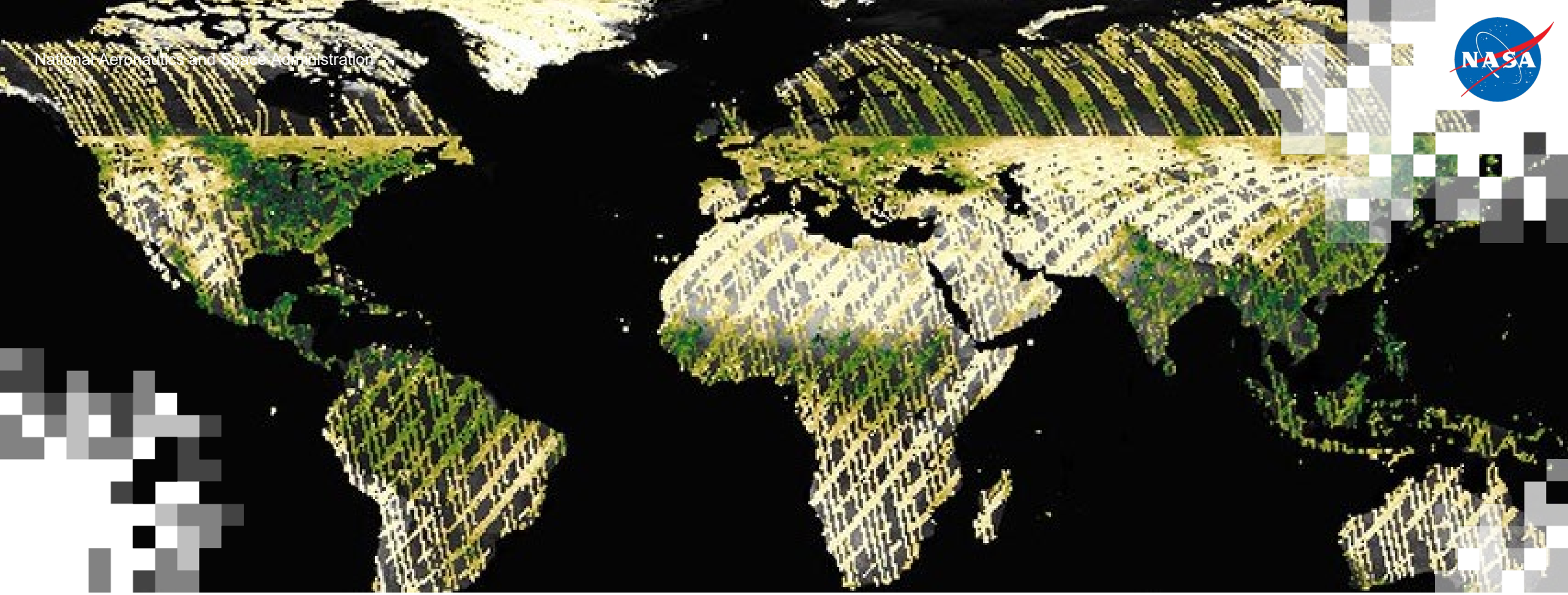


Solar Induced Fluorescence (SIF) Observations for Assessing Vegetation Changes Related to Drought, Land Change, and Pre-Fire Conditions

Session 2: Overview of Orbiting Carbon Observatory (OCO)-2 and OCO-3 Observing Modes and Solar Induced Chlorophyll Fluorescence (SIF) Observations

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

October 22, 2025

Training Outline

Session 1

Solar Induced Chlorophyll Fluorescence (SIF) Measurements from Space

October 15, 2025

12:00-2:00 p.m. EDT(1600-1800 UTC)

Session 2

Overview of Orbiting Carbon Observatory (OCO)-2 and OCO-3 Observing Modes SIF Observations

October 22, 2025

12:00-2:00 p.m. EDT(1600-1800 UTC)

Session 3

Working with Gap-Filled SIF Products

October 29, 2025

12:00-2:00 p.m. EDT(1600-1800 UTC)

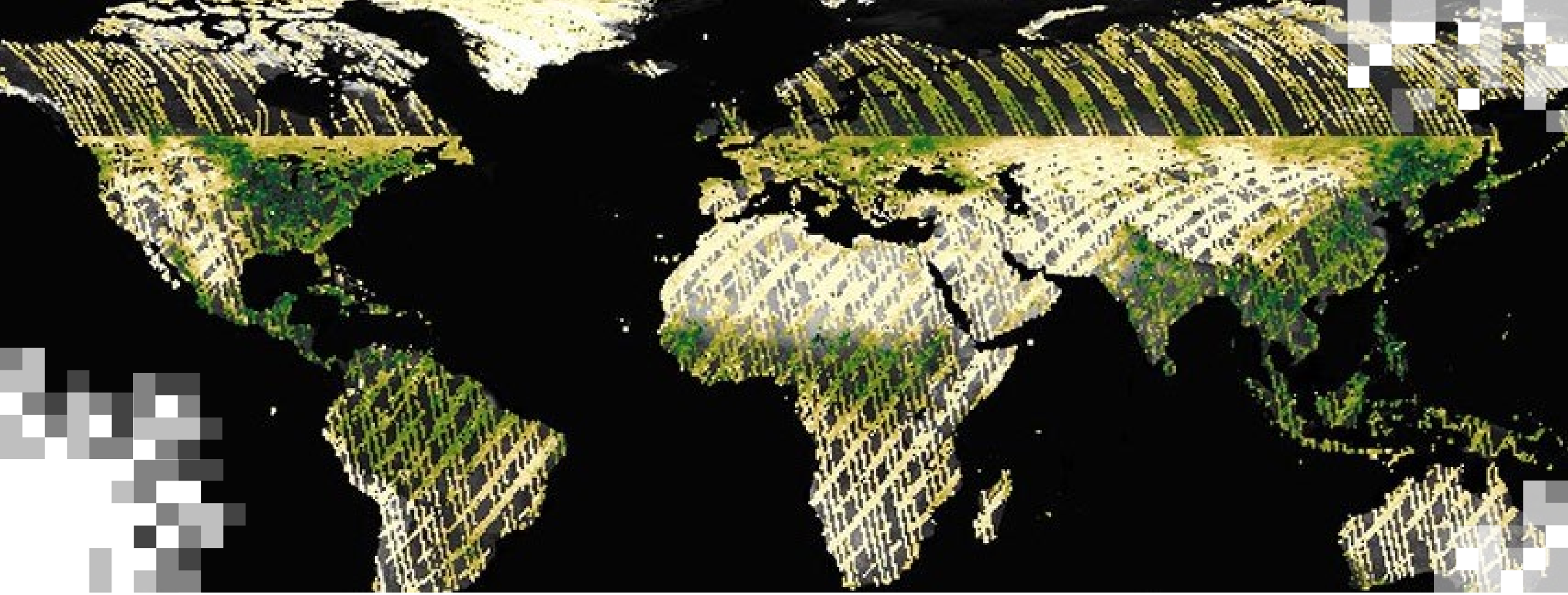
Homework

Opens October 29 – Due November 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



Session 2: Overview of Orbiting Carbon Observatory (OCO)-2 and OCO-3 Observing Modes SIF Observations

