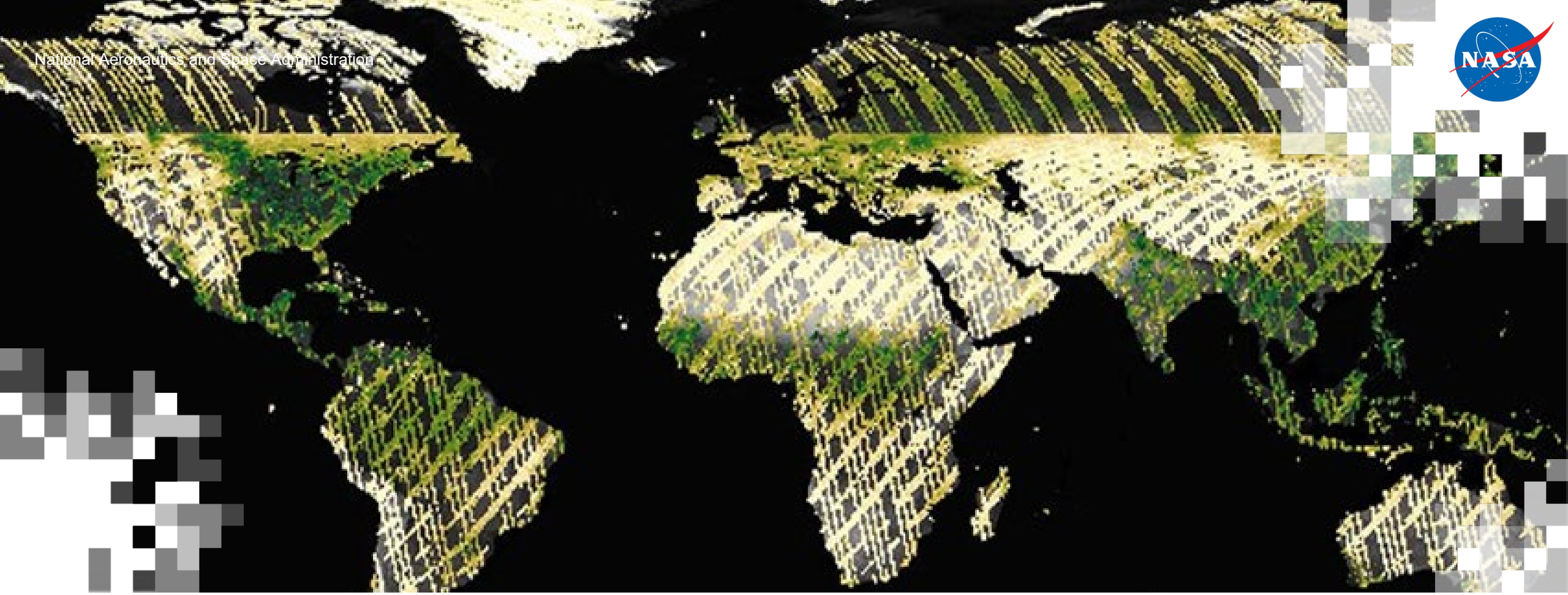
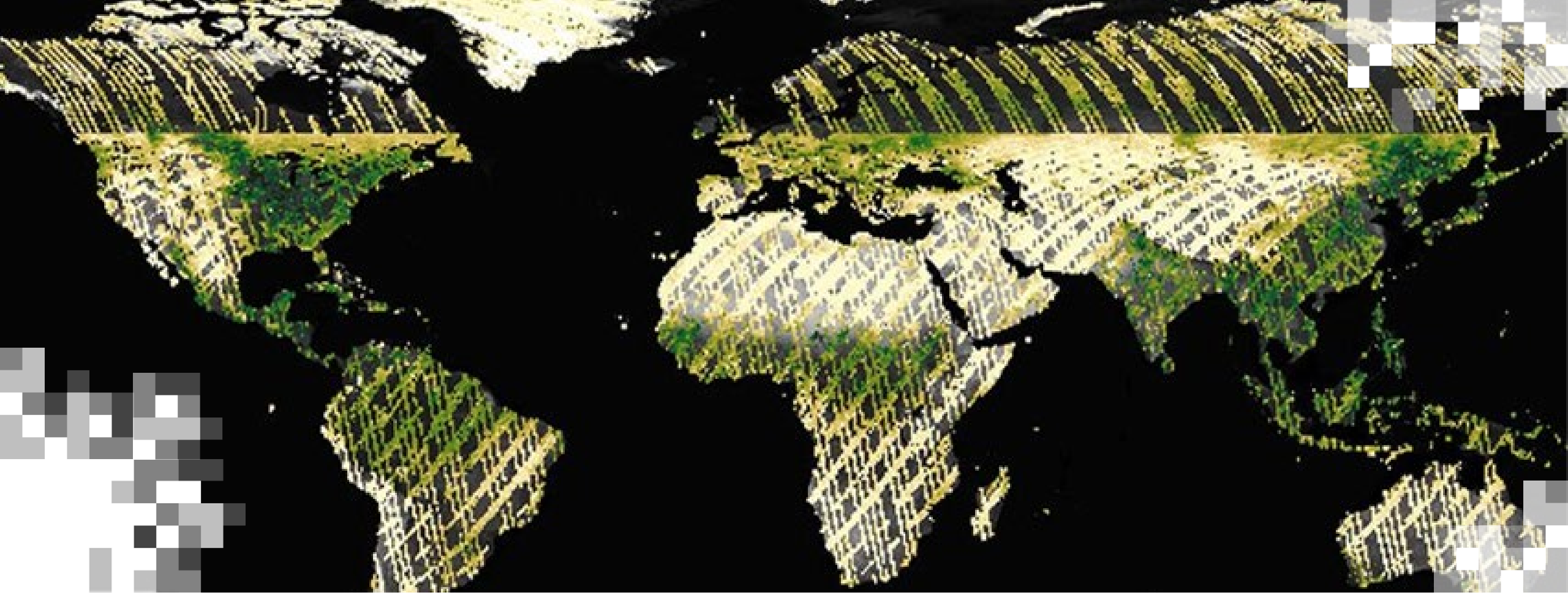


Solar Induced Fluorescence (SIF) Observations for Assessing Vegetation Changes Related to Floods, Drought, and Fire Impacts

Session 1: Solar Induced Chlorophyll Fluorescence (SIF) Measurements from Space

Erika Podest, Ph.D. (NASA Jet Propulsion Laboratory, California Institute of Technology), Jackie Ryan (NASA Jet Propulsion Laboratory, California Institute of Technology) & Dr. Nick Parazoo (NASA Jet Propulsion Laboratory, California Institute of Technology)

October 15, 2025



About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

HEALTH & AIR QUALITY

WATER RESOURCES

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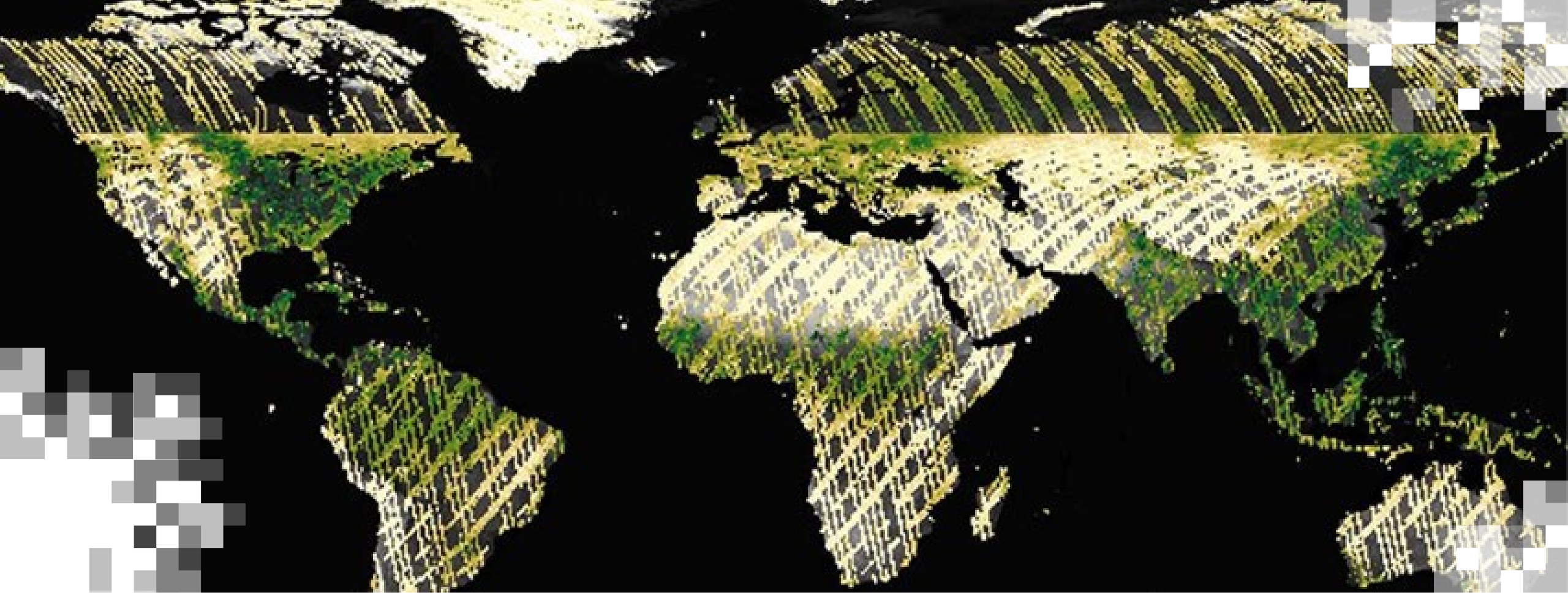
About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.



Solar Induced Fluorescence (SIF) Observations for Assessing Vegetation Changes Related to Floods, Drought, and Fire Impacts Overview

Training Outline

Session 1

Part 1: Solar Induced Chlorophyll Fluorescence (SIF) Measurements from Space

Oct. 15, 2025

Session 2

Overview of OCO-2 and OCO-3 Observing Modes and SIF Observations

Oct. 22, 2025

Session 3

Working with Gap-Filled SIF Products

Oct. 29, 2025

Homework

Opens Oct. 29 – Due Nov. 12, 2025 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live parts and complete the homework assignment(s) before the given due date.

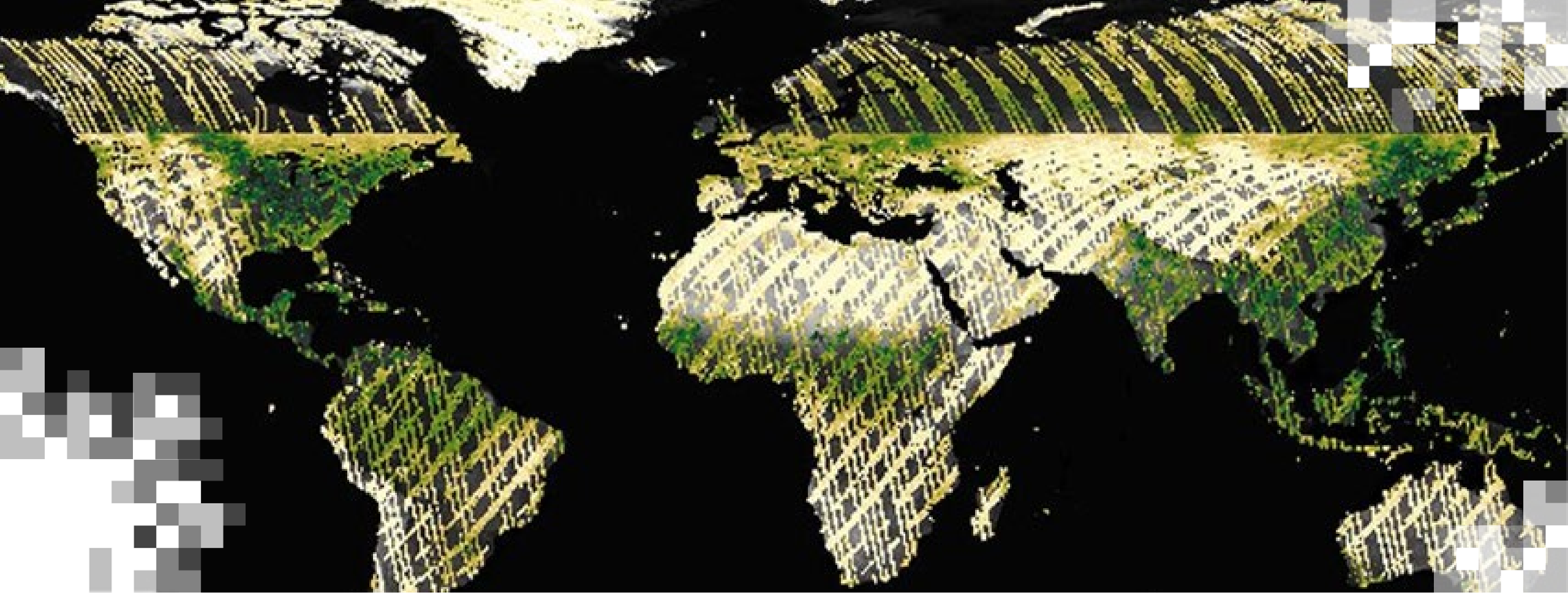
Prerequisites

- Fundamentals of Remote Sensing
- Use of Solar Induced Fluorescence and LIDAR to Assess Vegetation Change and Vulnerability

Training Learning Objectives

By the end of this training, participants will be able to:

- Recognize how the Solar Induced Fluorescence (SIF) is measured and used as a complementary measurement to commonly used indices (NDVI) for land and vegetation applications.
- Identify advantages and limitations of using space-based SIF measurements to monitor and evaluate vegetation health and condition.
- Run a given Jupyter Notebook to generate a Snapshot Area Map (SAM) plot from OCO-3 data for selected regions of interest to analyze and evaluate vegetation and land change due to fire impacts.
- Run a given Jupyter Notebook using GoSIF data for selected regions of interest to produce visualizations to analyze and interpret episodic land change due to droughts and floods.
- Compare how SIF products aggregated in space and time using open source tools are used to study vegetation change across different regions in a variety of science and applied use cases.



