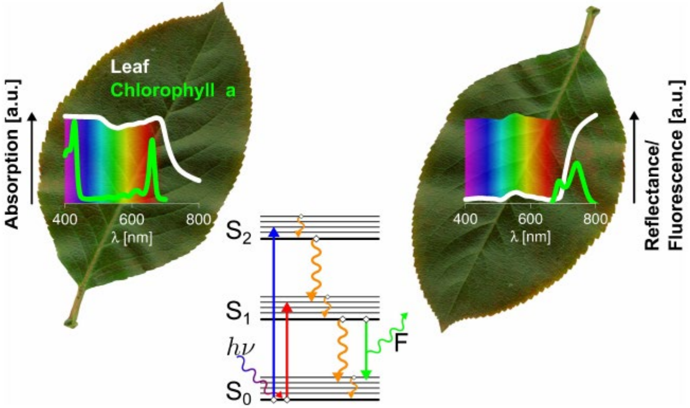
Part 4

- Background and Satellites that Provide SIF Products
- Introduction to SIF Products
- Available Datasets
- Accessing the Data
- Tools
- Tutorial

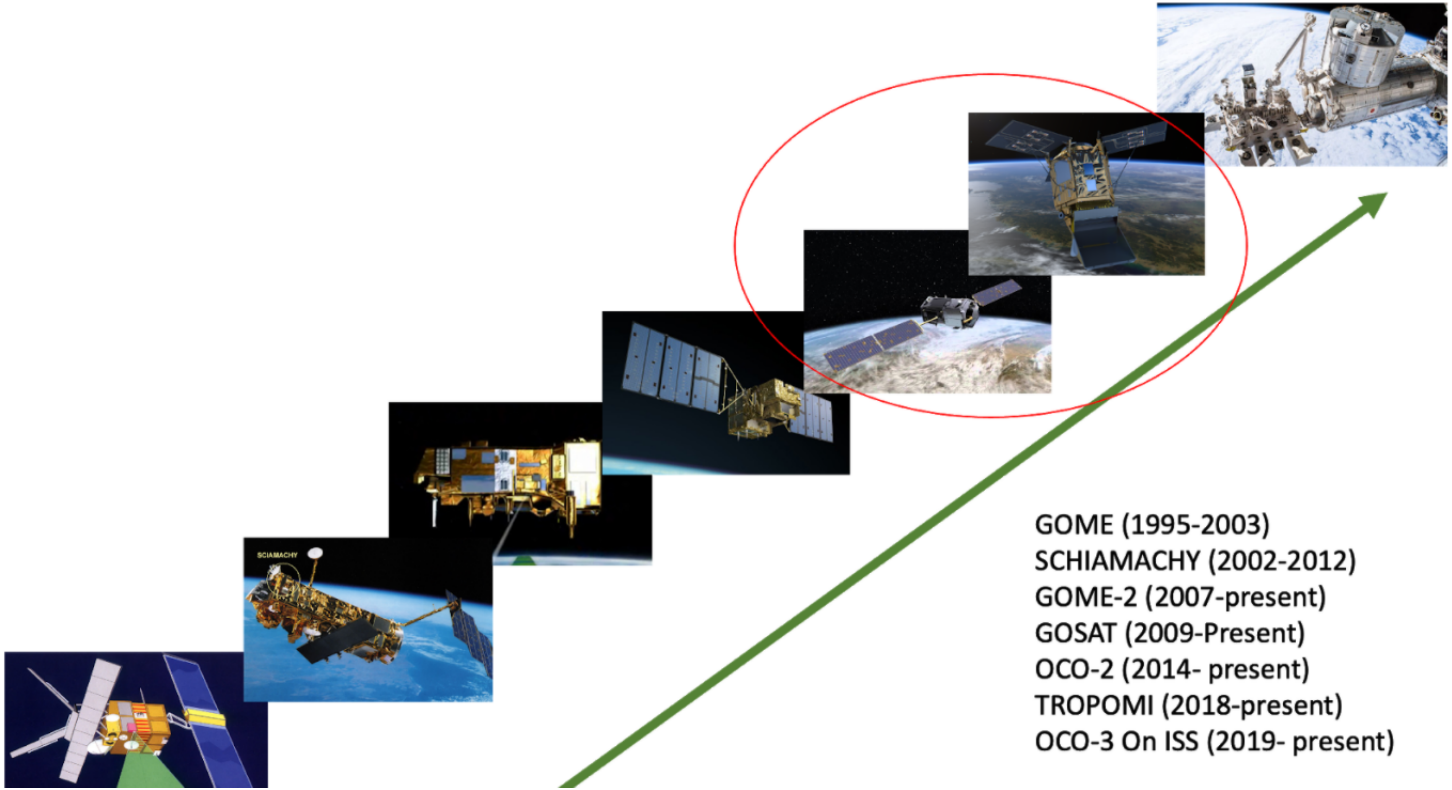
Solar Induced Chlorophyll *a* Fluorescence (SIF)