Session 2 – Trainers

Dr. Erika Podest

Scientist

NASA Jet Propulsion Laboratory, California Institute of Technology

Dr. Junjie Liu

Scientist

NASA Jet Propulsion Laboratory, California Institute of Technology

Jackie Ryan

Data Visualization Developer

NASA Jet Propulsion Laboratory, California Institute of Technology

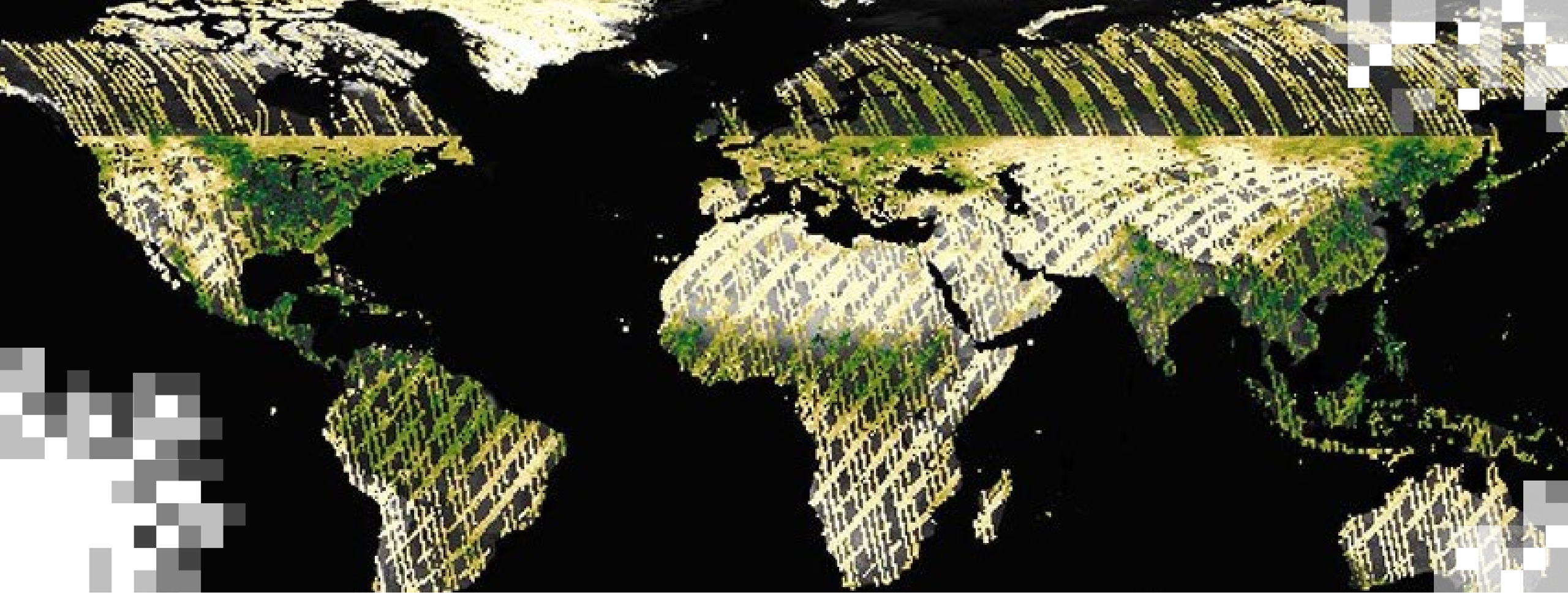
Session 2: Objectives

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

- Identify the characteristics and operating modes of OCO-2, OCO-3 and other SIF datasets
- Recognize the synergistic use of SIF with other datasets
- Recognize the applications of SIF
- Recognize how the new OCO-3 Snapshot Area Map (SAM) mode can be visualized using an open source Jupyter Notebook as a means to evaluate land change due to fire impacts.
- Run the Jupyter Notebook environment from lesson 1 and run the OCO-3 SAM notebook to analyze and visualize vegetation change due to fire across two case study sites.
- Quantify the SIF-GPP relationship by comparing remote sensing data from OCO-3 with eddy flux tower data at the two case study sites.

How to Ask Questions

- Please write your questions in the Questions box located in the three … in the lower right corner.
- Feel free to enter your questions during the presentation. 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.



Overview of Orbiting Carbon Observatory (OCO)-2 and OCO-3 Observing Modes and Solar Induced Chlorophyll Fluorescence (SIF) Observations

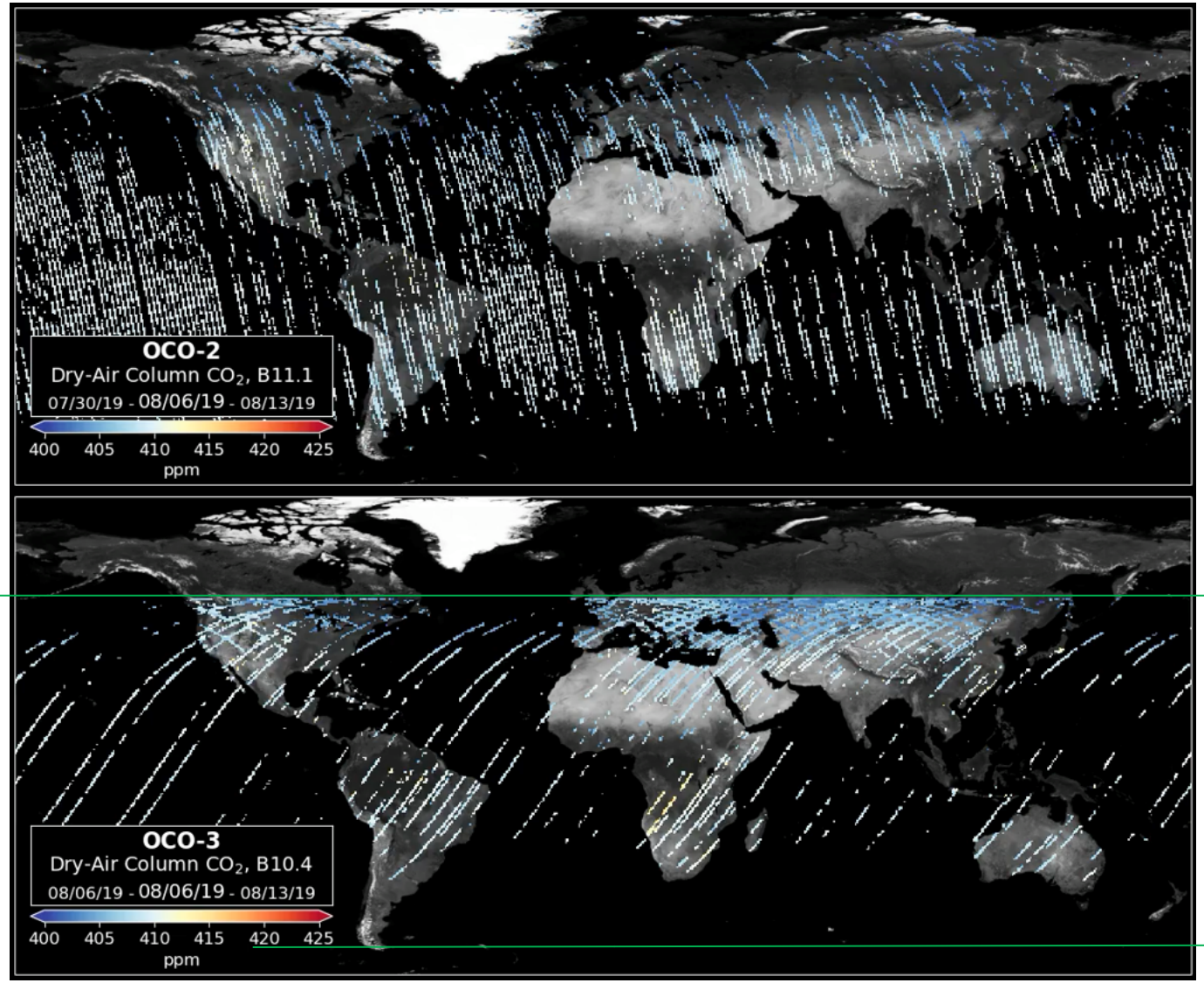
OCO-2 and OCO-3 Provide Complementary Coverage and Sampling

OCO-2

- "Pole-to-pole" coverage, depending on season
- Fixed 13:30h equator crossing time (and local overpass time)
- Launched in July 2014
- Footprint: ~1.9km x 2.0km
- Eight footprints cross track
- 16-day repeat cycle

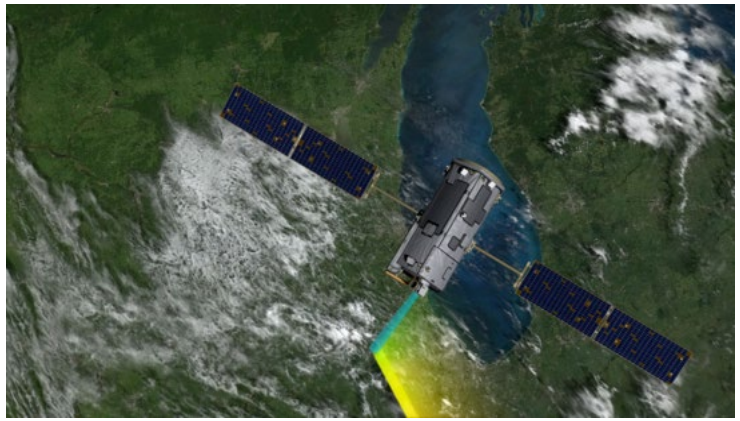
OCO-3

- Coverage limited to ±52° latitude, changing with season
- Observations span all times of day
- Irregular repeat cycle
- Launched in May 2019



What are the Different Observation Modes?

To enhance the quality and to verify the validity of mission data, OCO-2 collects science observations in Nadir, Glint, and Target Modes (please hover image to play video).



Nadir Mode, or looking straight down, provides the highest spatial resolution on the surface and is expected to return more useable soundings in regions that are partially cloudy or have significant surface topography. Nadir observations may not provide adequate signal-to-noise over dark ocean surfaces.

Glint Mode, the spacecraft points the instrument toward the bright "glint" spot, where solar radiation is reflected from the surface. At high latitudes over the ocean, observations of the bright glint spot provide up to 100 times as much signal as measurements collected while looking straight downward at the ocean surface. Thus, the use of glint measurements significantly improves the signal-to-noise ratio over the dark ocean.

Target Mode, the Observatory locks its view onto a specific surface location and retains that view while flying overhead. Comparison of space-based and ground-based measures provides a means to identify and correct systematic and random errors in the OCO-2 *XCO2* data products.