Solar Induced Fluorescence (SIF) Observations for Assessing Vegetation Changes Related to Floods, Drought, and Fire Impacts

Session 1: Solar Induced Chlorophyll Fluorescence (SIF) Measurements from Space

Session 1 – Trainers

Erika Podest

Scientist and ARSET Instructor

NASA Jet Propulsion Laboratory, California Institute of Technology

Dr. Nick Parazoo

Discipline Program Manager, Carbon Cycle and Ecosystems

NASA Jet Propulsion Laboratory, California Institute of Technology

Jackie Ryan

Data Visualization Developer

NASA Jet Propulsion Laboratory, California Institute of Technology

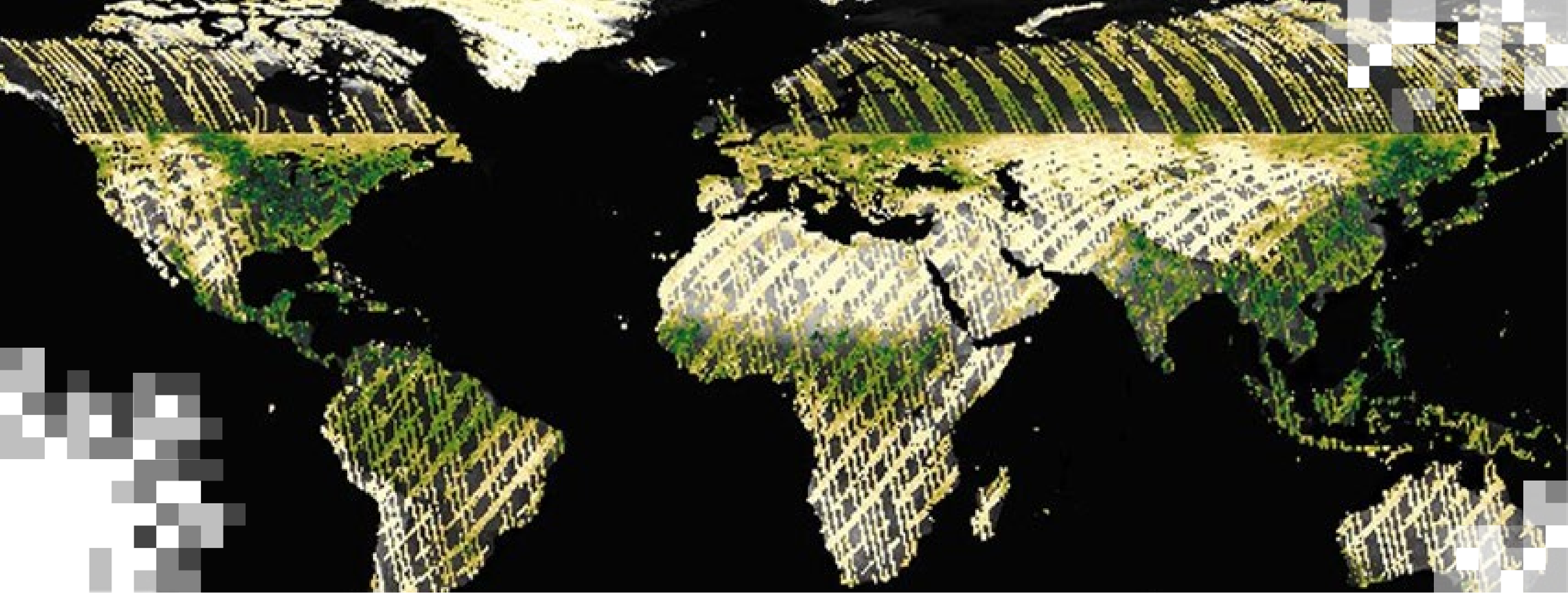
Session 1 Objectives

By the end of Session 1, participants will be able to:

- Define what is SIF and how it is measured and describe where it performs well and where it has limitations.
- Identify how SIF measurements are used for scientific research and land-based applications.
- Setup a Jupyter Notebook environment and retrieve SIF data from NASA's Earthdata system.
- Identify how to overcome a key limitation of Level 2 SIF data by aggregating multiple days to create gridded raster products with greater spatial context.
- Run Jupyter Notebooks to explore the ancillary information included in SIF products and how this data can be used to refine an analysis.

How to Ask Questions

- Please write your questions in the Questions box and we will answer them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to respond all the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



What is SIF?

EARTH'S MYSTERIOUS RED GLOW

TEDEd

SIF FAQ: What is SIF?

SIF = Solar-Induced Fluorescence
A small red-light signal emitted by excited chlorophyll molecules

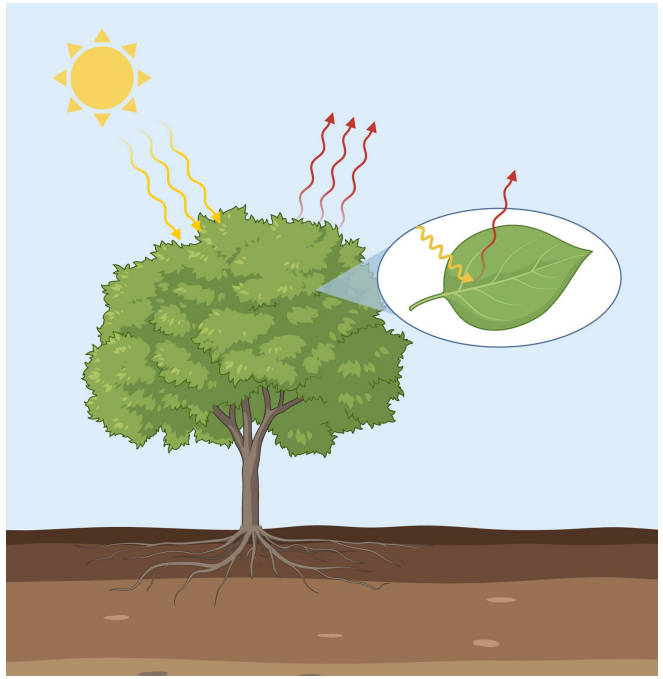
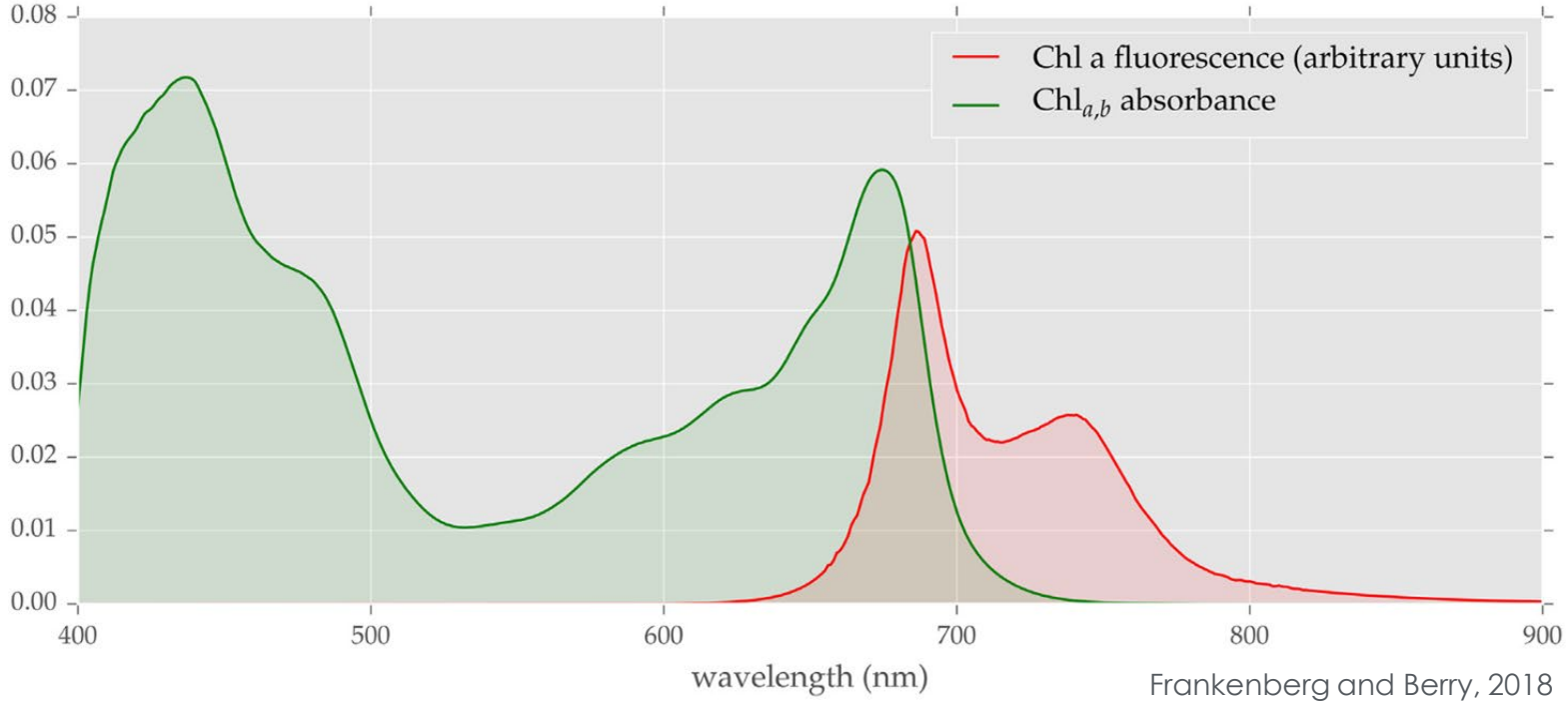


Image Created with BioRender

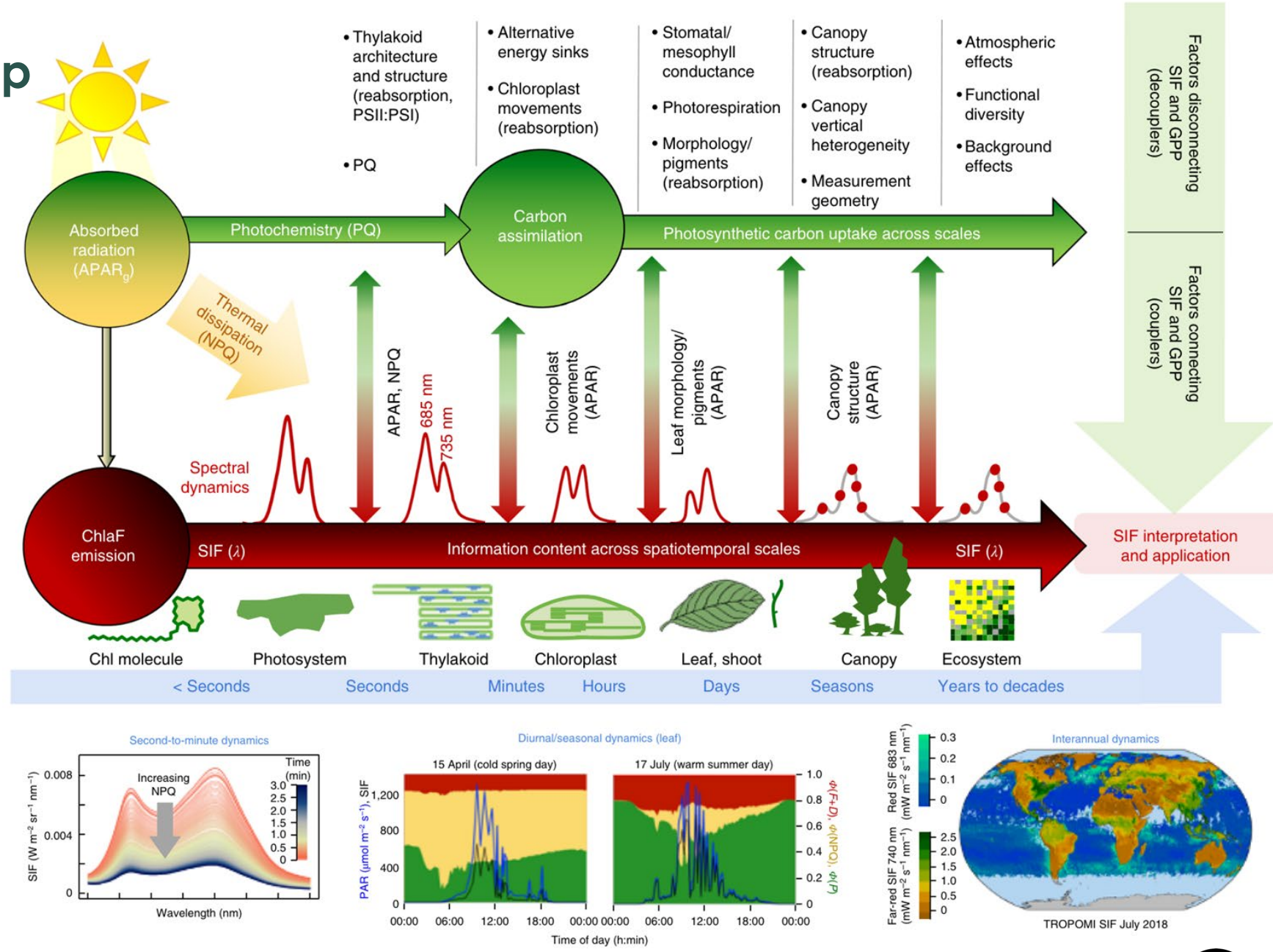


Frankenberg and Berry, 2018

Previous Video: Earth's Mysterious Red Glow, Explained - Zoe Pierrat (TedEd)