- During photosynthesis, a small fraction of energy is re-emitted as fluorescence.
- Sensors designed for atmospheric remote sensing are sensitive enough to measure SIF.
- SIF is more directly related to photosynthetic activity than traditional vegetation indices.





Satellites that Provide SIF Data



GOME (1995-2003)
SCHIAMACHY (2002-2012)
GOME-2 (2007-present)
GOSAT (2009-Present)
OCO-2 (2014- present)
TROPOMI (2018-present)
OCO-3 On ISS (2019- present)

Introduction to SIF Products

SIF is a weak signal, typically below 2% of the radiance level at the top-of-atmosphere.

SIF can be inferred from satellite sensors designed for atmospheric remote sensing.

- Coarse spatial resolution (several km),
- High spectral resolution (sub-nanometer),
- High sensitivity (signal-to-noise ratio > ~1000),
- High single measurement uncertainties (~50%)

Satellite data are shared via NetCDF (Network Common Data Format) files.

- **Level 2:** Derived geophysical variables at the same resolution and location as source data (Level 1)
- Level 3: Variables mapped on uniform space-time grid scales

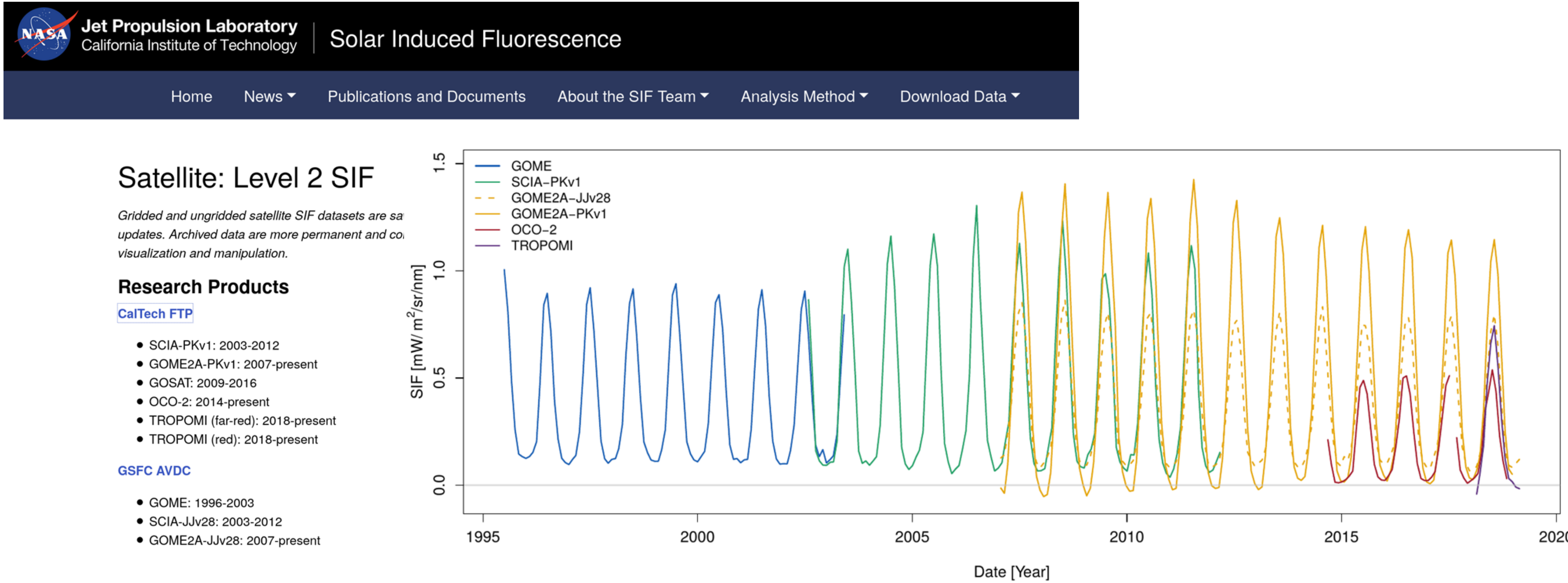
Level 2 SIF data should be the preferred choice for most analyses!