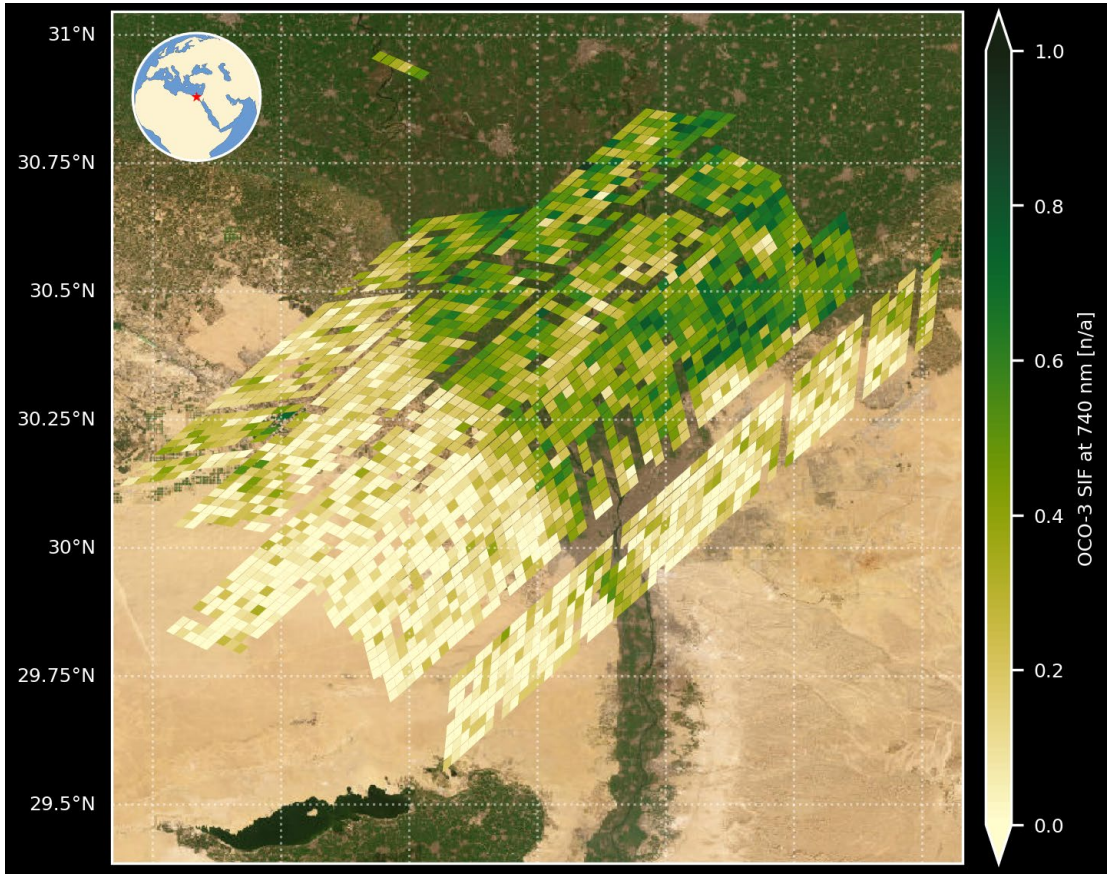
OCO-3 Snapshot Area Maps (SAMs) SIF Observation Distributions

- Top panel: low SIF sites
- Bottom panel: High SIF sites

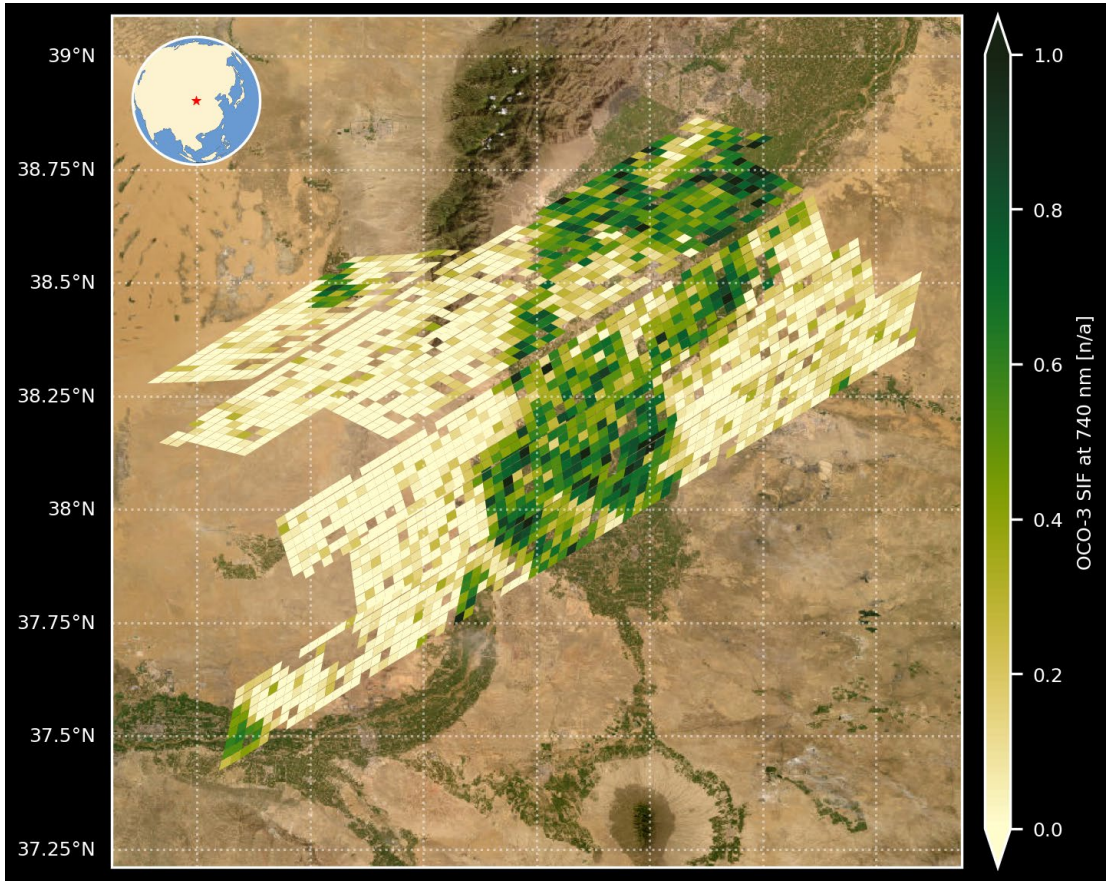
- Request additional SAM observations: request