SIF FAQ: The Relationship Between SIF and Plant Photosynthesis: Short Story

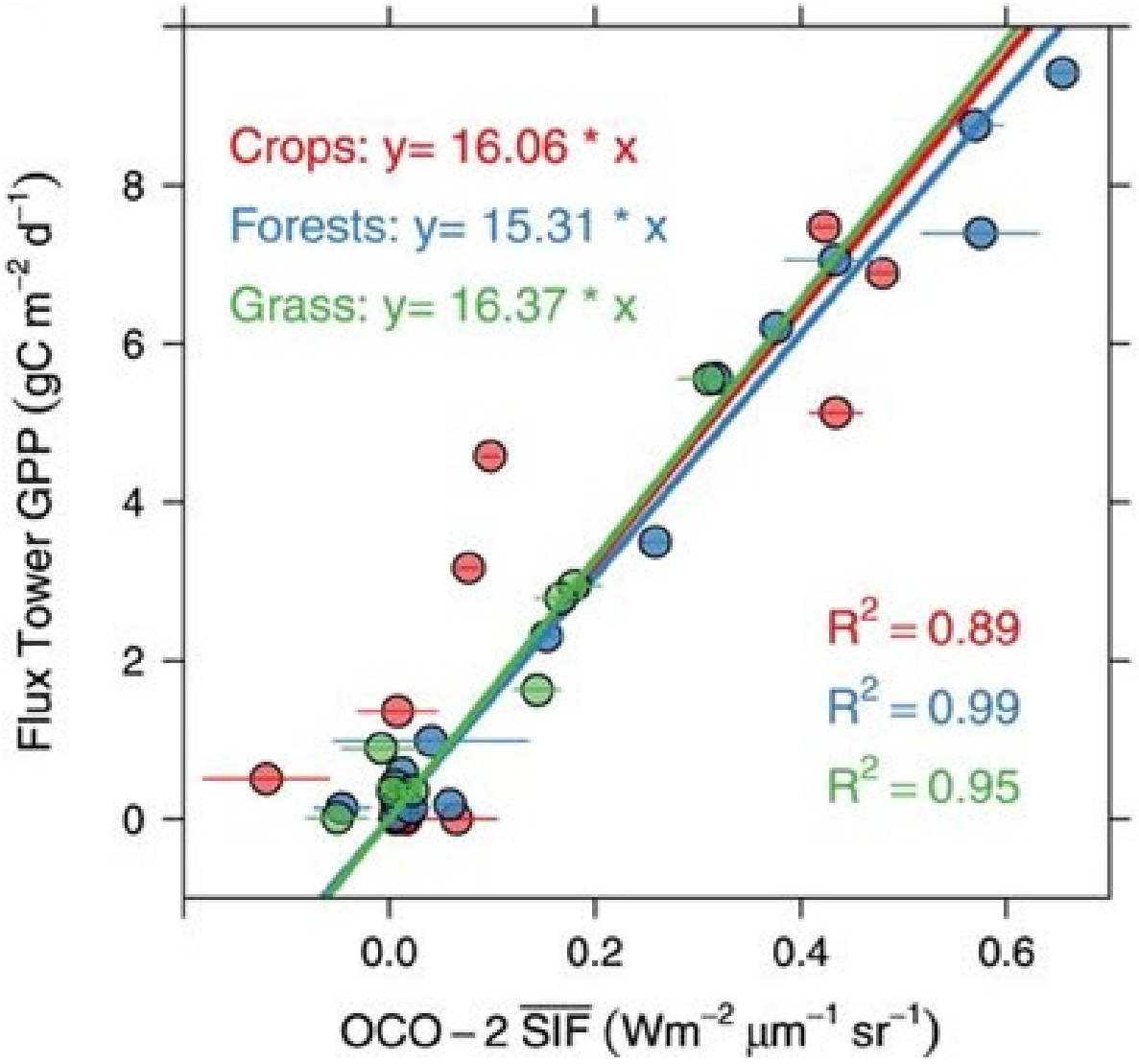
Long Story: It's complicated.



Porcar-Castell et al., 2021

SIF FAQ: The Relationship Between SIF and Plant Photosynthesis: Short Story

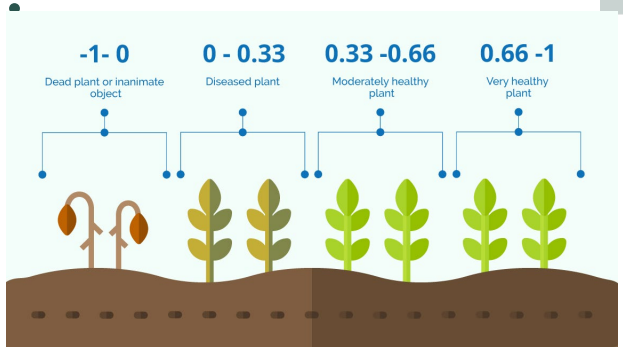
Short Story: SIF = Photosynthesis



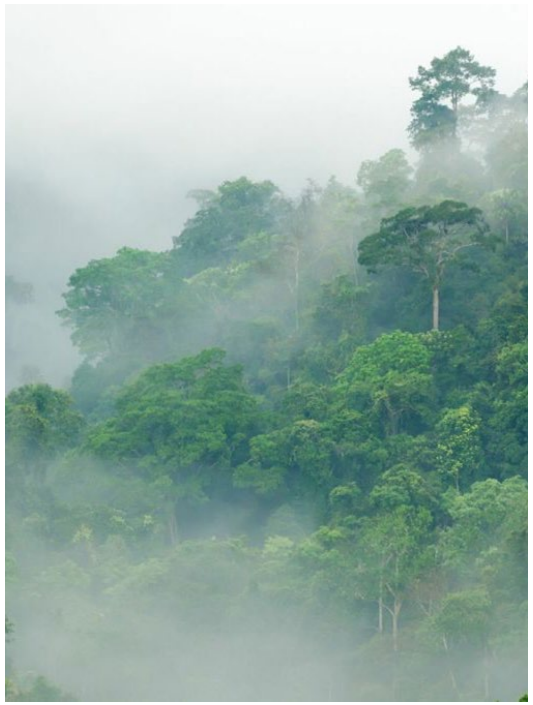
Sun et al., 2017

SIF FAQ: Why is SIF Optimal for Detecting Plant Activity?

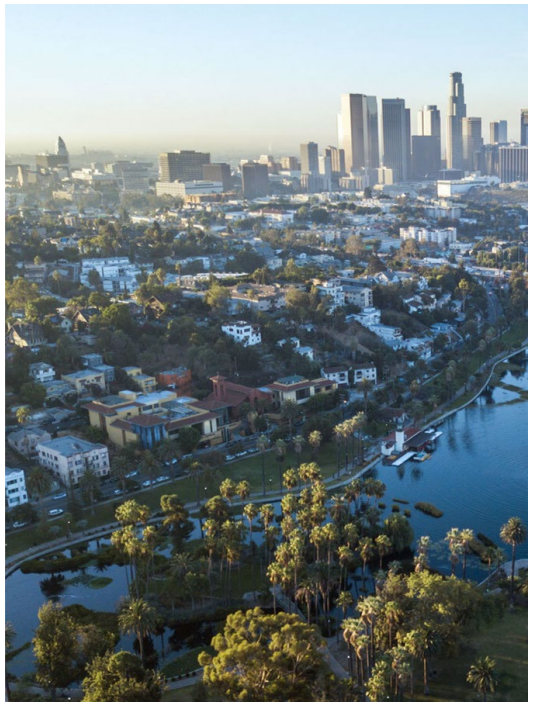
- Reflectance metrics (e.g., NDVI) tell us the color.
- SIF is a direct emission with mechanistic ties to photosynthesis.



Independent of Color

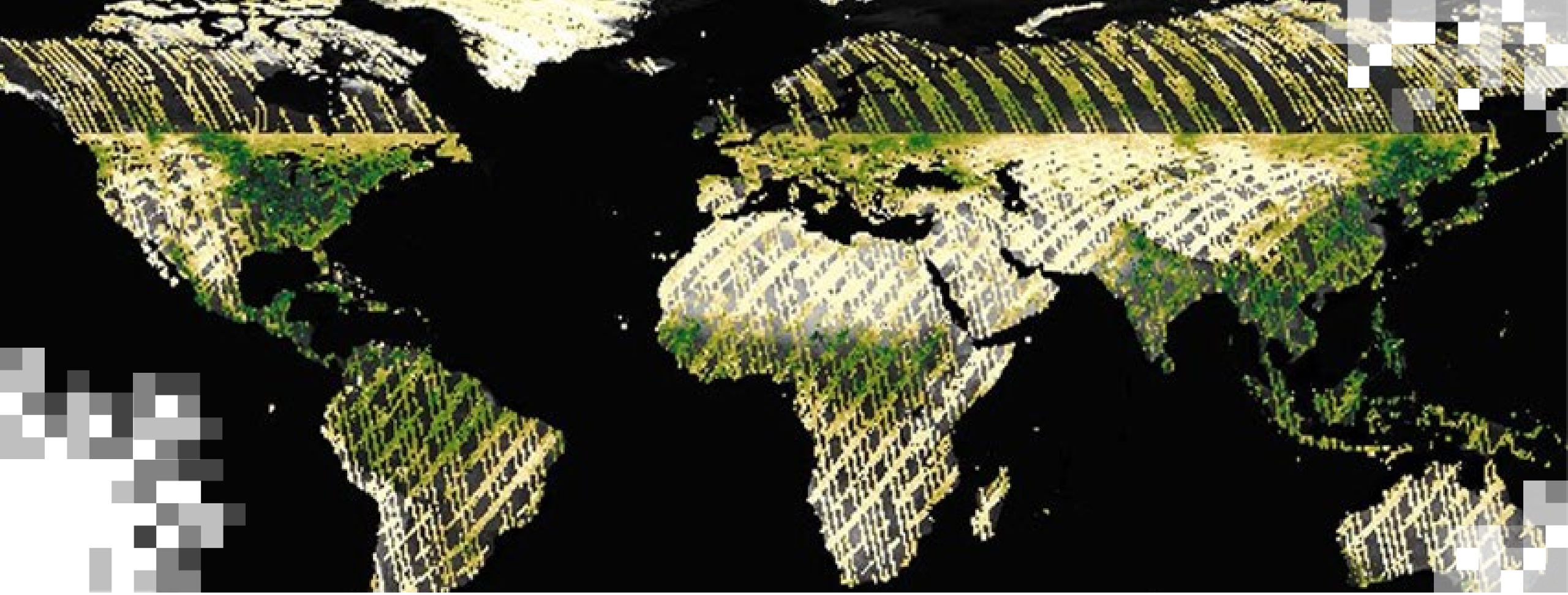


Low Sensitivity to Clouds



Low Sensitivity to Paved and Wet Surfaces

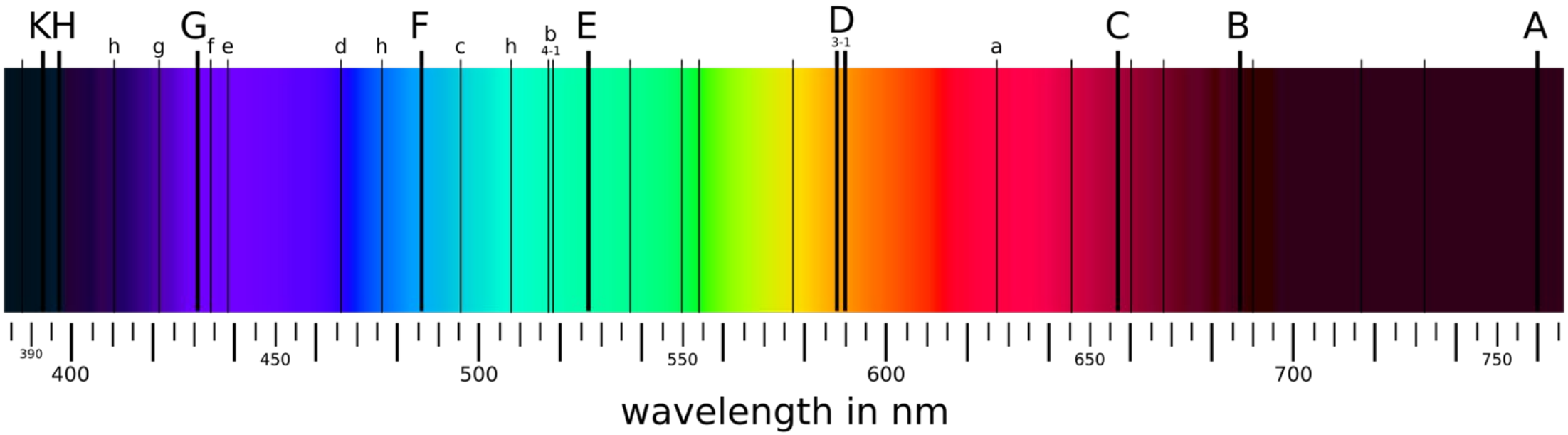
Low Sensitivity to Soils



How is SIF Retrieved?