Comparison of the Different Instruments/Spectral Range

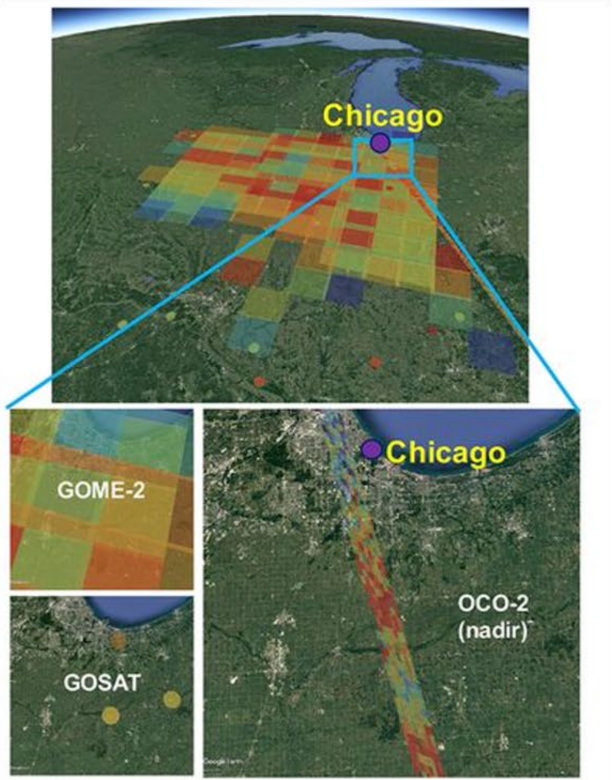
	Terrestrial SIF Emission (685-850 nm)		
	Instrument Spectral Range	**Spatial Resolution**	**Temporal Resolution**
GOME	240 nm to 790 nm	40 X 40 km	1995-2011
SCHIMACHY	240 nm to 1700 nm (866nm)	30 x 60 km	2002-2012
GOME-2	240 to 790 nm	80 km x 40 km	1.5 days
GOSAT	755 and 775 nm	10.5 km	3 days
OCO-2	757 and 771 nm	1.29 x 2.25 km	16 days
TROPOMI	Near IR 675-775nm	7 x 3.5 km	Daily
OCO-3	757 and 771 nm	12.8 km path	Daily

Timeline of Available Datasets

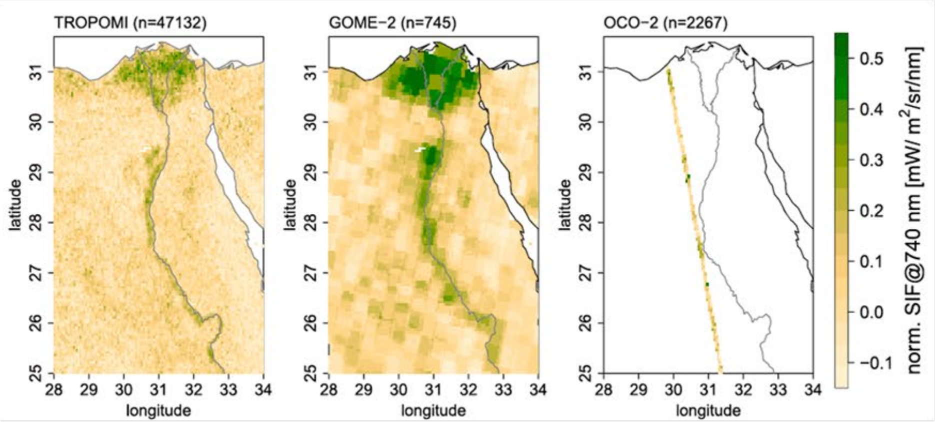
https://climatesciences.jpl.nasa.gov/sif/download-data/level-2/