- Website: OCO3-SAM

Examples of OCO-3 SAM Observations

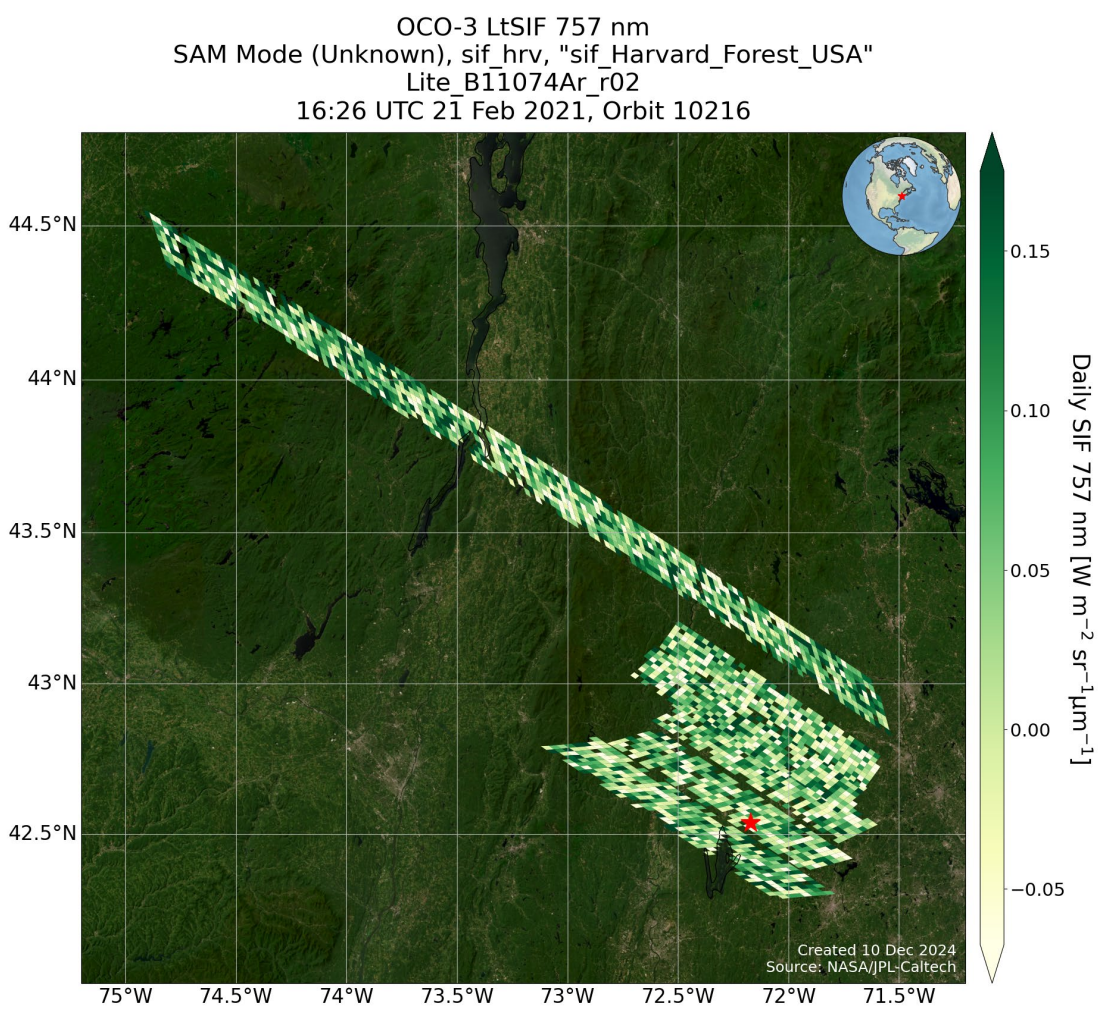


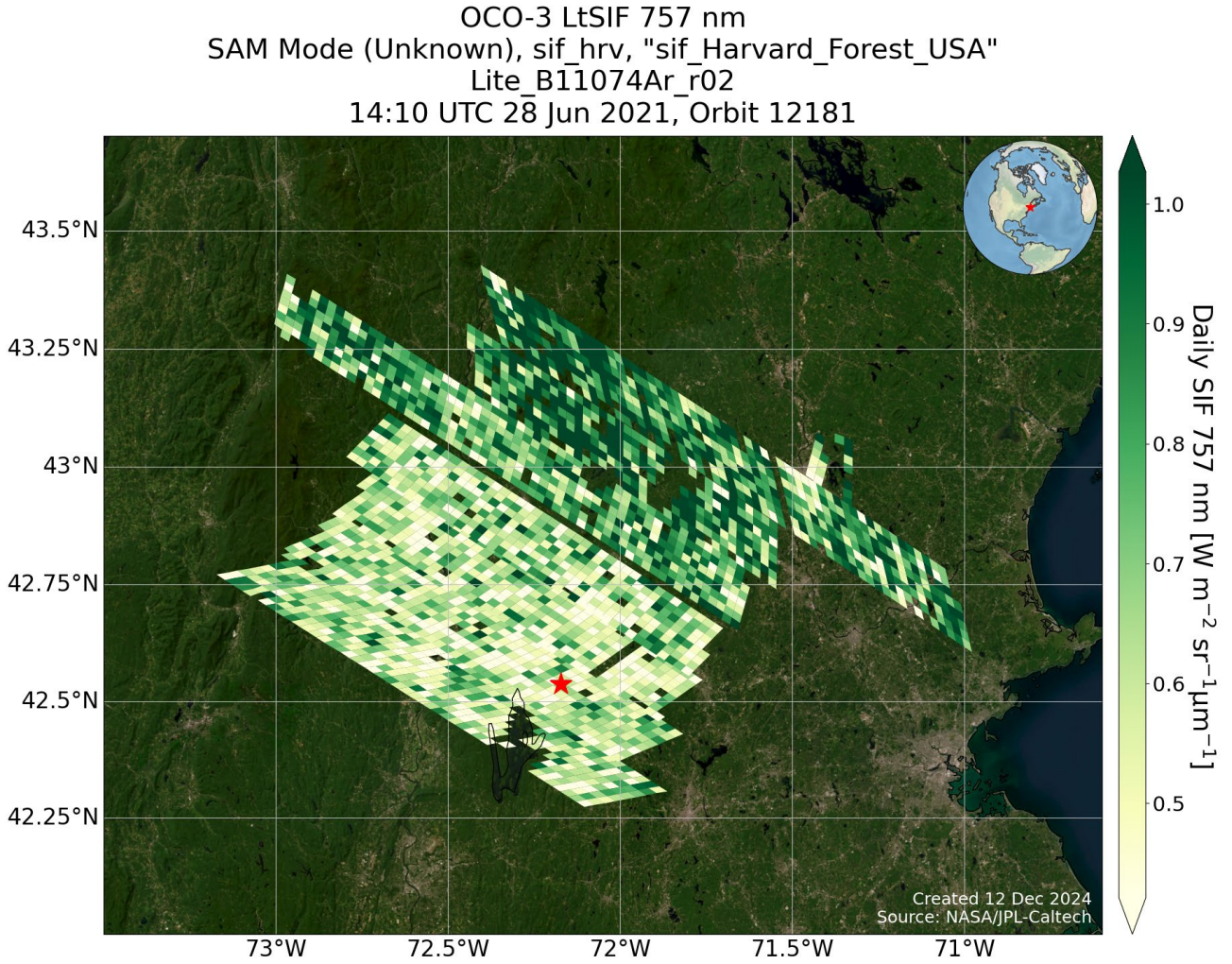
Cairo, Egypt (30 Jan 2021)



Yinchuan, China (13 Aug 2020)