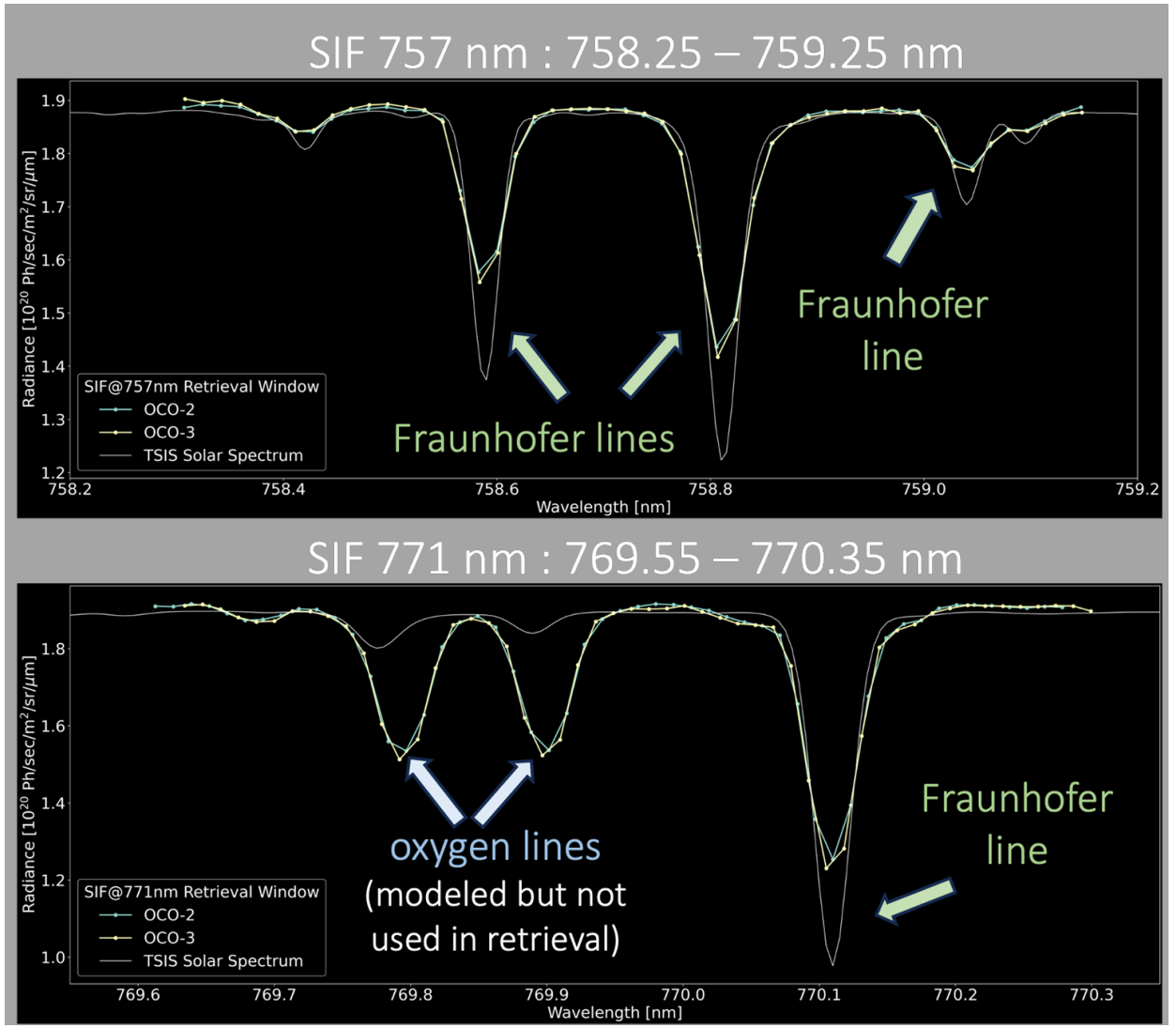
How is SIF Measured?

- Fraunhofer Lines

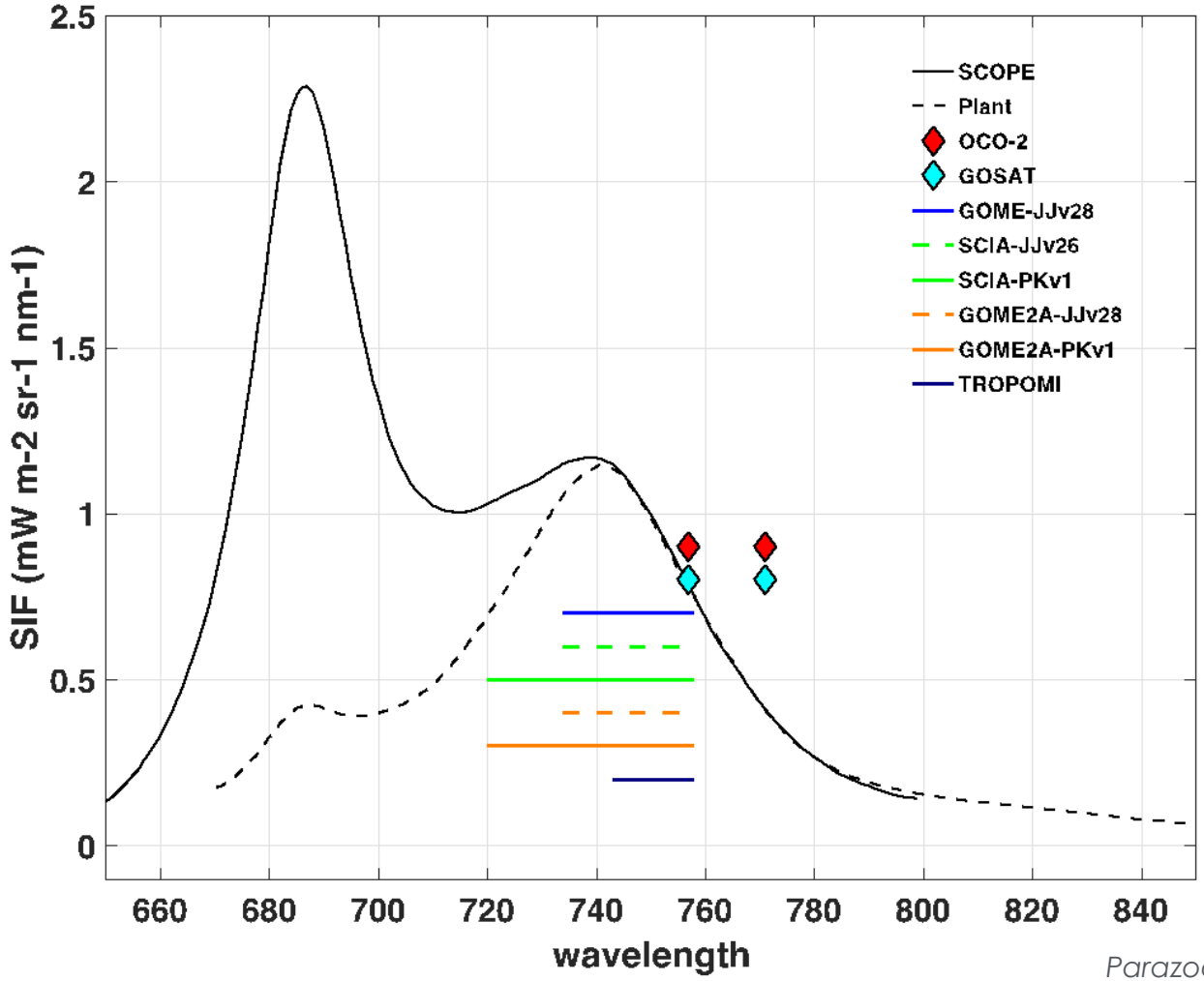


How is SIF Retrieved?

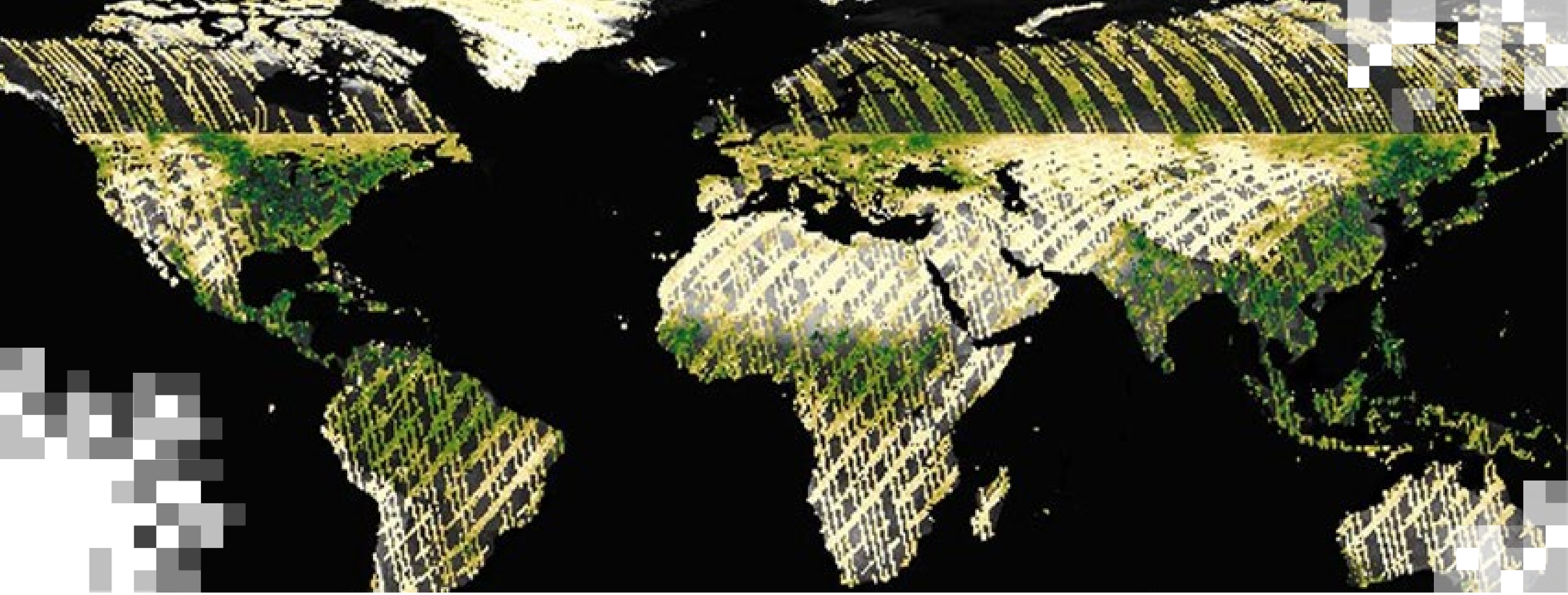
- Exploit the change of depth in solar Fraunhofer lines due to the fluorescence emitted from plants (in different spectral region than absorbed)
- For high spectral resolution instruments such as OCO, SIF retrievals are performed in two narrow spectral bands around the O_2 A-band (called "757" and "771" for historical reasons)
- Other SIF observers leverage Fraunhofer lines at higher wavelengths (e.g., TROPOMI, GOME-2, SCIAMACHY)