Evolution of Spatial Resolution

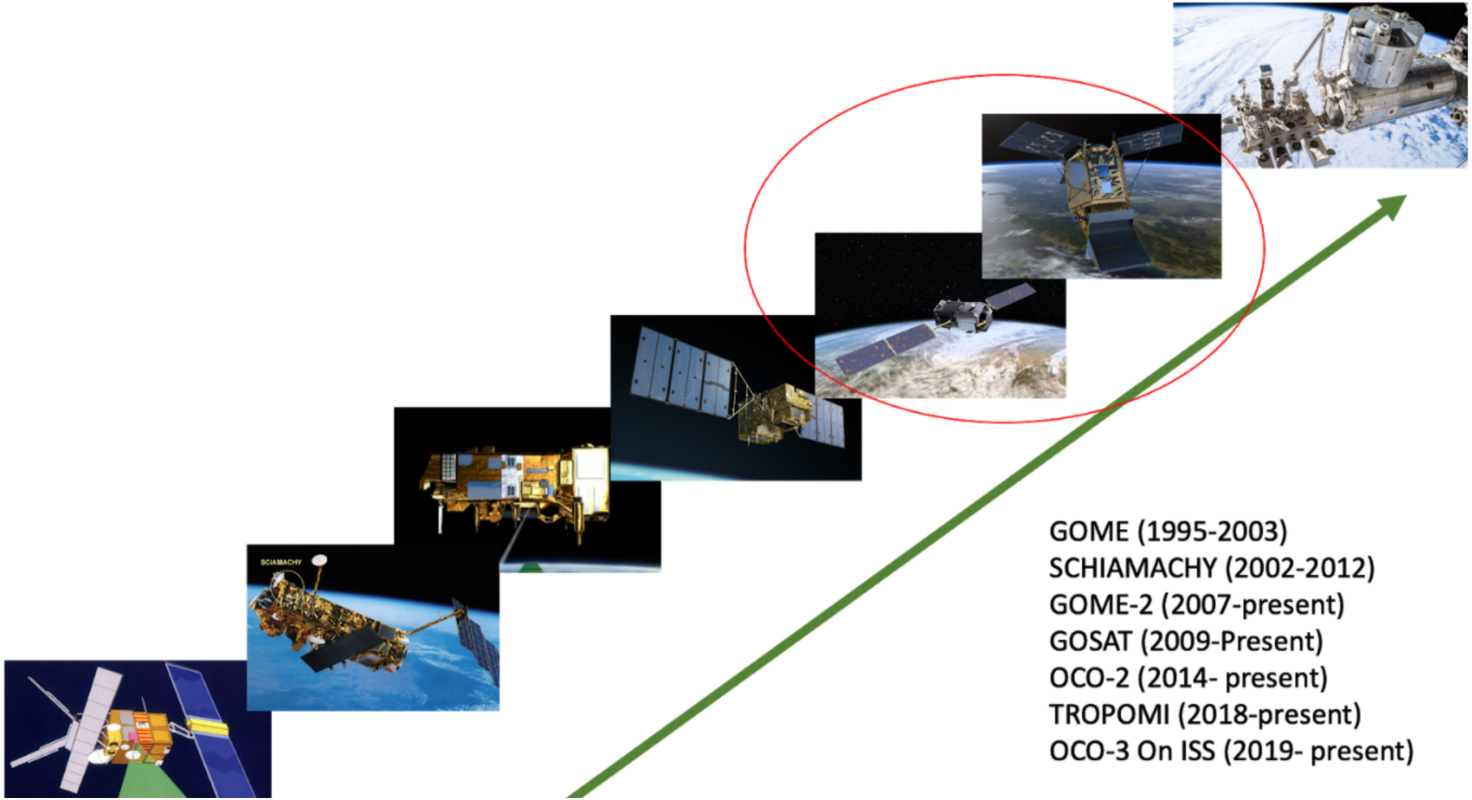


Science 2017 Oct 13;358(6360):eaam5747. doi: 10.1126/science.aam5747.