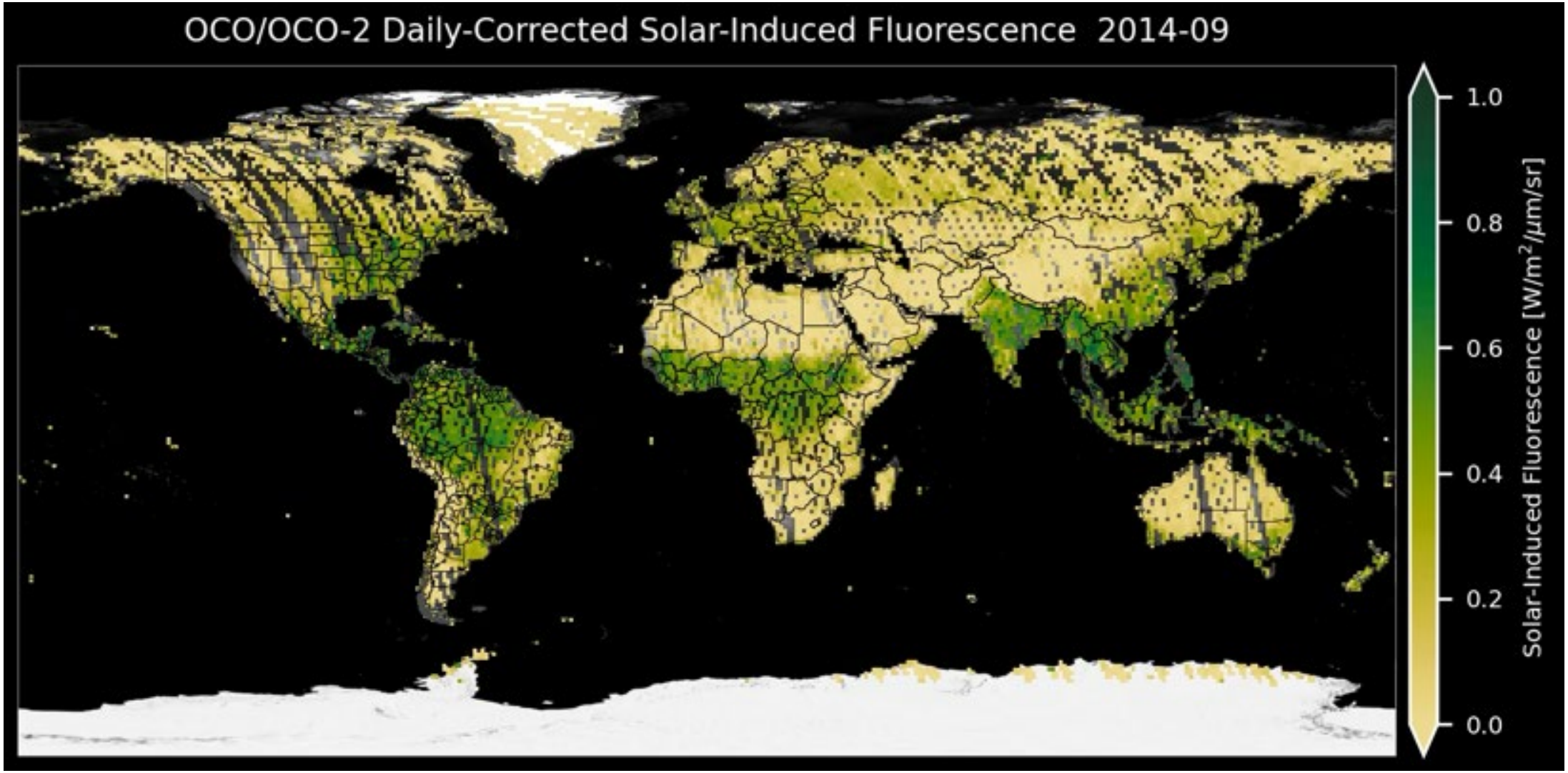
OCO-3 SAM SIF Observations



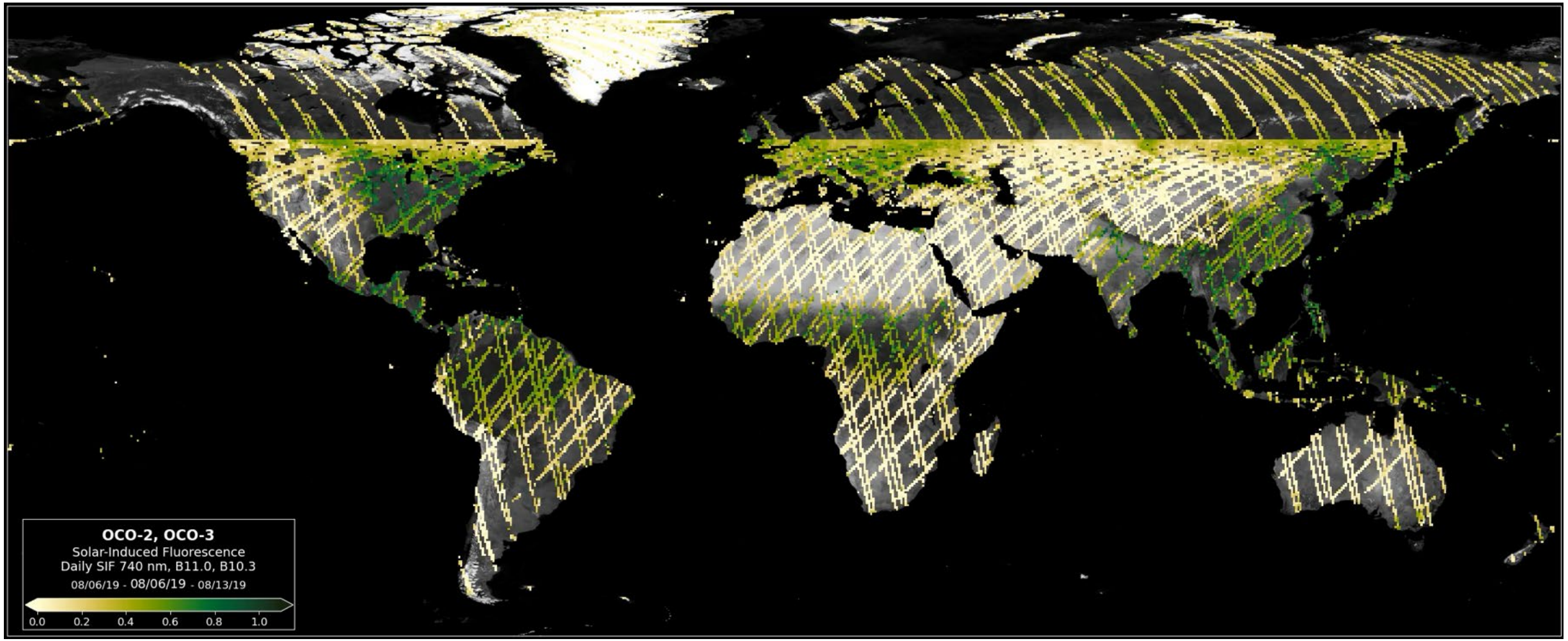


Check out more OCO-3 SAM observations here: [OCO-3 SAM]

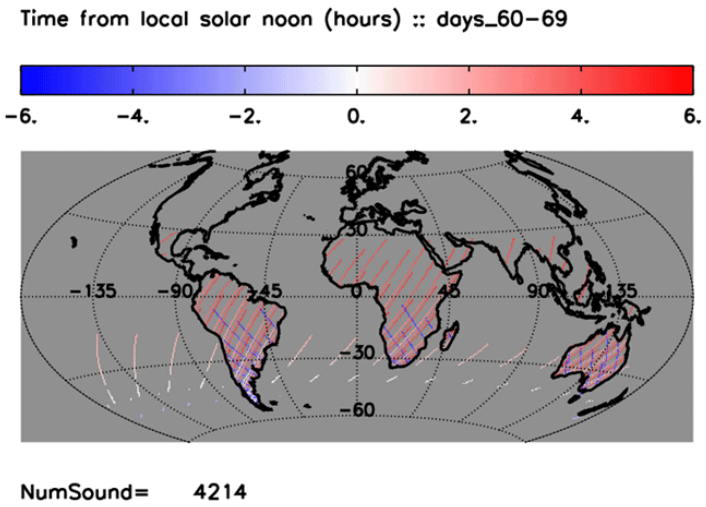
OCO-2 SIF

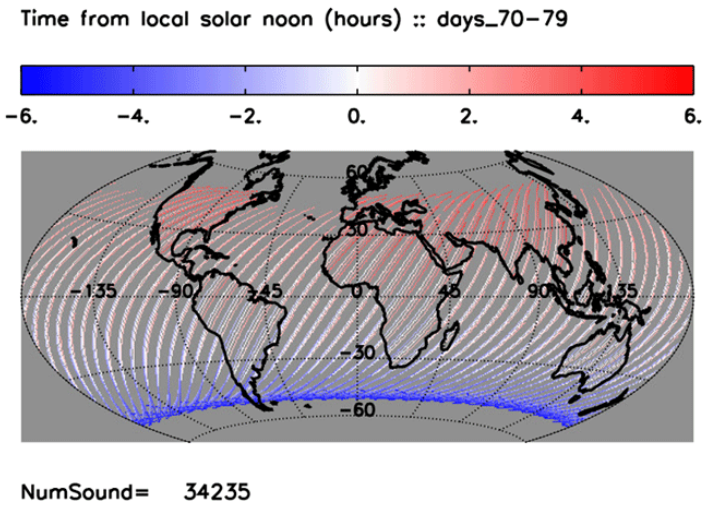

OCO/OCO-2 Daily-Corrected Solar-Induced Fluorescence 2014-09
1.0
0.8
0.6
0.4
0.2
0.0
Solar-Induced Fluorescence [W/m²/μm/sr]

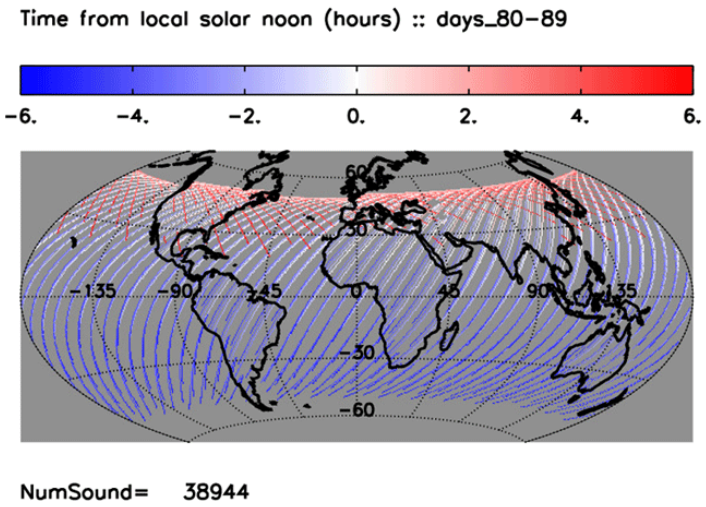
OCO-2/3 SIF

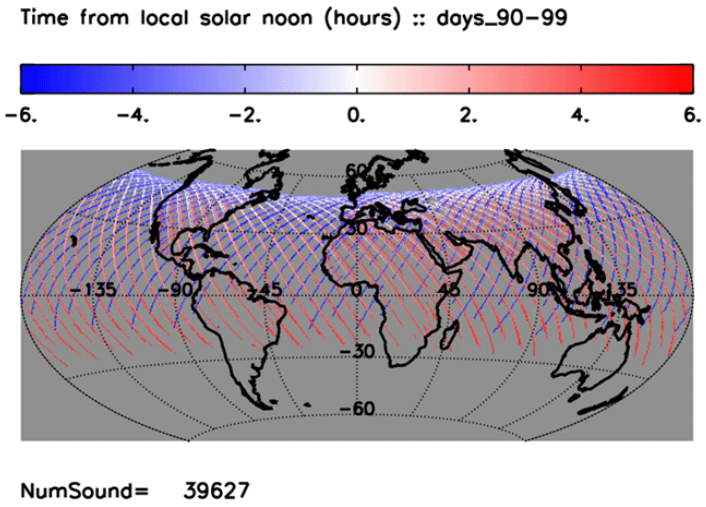

OCO-2, OCO-3
Solar-Induced Fluorescence
Daily SIF 740 nm, B11.0, B10.3
08/06/19 - 08/06/19 - 08/13/19
0.0
0.2
0.4
0.6
0.8
1.0