Typical Spectral Bands Used to Retrieve SIF from Space

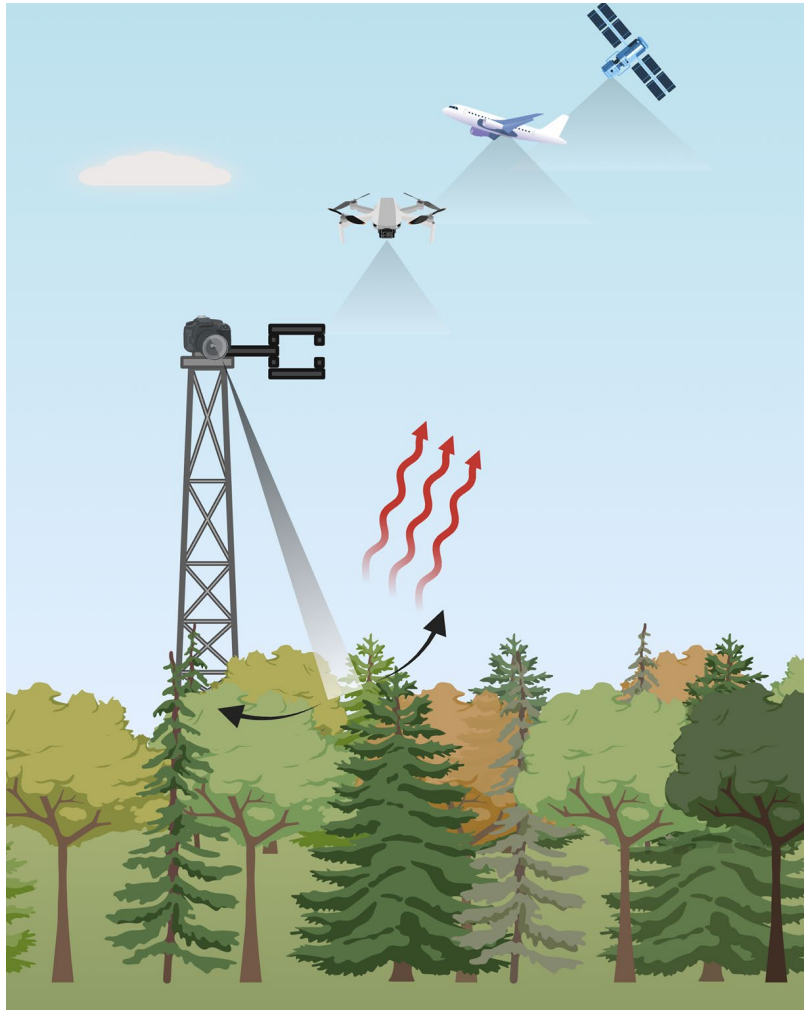


Parazoo et al., 2019



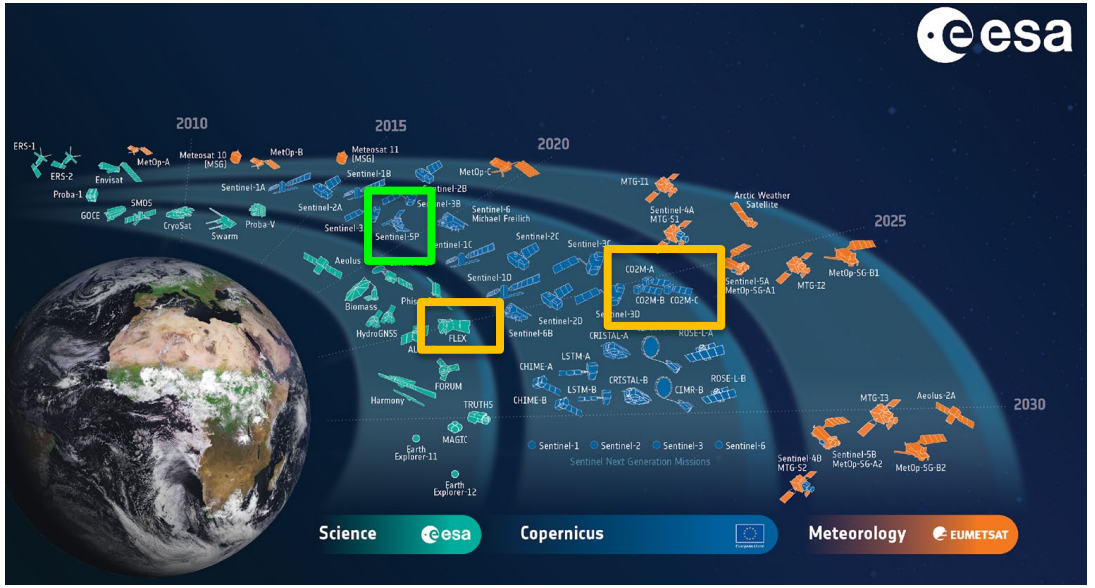
What SIF Products Exist?

What SIF Data are Available?



Adapted from Pierrat et al., 2025

Satellite-Based



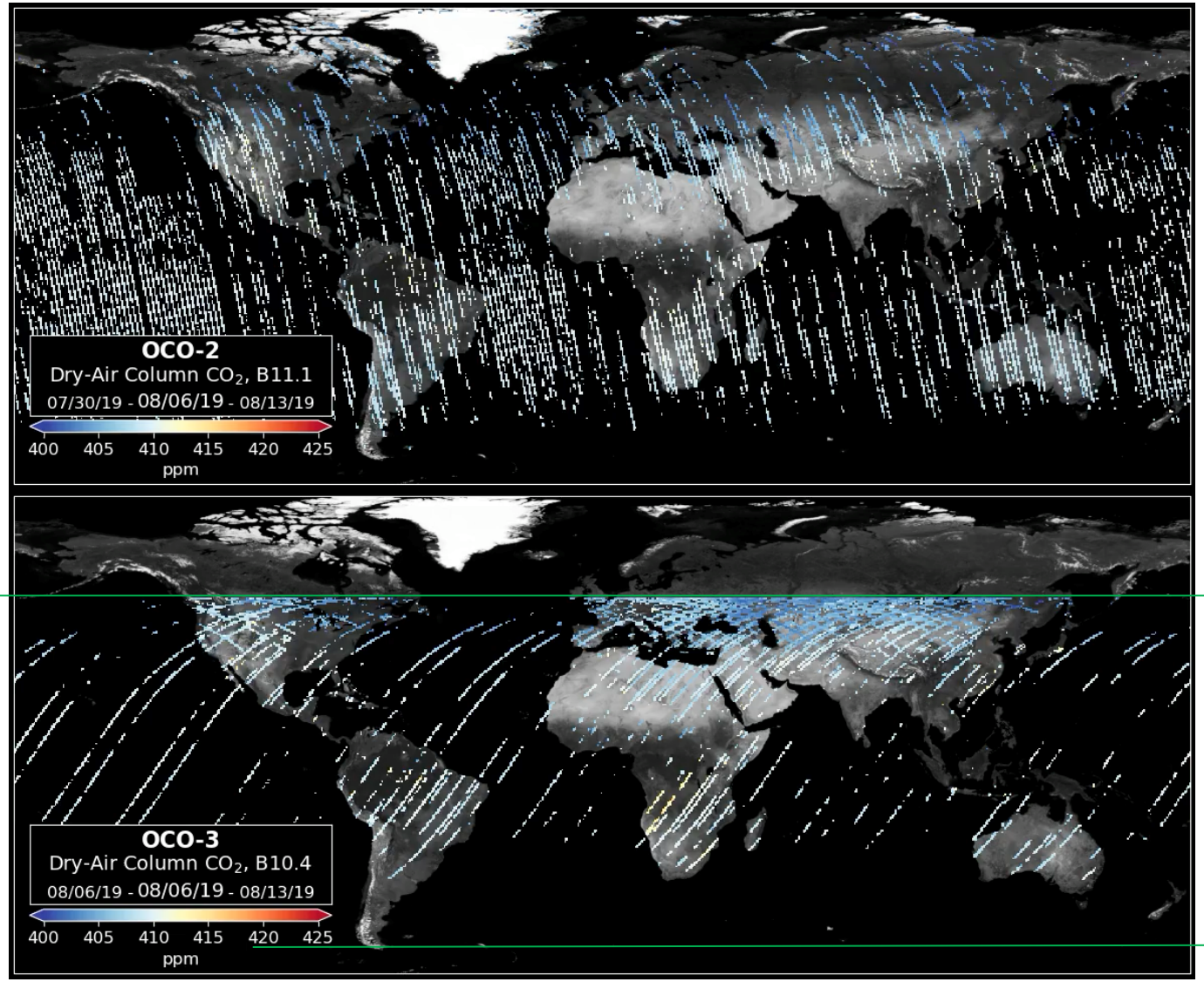
OCO-2 and OCO-3 Provide Complementary Coverage and Sampling

OCO-2

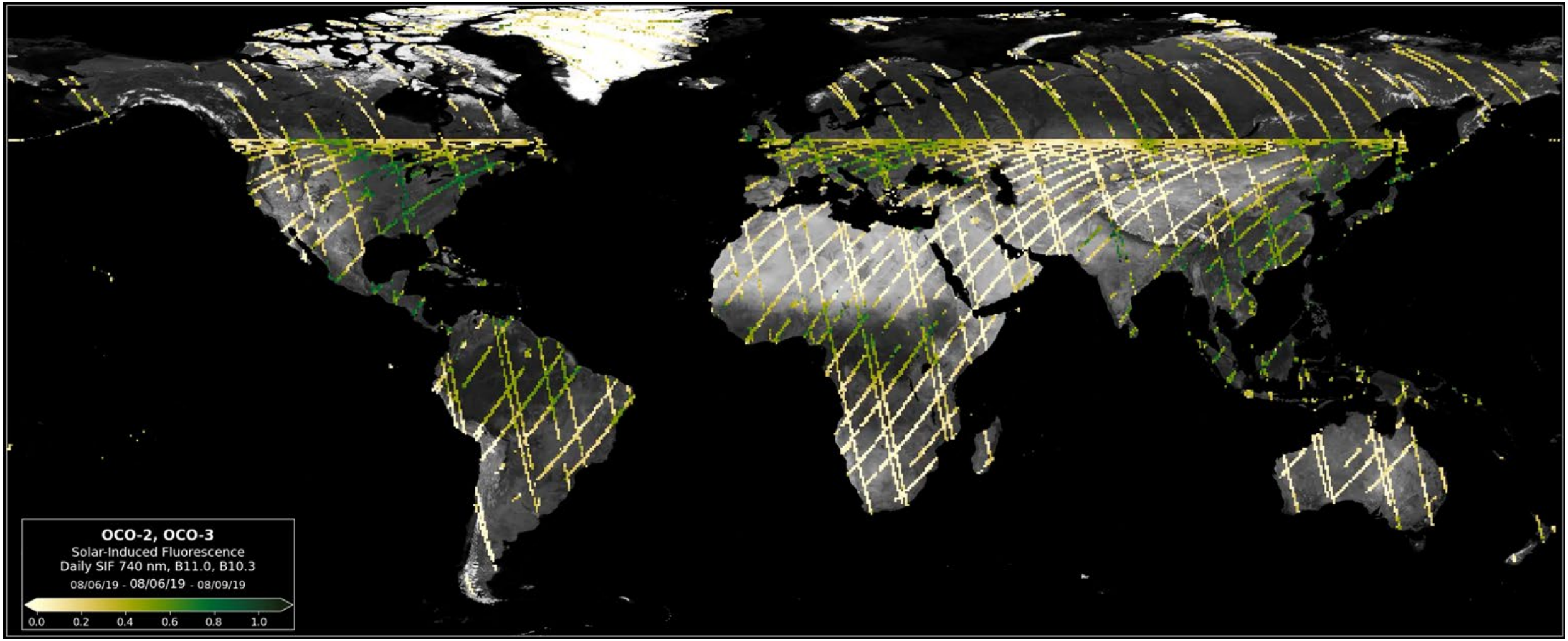
- "Pole-to-pole" coverage, depending on season;
- Fixed 1330h equator crossing time (and local overpass time)

OCO-3

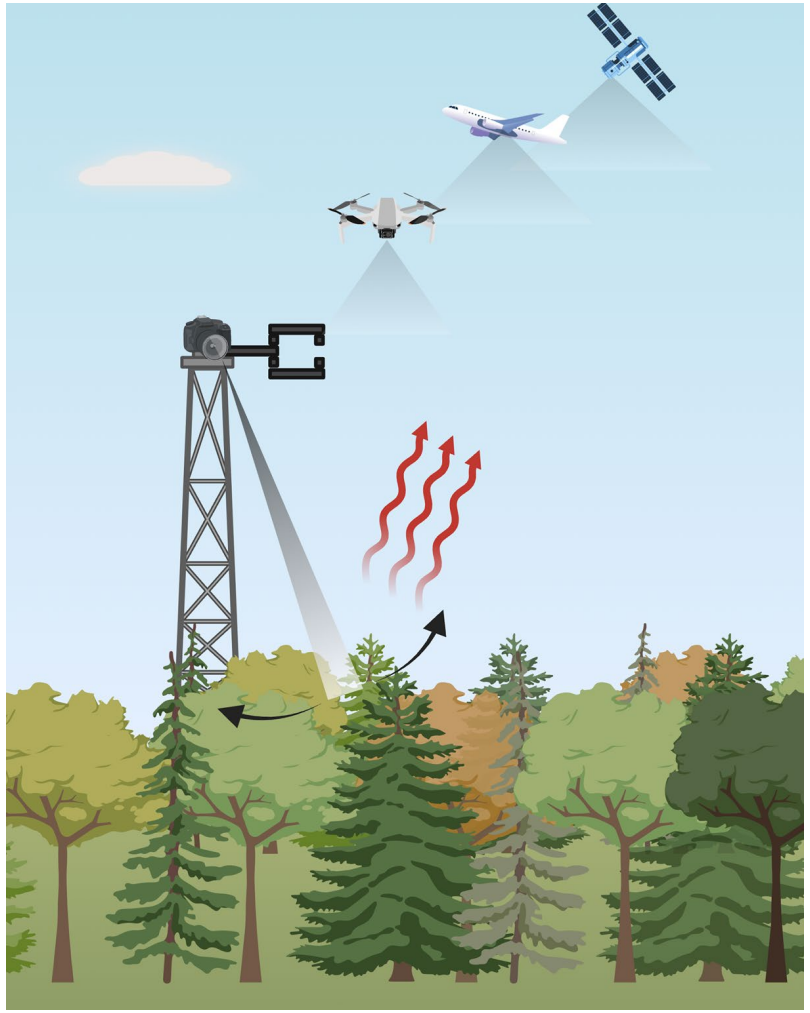
- Coverage limited to ±52° latitude, changing with season;
- Observations span all times of day



SIF Retrievals from OCO-2/3



What SIF Data are Available?