https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL079031

Focusing on OCO-2 & TROPOMI



GOME (1995-2003)
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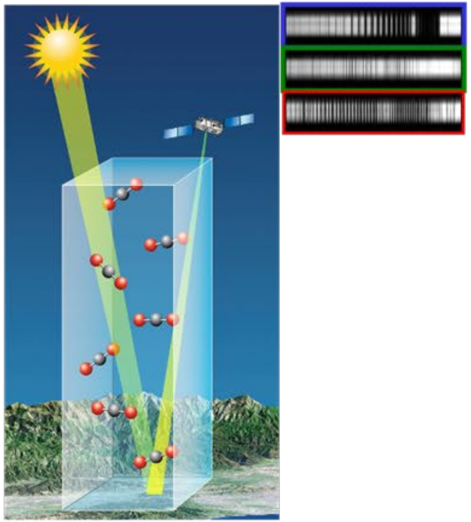
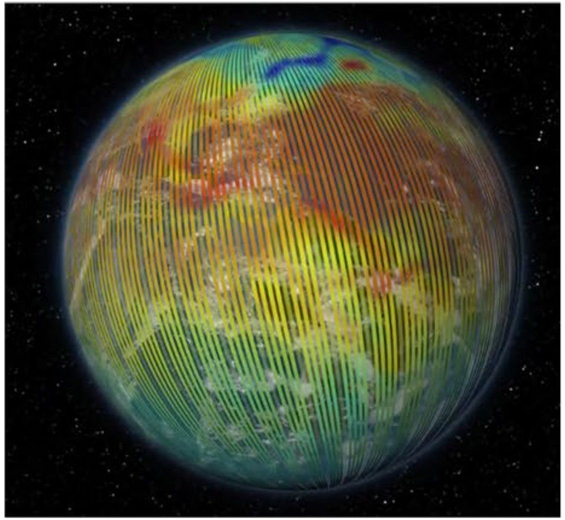
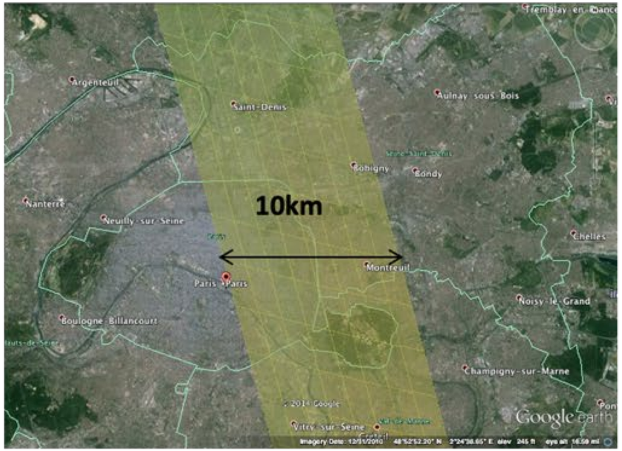
OCO-3 On ISS (2019- present)