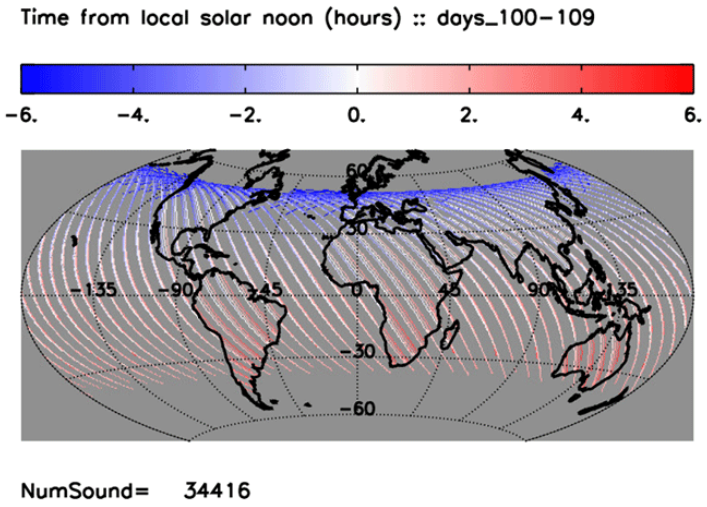
Different Time of the Day Observations from OCO-3