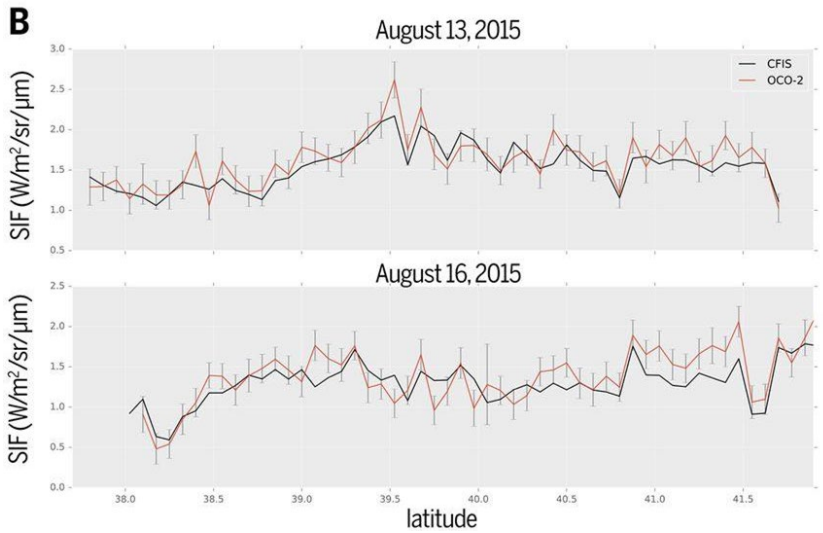


Adapted from Pierrat et al., 2025

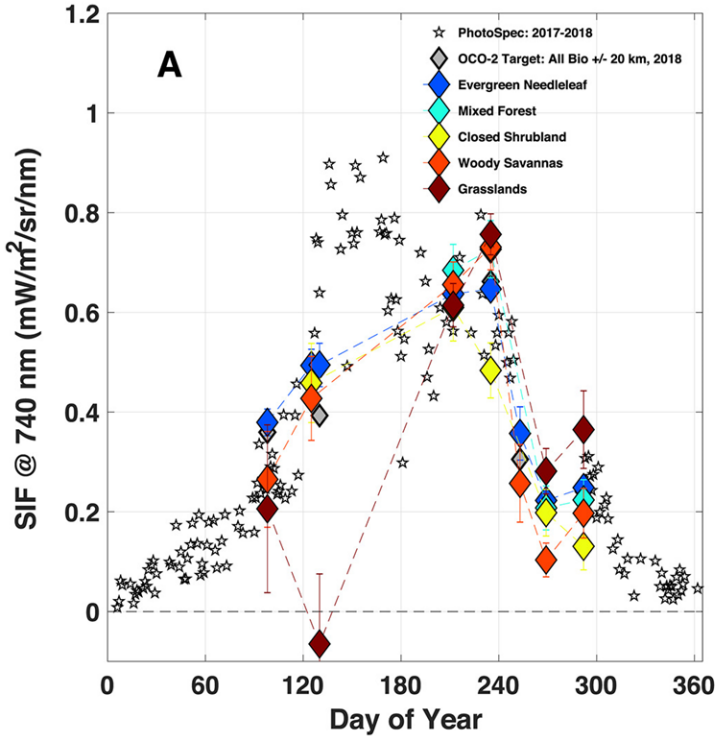
Tower-Based

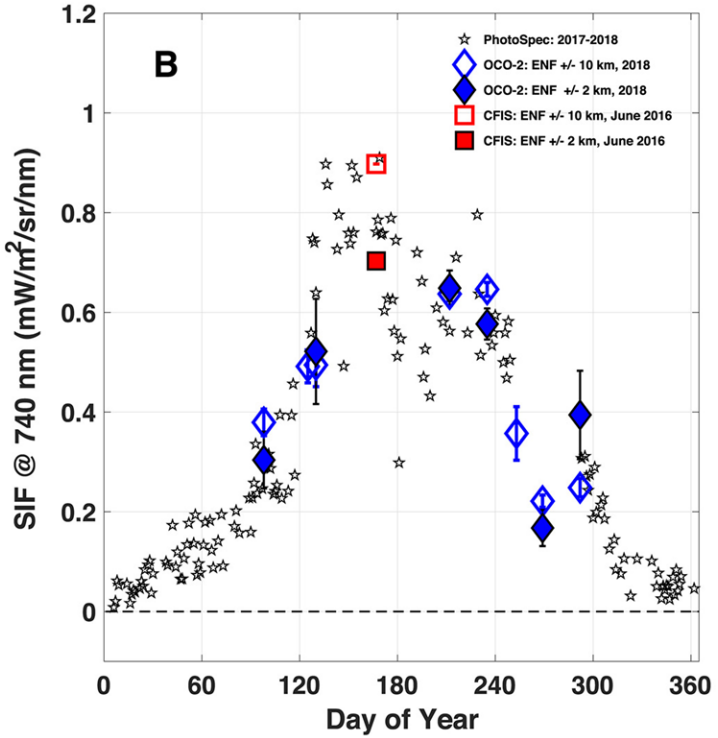
[JPL: Tower SIF Data]

Comparison of Satellite, Aircraft, and Tower Data



Sun et al., 2017

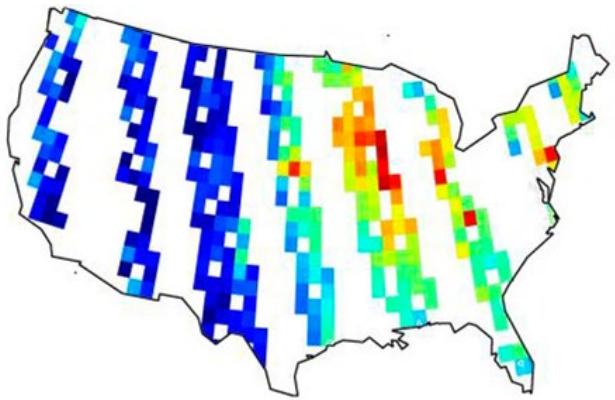


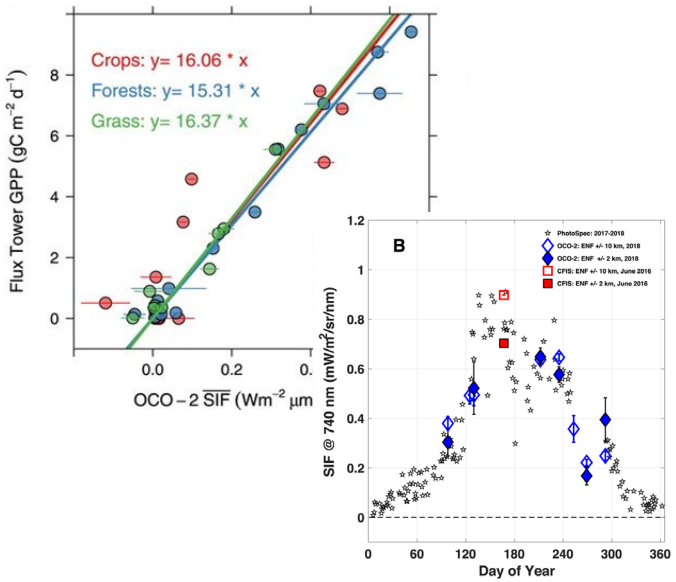


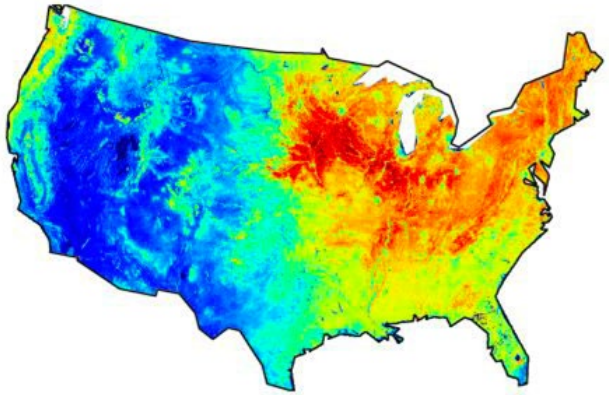
Parazoo et al., 2019

Combining Products With Machine Learning

OCO-2 + OCO-3 SIF + Traceability to Towers + Ancillary Vegetation Data (e.g., MODIS)

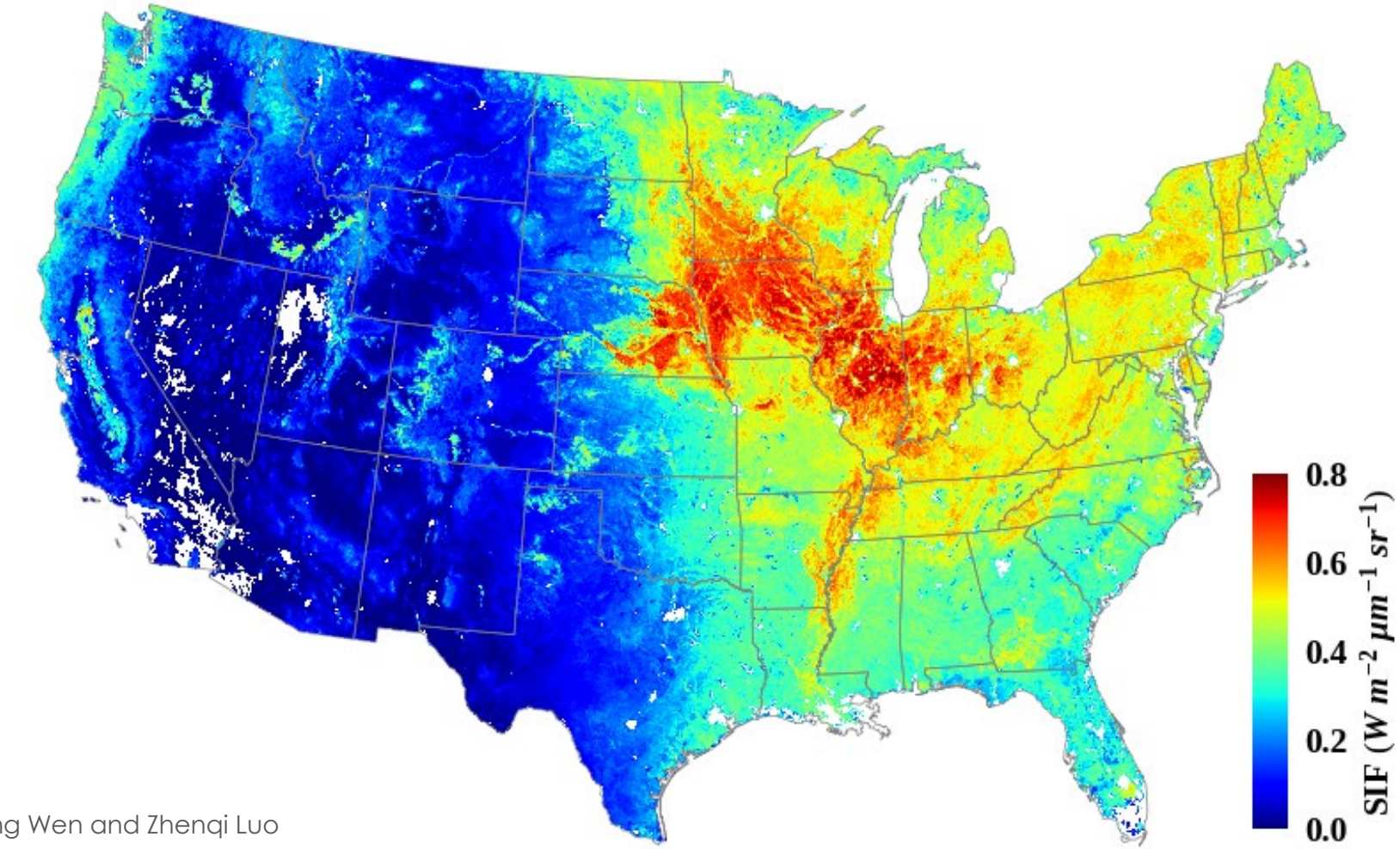






Yu et al., 2019

High Resolution Mapping of Vegetation Activity



Courtesy Jiaming Wen and Zhenqi Luo

Data Availability:

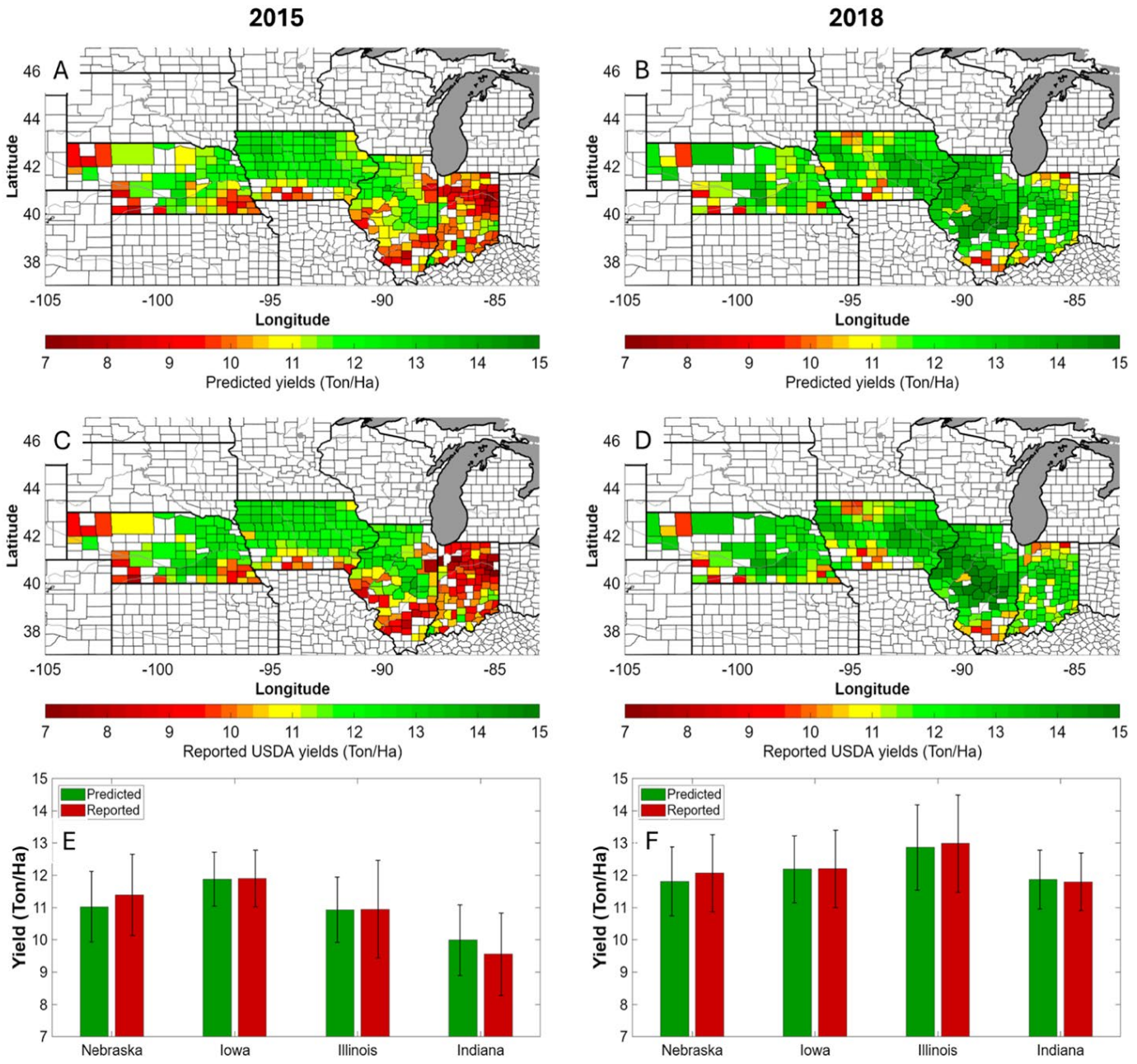
- https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1863

Example Application: Crop Yield Prediction

Top: OCO-2 driven crop yield product in US Corn Belt

Middle: Crop yield reported by US Department of Agriculture (USDA)

Bottom: OCO-2 driven product reproduces spatial pattern and year-to-year variability, and has comparable prediction accuracy when applied a month prior to harvest (not shown)



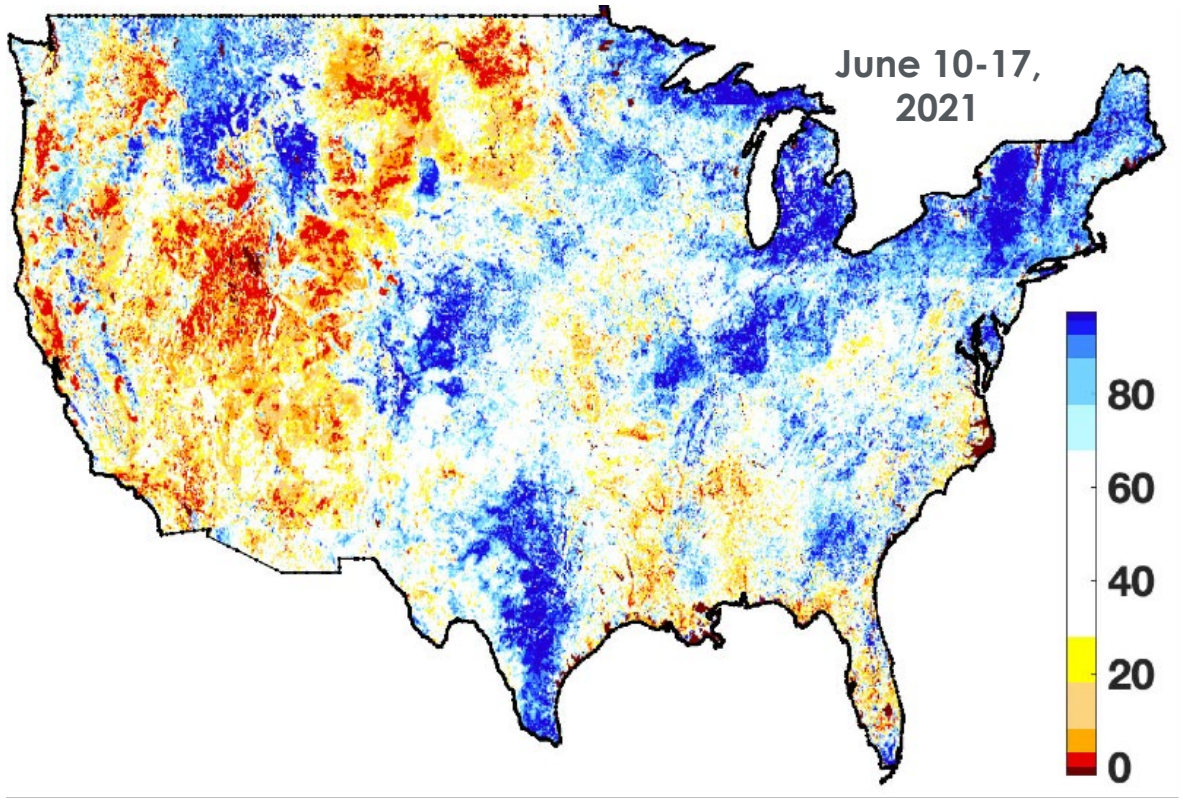
Predicted

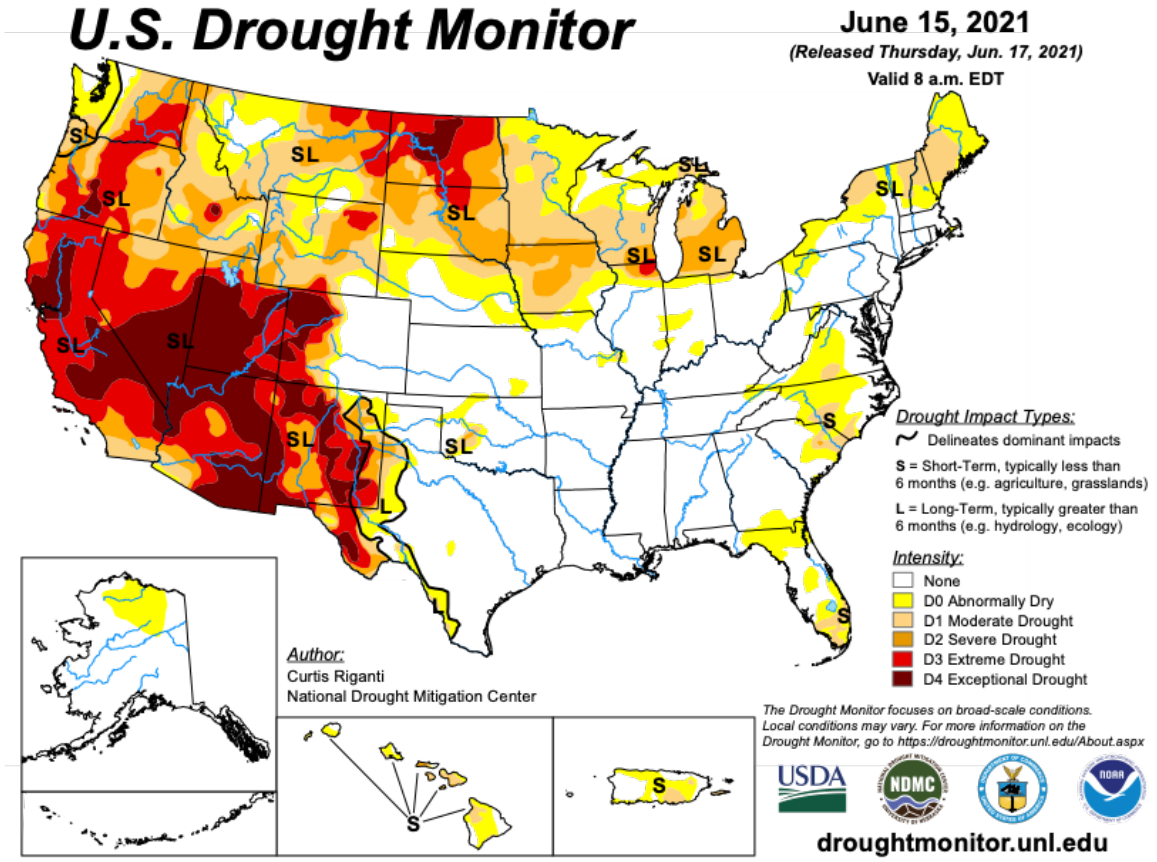
Observed

Modified from Kira et al., 2024

Example Application: Drought Early Warning

SIF Percentile



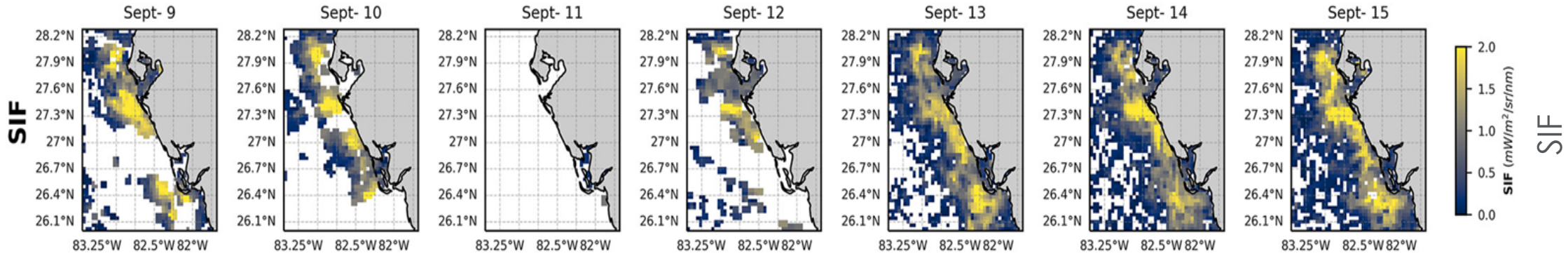


OCO-2-based SIF products offer early warning information on flash drought of potential value to agencies such as the US Drought Monitor.

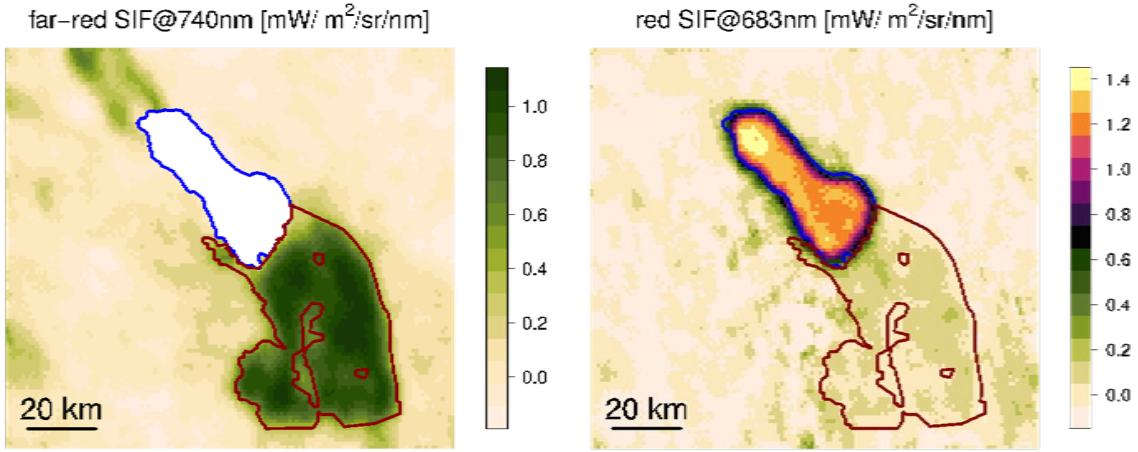
Aquatic SIF: TROPOMI

Harmful Algal Bloom (HAB)