OCO-2 Measurement Approach

Collect spectra of CO_2 & O_2 absorption in reflected sunlight over the globe



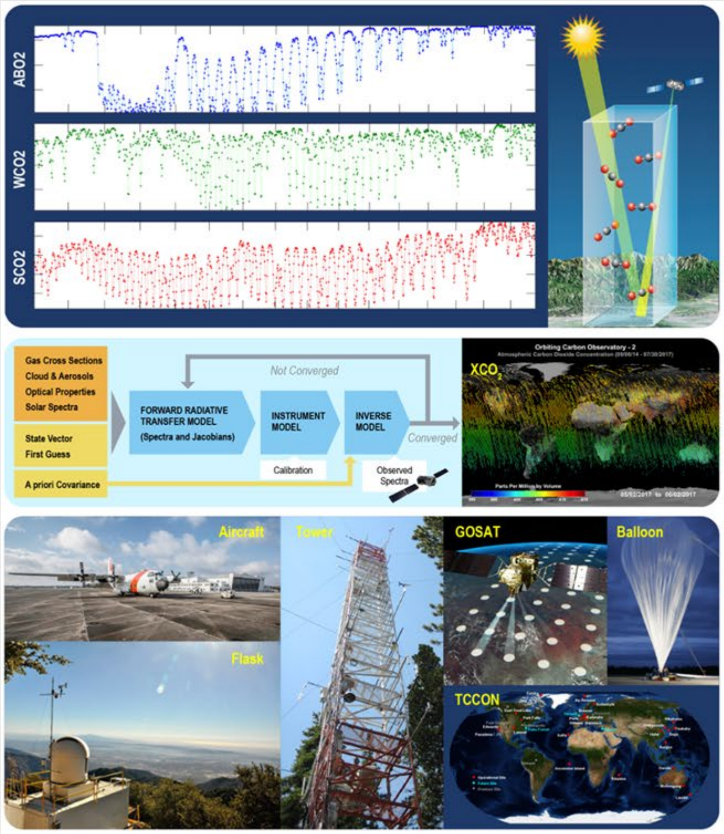


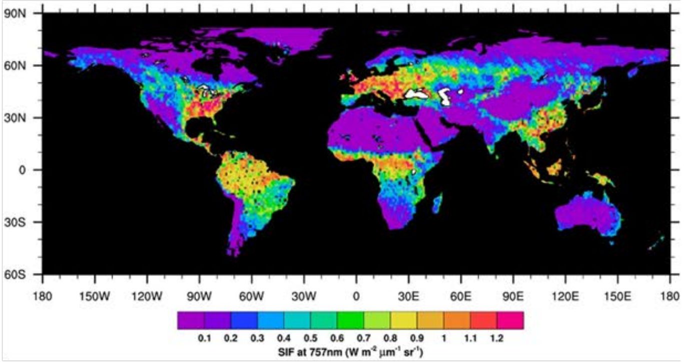


OCO-2 measurements:

- **Global**
- **Precise**
- **Small Footprints**

How OCO-2 Works





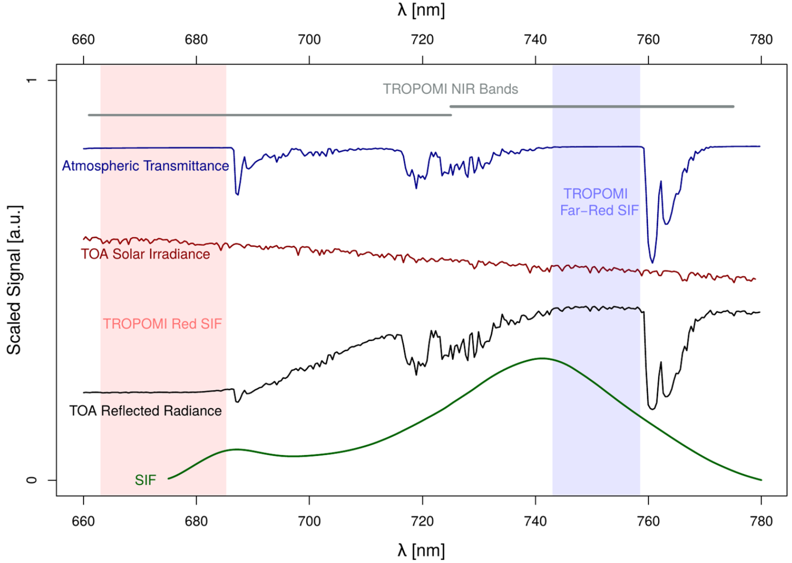
SIF Retrievals

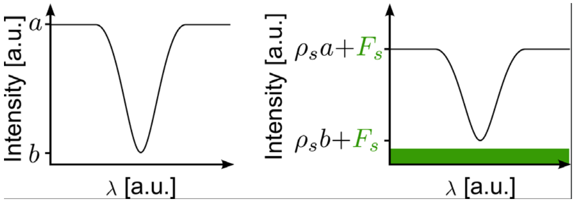
- Basic Idea:
  Exploit the change in optical depth of solar Fraunhofer lines by SIF

- Typically confined to atmospheric windows devoid of atm. absorption features

- Retrieval windows & strategies change from sensor to sensor

- Two approaches to model radiances:
  - Data-Driven (TROPOMI)
  - Physically-Based (OCO-2)

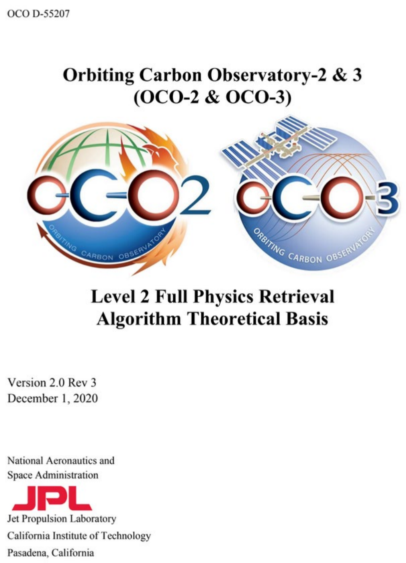




ATBD & User Guide

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

https://docserver.gesdisc.eosdis.nasa.gov/public/project/OCO/OCO2_OCO3_SIF_DUG.pdf