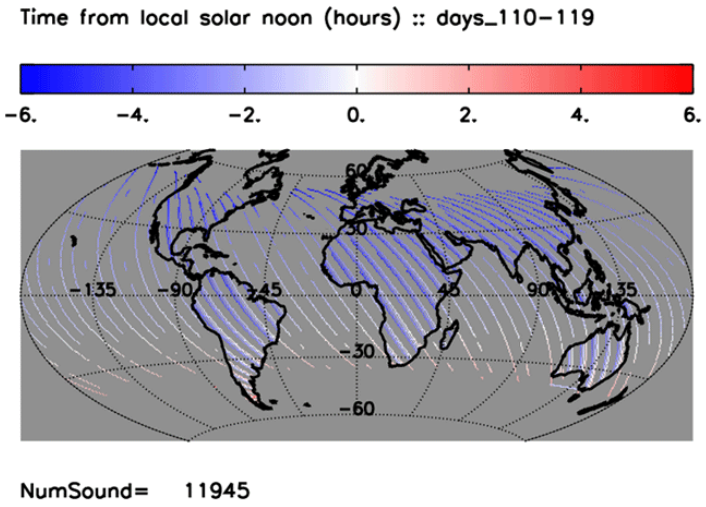




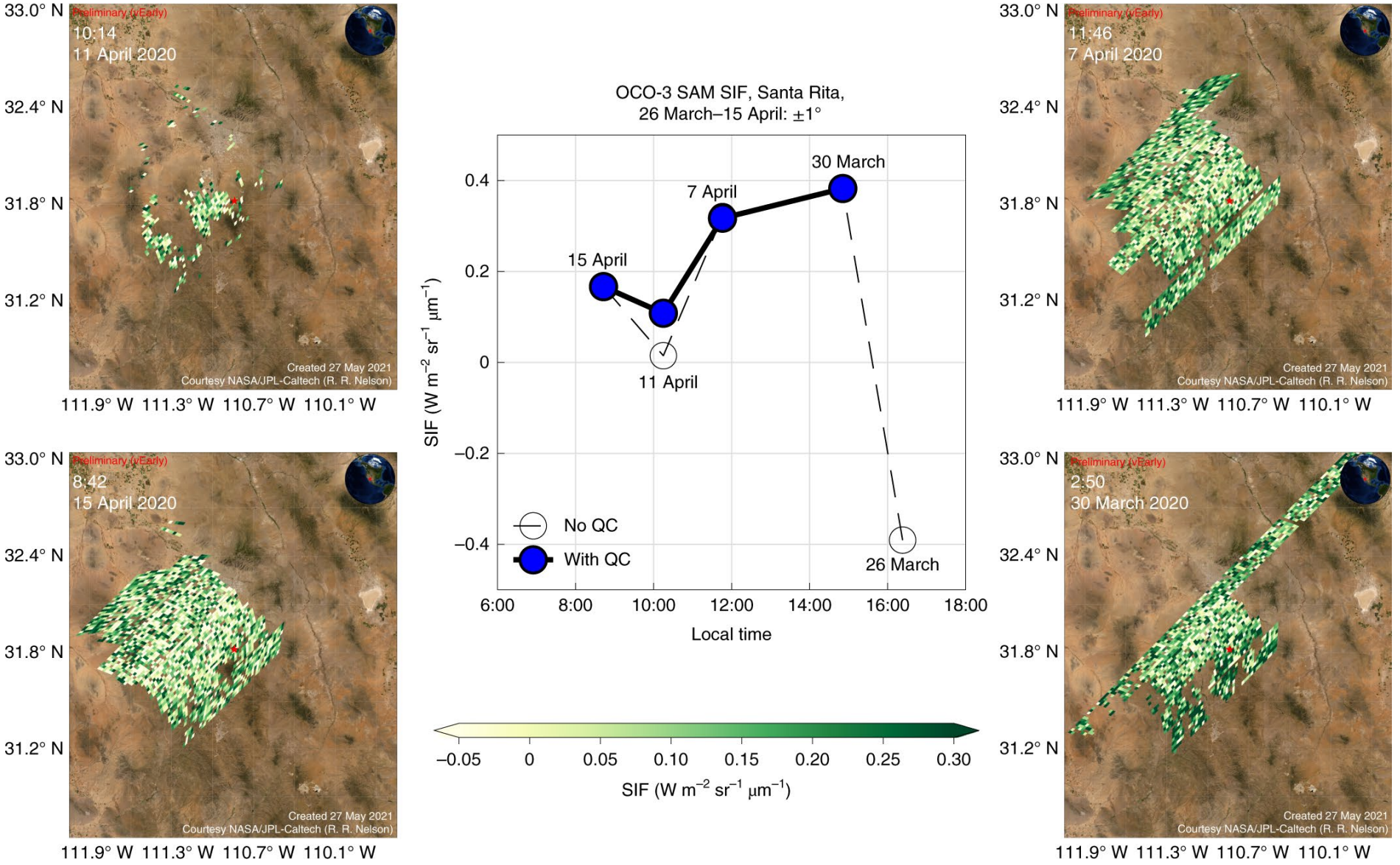






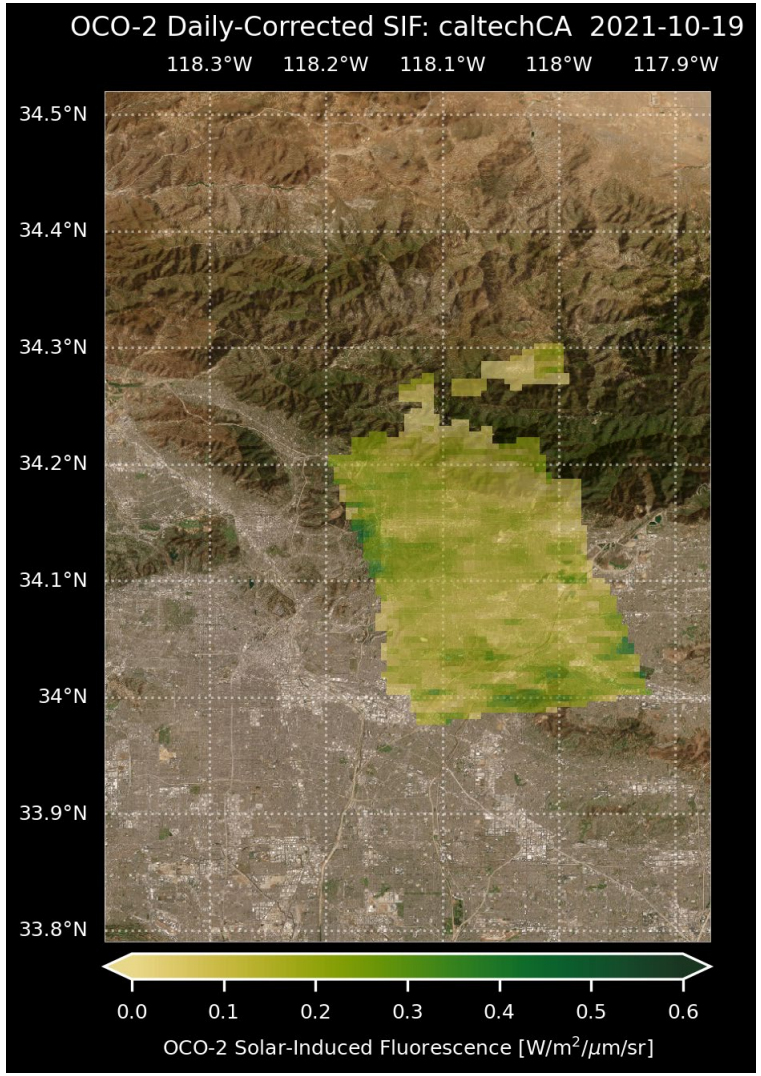


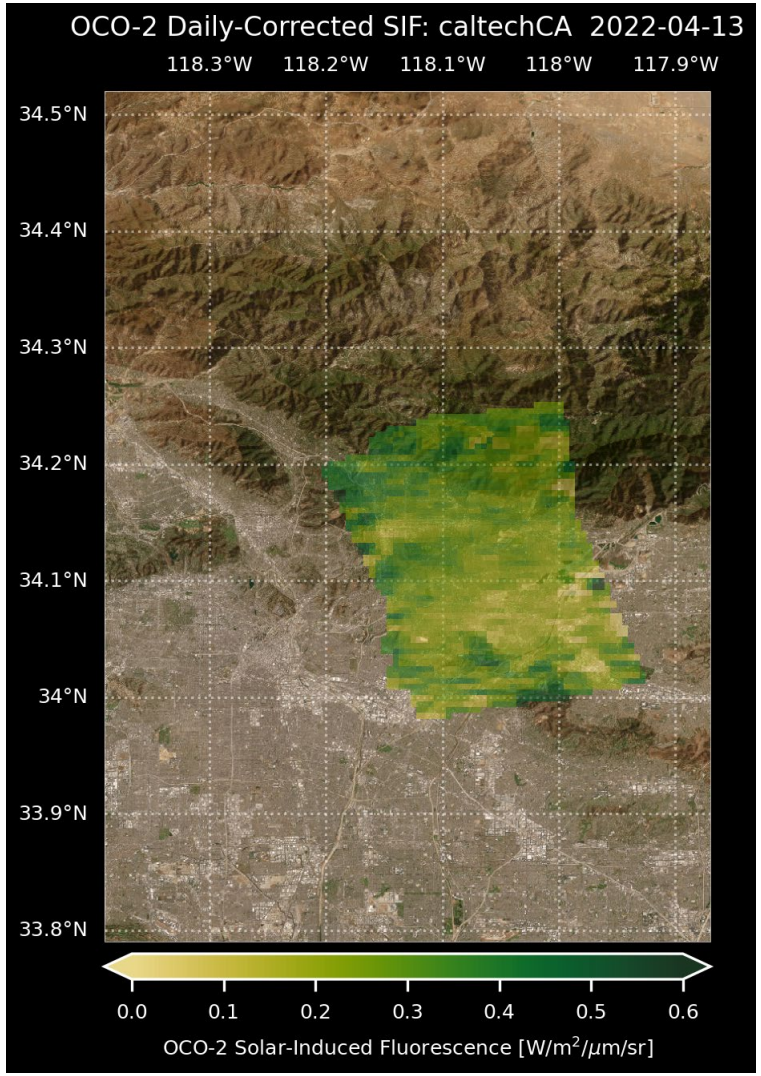
Diurnal Productivity Observed by OCO-3



Example of Re-Gridded TARGET SIF Observations

- California Institute of Technology (Caltech) site in Los Angeles
- SIF in Oct 19th, 2021 and April 13th, 2022
- Higher productivity during spring than during early fall

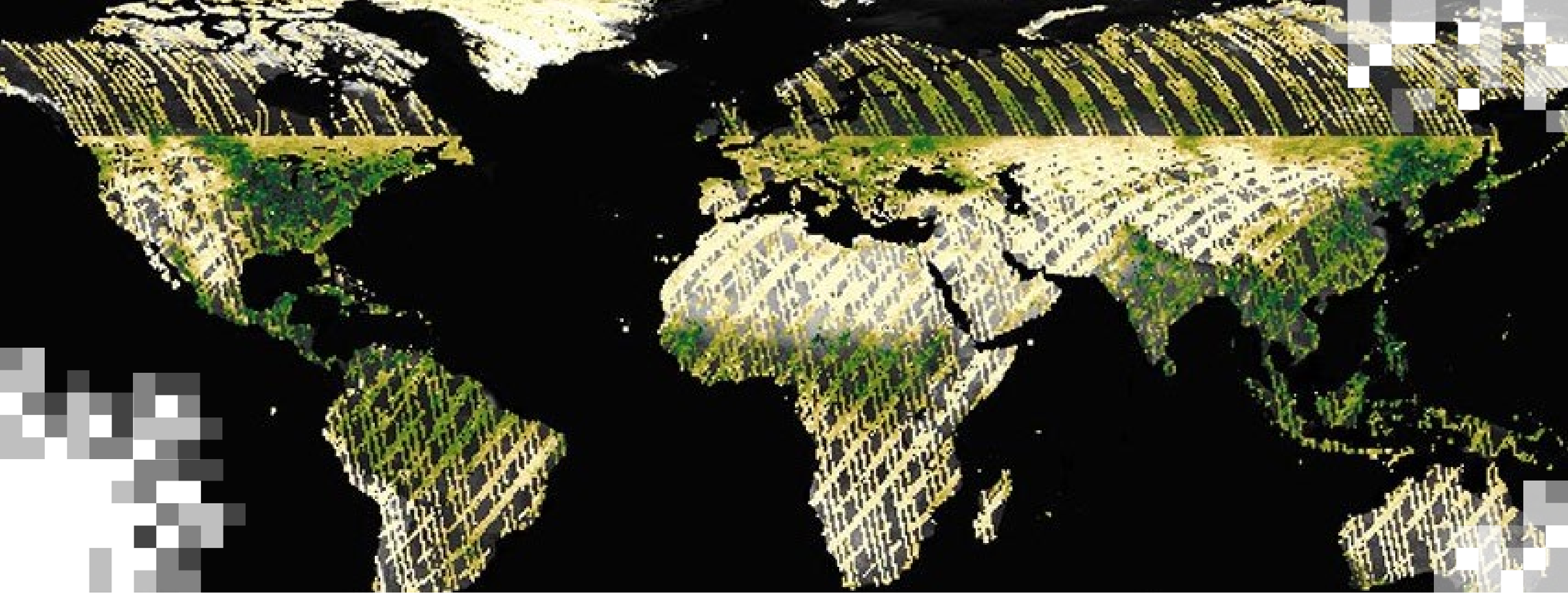




500m x 500m resolution

Credit: T. Kurosu

OCO-2 Target Site Distributions

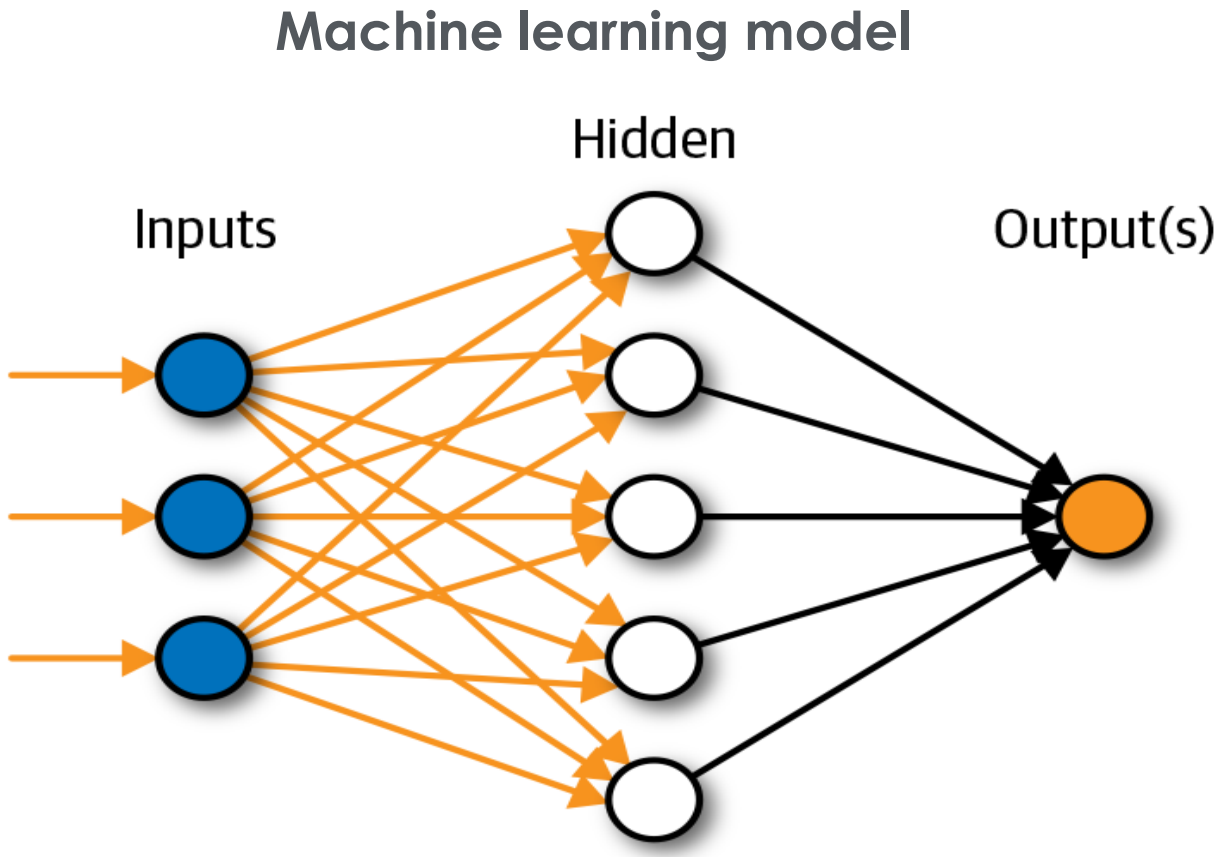


Level 3 SIF Products Derived from OCO-2 and OCO-3 Level 2 SIF

Process to Generate L3 SIF with Machine Learning

Satellite measurements of Vegetation indices (EVI, FPAR)