Luis et al., 2023

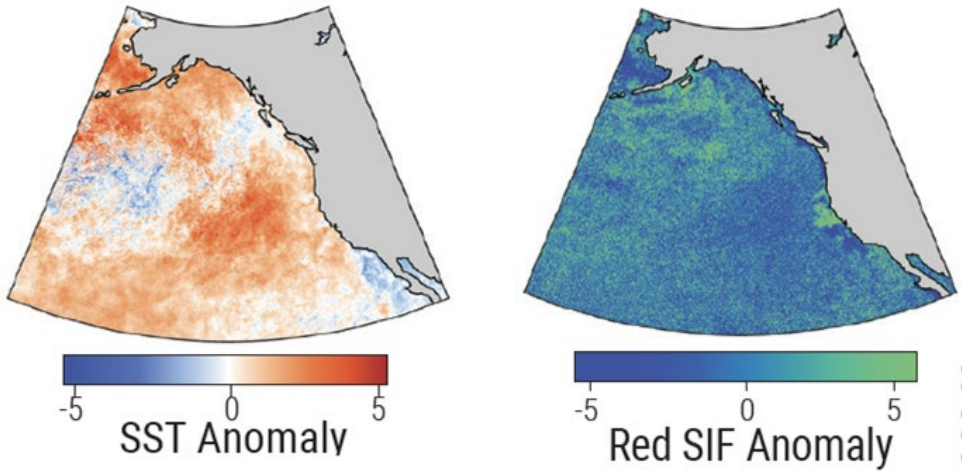


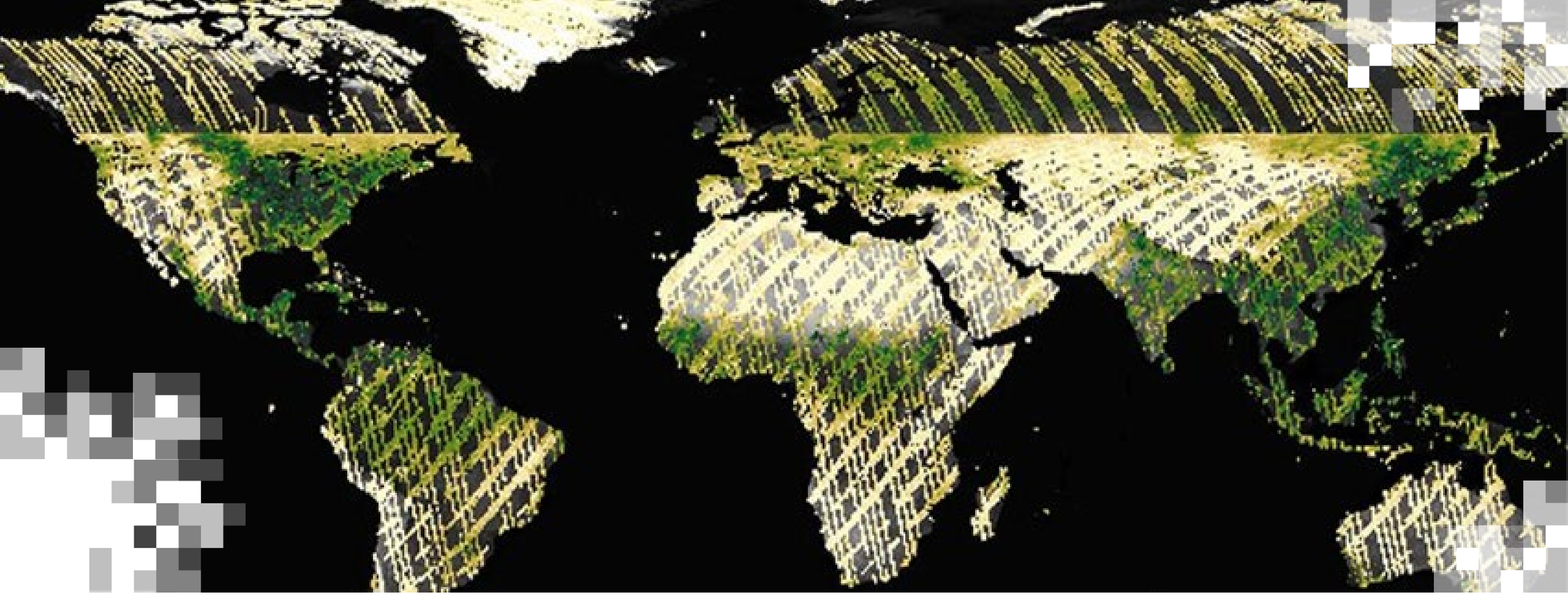
Agricultural Runoff



Kohler et al., 2020

Oceanic Climate Extremes





Demonstration

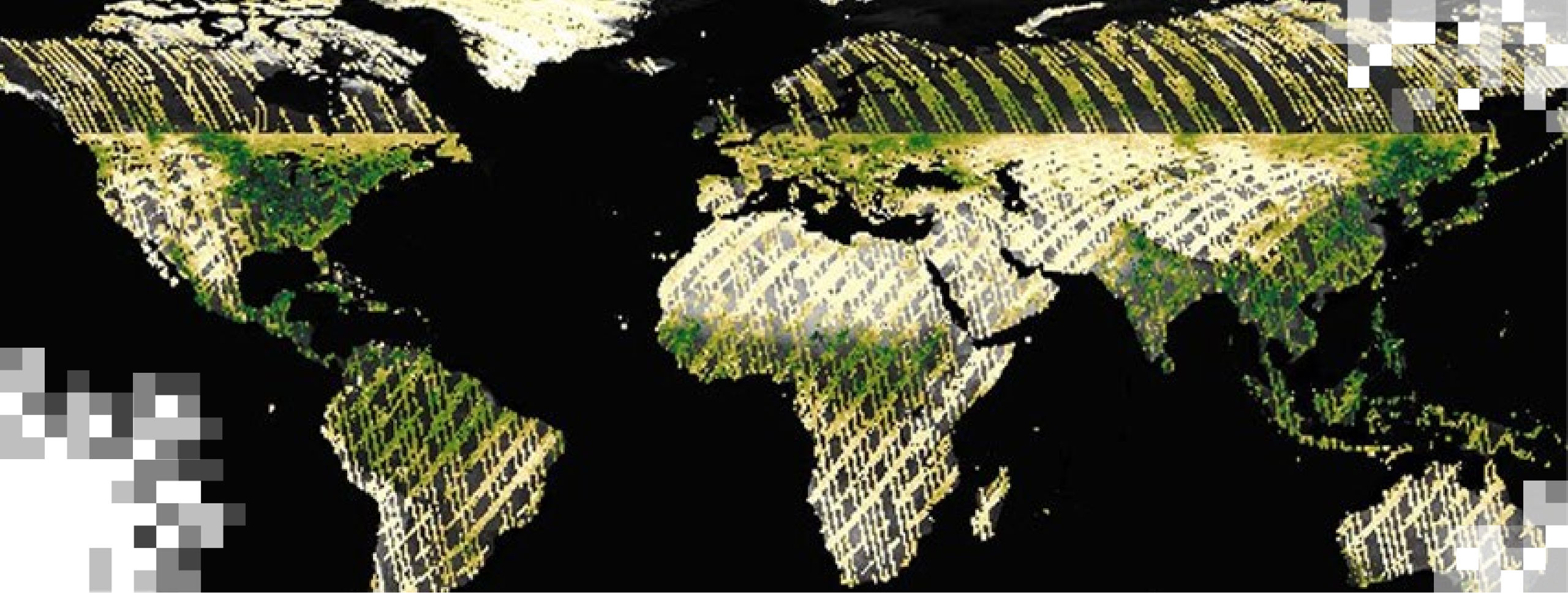
Demo Outline

- Session 1
  - Setting up your environment to work on SIF data sets
  - Retrieving and spatially gridding SIF data
- Session 2
  - OCO-3 Snapshot Area Map (SAM) mode
  - Comparison with flux tower data
  - Case study: fire conditions and SIF in Oregon, 2020
- Session 3
  - Use of gap-filled SIF data products
  - Case study: 2019 Midwestern US floods and impacts to agriculture

Session 1 Demonstration Objectives

By the end of session 1 demonstration, participants will be able to:

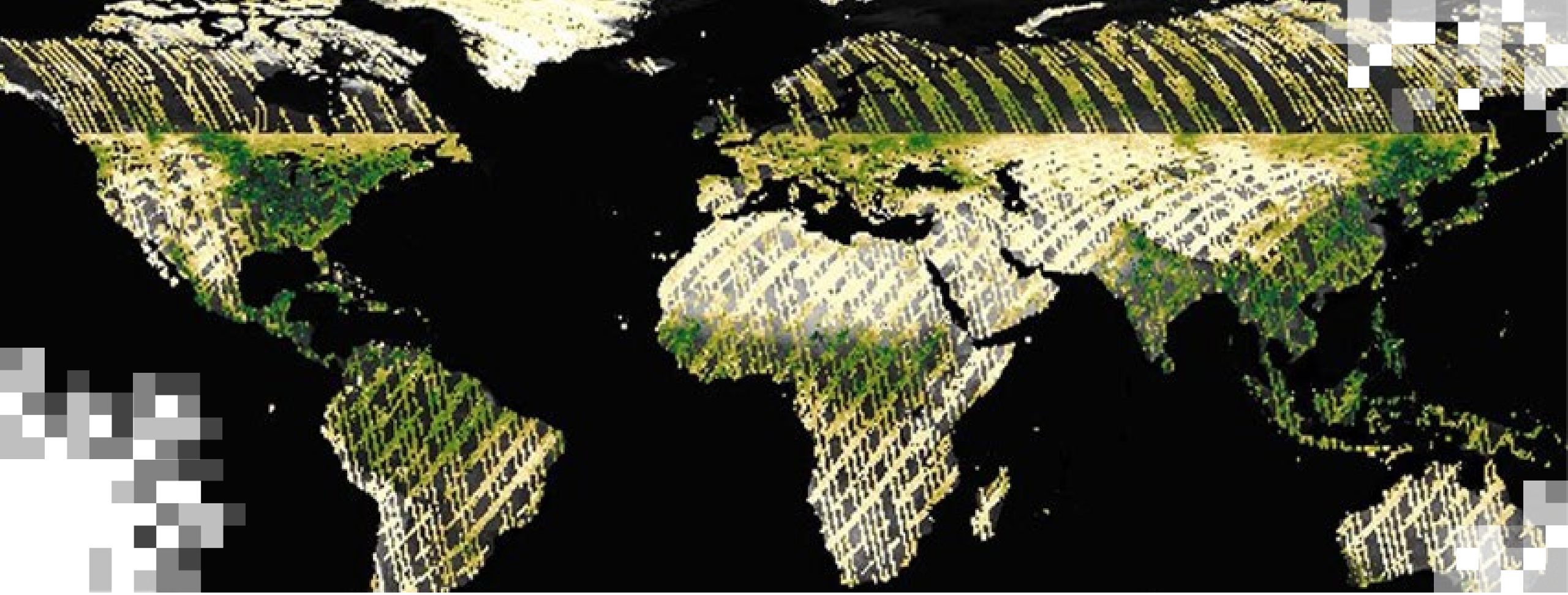
- Download and set up the course code materials
- Recognize how the Solar Induced Fluorescence (SIF) is measured and used as an alternative or complementary measurement for land and vegetation studies.
- Retrieve and plot an individual day worth of SIF data
- Create a gridded raster covering one month of instrument data
- Identify advantages and limitations of using space-based SIF measurements to monitor and evaluate vegetation health and condition



Setting Up Your Environment to Work on SIF Data Sets

Welcome to the Demonstration Portion of the Training!

- You will be following along an actual demonstration to familiarize with the steps to the notebook.
- The Jupyter notebooks are available at https://github.com/jackiryan/SIF-ARSET for the duration of the live training and homework submission.
- For future reference, the notebooks will be uploaded to the ARSET Github associated with this training.



Session 1:
Summary

Summary

- SIF is the reemission of absorbed sunlight by excited chlorophyl molecules in plants.
- SIF is emitted primarily through the absorption of the red portion of sunlight.
- SIF equals photosynthesis.
- SIF is independent of color and weakly sensitive to interference by clouds and reflections from non-photosynthesizing surfaces such as pavement, water, and soils.
- SIF is very good at detecting rapid changes in photosynthetic activity and plant health.
- The key to the SIF retrieval are the Fraunhofer Lines, which are very narrow regions in the optical spectrum of the Sun, where sunlight and atmospheric interference are minimal. The outgoing fluorescing light from plants fills the solar Fraunhofer lines, resulting in a change in depth of Fraunhofer lines.
- Spaceborne missions that measure SIF are NASA's OCO-2 and OCO-3 and the European Space Agency's Sentinel 5 precursor mission, which carries the TROPOMI instrument. Future missions include ESA's CO2M and FLEX.

Summary

- The OCO-2 satellite has provided sustained, pole to pole coverage and midday sampling during the daily peak of photosynthesis since its launch in 2014.

- OCO-3 is a sensor on the International Space Station. It launched in 2019 and is in a precessing orbit, providing spatial coverage from equatorial to temperate latitudes, and temporal coverage at all times of day.

- Some important applications of SIF are crop yield predictions, drought early warning, and algal bloom detection.

-A single day of SIF measurements from OCO-2 or OCO-3 provides limited spatial coverage. Aggregating data over several days will ensure more continuous coverage.

-An OCO-2 or OCO-3 quality flag of 0 is considered good quality data; a quality flag of 1 is still considered good but might have higher uncertainty; and a quality flag of 2 indicates bad quality data.

-Nadir mode provides an ideal set of measurements over terrestrial vegetation because the sensor is looking straight down, minimizing the influence of the view angle geometry.

-The 757 nanometer SIF data has the lowest uncertainty and the highest signal to noise ratio in general.

Resources: SIF Products and Videos

- SIF005 – https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1863
- GOSIF – https://globalecology.unh.edu/data/GOSIF.html
- Tower SIF – https://climatesciences.jpl.nasa.gov/sif/download-data/tower/
- "What is SIF" TedEd Link – https://www.youtube.com/watch?v=3jpy8UZUEOw&t=4s

Resources: Publications

- Kira, O., Wen, J., Han, J., McDonald, A. J., Barrett, C. B., Ortiz-Bobea, A., ... & Sun, Y. (2024). A scalable crop yield estimation framework based on remote sensing of solar-induced chlorophyll fluorescence (SIF). *Environmental Research Letters*, *19*(4), 044071. https://doi.org/10.1088/1748-9326/ad3142
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- ARSET Website
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Looking Ahead to Session 2

- SIF measurements in science and applications
- Examples of SIF in OCO-3 Snapshot Area Map (SAM) mode
- Comparison with flux tower data
- Case study: fire conditions and SIF in Oregon, 2020


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