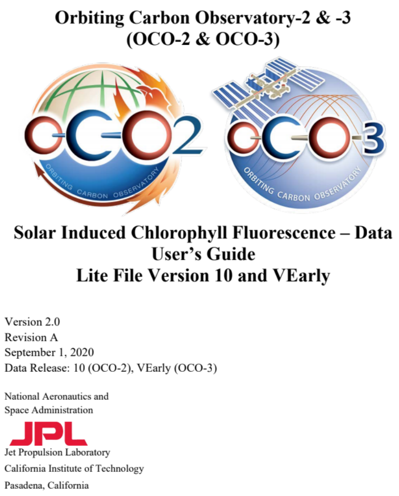
OCO D-55207

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
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California



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

Solar Induced Chlorophyll Fluorescence – Data
User's Guide
Lite File Version 10 and VEarly

Version 2.0
Revision A
September 1, 2020
Data Release: 10 (OCO-2), VEarly (OCO-3)

National Aeronautics and
Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

OCO-2 and TROPOMI Access & Naming Conventions

ftp://fluo.gps.caltech.edu/data/OCO2/sif_lite_B8100/

ftp://fluo.gps.caltech.edu/data/tropomi/ungridded/SIF740nm/

OCO-2 Lite SIF File Naming Convention

oco2_LtSIF_[AcquisitionDate]_{ShortBuildID]_[ProductionDateTime]{Source].nc4

oco2_LtSIF_200101_B8102r_200204190415s.nc4

TROPOMI File Naming Convention

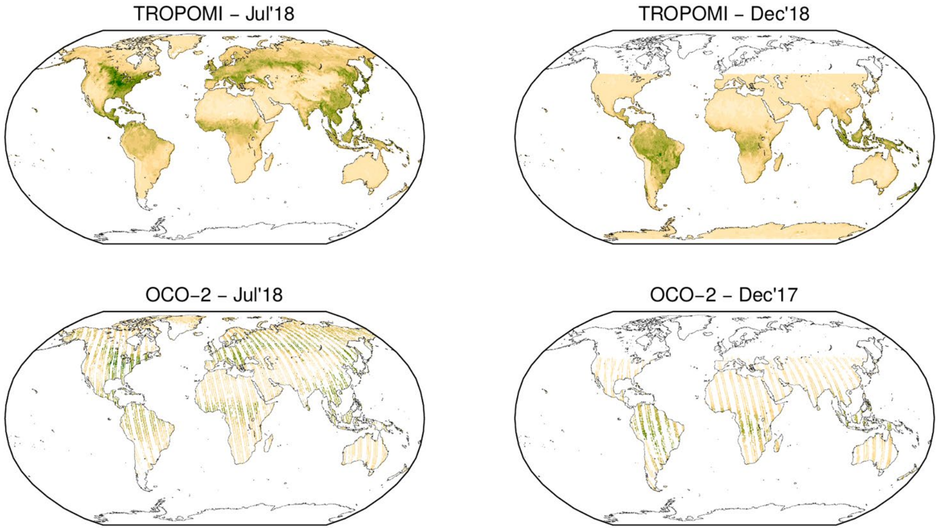
TROPO_SIF_YYYY-MM-DD_ungridded.nc

Spatio-Temporal Resolution

Satellite sensors for atmospheric remote sensing have a coarser footprint than typically required for land surface remote sensing.

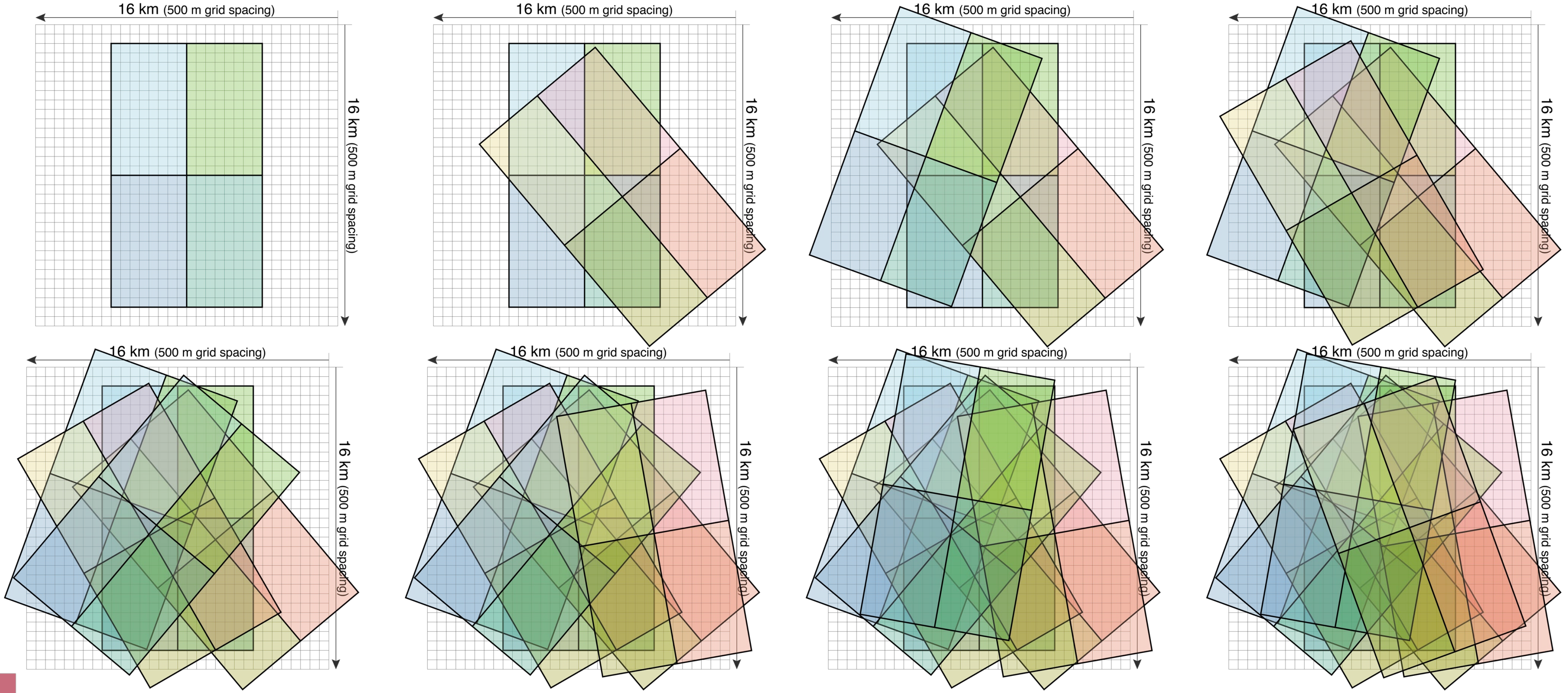
TROPOMI
5km (7km before Aug. 2019) x 3.5-14km,
almost daily surface coverage,
17-day revisit time

OCO-2
1.3km x 2.25km,
large gaps between swaths,
16-day revisit time



-> Large-scale studies and oversampling/downscaling to mitigate coarse spatial resolution

Oversampling



Credit: Alex Turner

Tools

Some tools to read/analyze TROPOMI & OCO-2 data (Python & R):

https://github.com/cfranken/SIF_tools

Gridding satellite data (Julia):

https://github.com/cfranken/gridding

Today's tutorial (Julia):

https://github.com/philag/TROPOMI-OCO-2_SIF_DEMO

Tutorial

https://github.com/philag/TROPOMI-OCO-2_SIF_DEMO

We will use Pluto, a simple, reactive notebook for Julia (similar to ipython notebooks).

1st Pluto Notebook "Demo_presentation.jl"

Reading and selecting TROPOMI & OCO-2 SIF data for arbitrary spatial shapes, temporal averaging, generating spatial composites (via oversampling), and evaluating uncertainties

2nd Pluto Notebook "Case_Study_illinois.jl"

Case Study: Impact of the 2019 Midwest Flood on SIF over Illinois