Meteorological variables (PAR, Tair, VPD, SM)



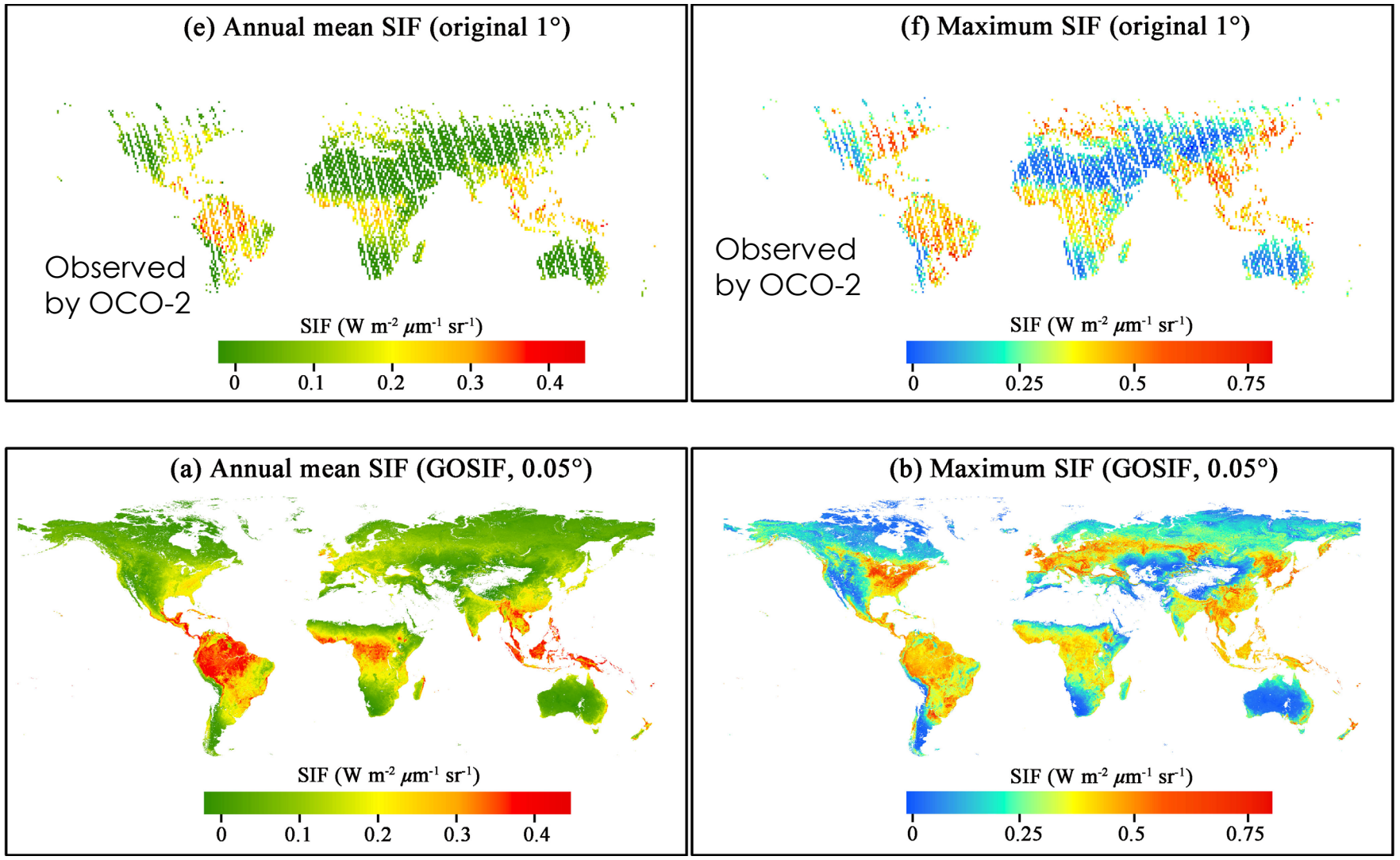
OCO-2 Based L3 SIF Products

Main products include:

- GOSIF: (Li and Xiao et al., Remote Sensing, 2019), 8-day, monthly, and annually at 0.05 x0.05 resolution and the corresponding GPP products (2000–onward)
- CSIF: (Zhang et al., Biogeosciences, 2018b), 4-day 0.05 x0.05 resolution (2000–onward)
- SIF(OCO2-005): (Yu et al., Geophysical Research Letters, 2018), bi-weekly, 0.05 x0.05 resolution (2014–onward)

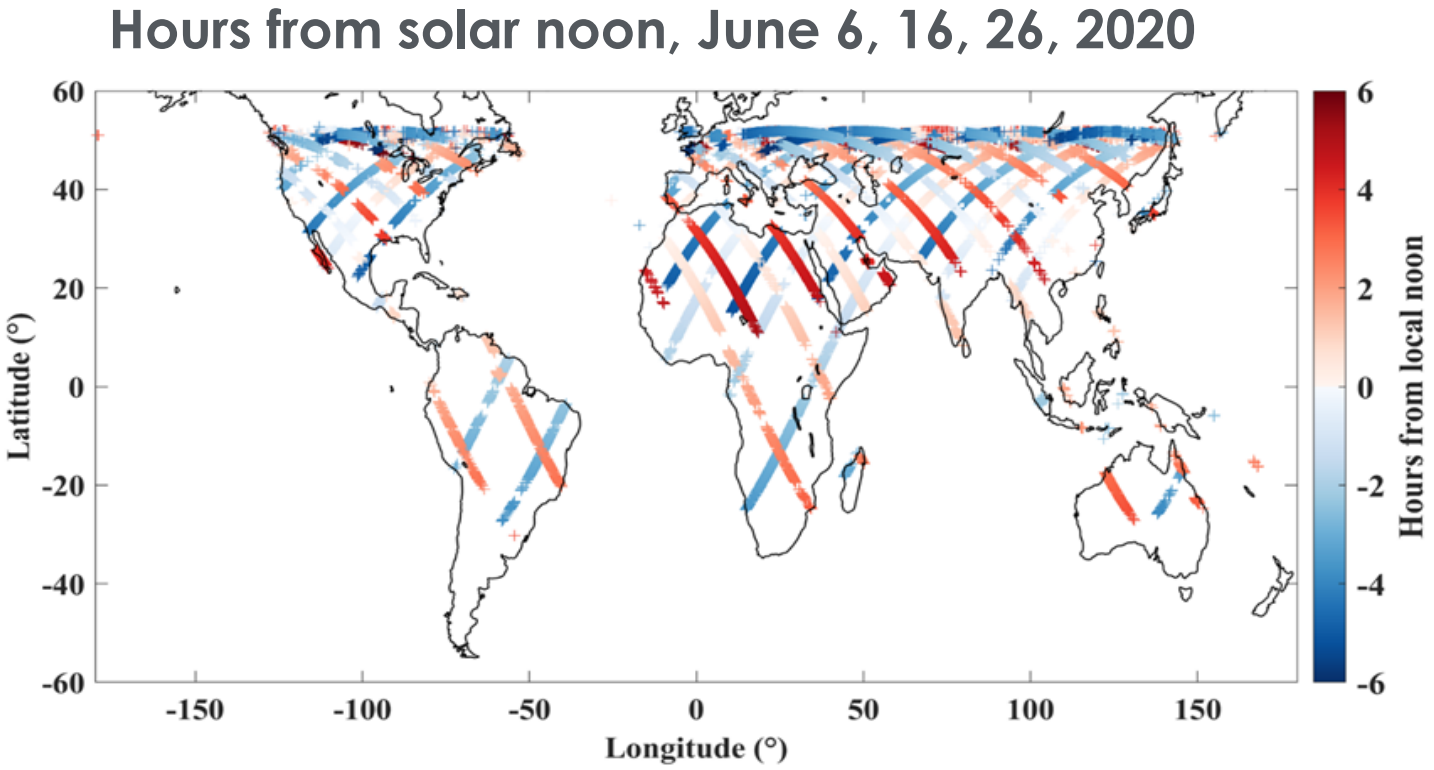
Example of OCO-2 L3 SIF Product

- L3 SIF product reproduce the original OCO-2 SIF spatial and temporal patterns
- Filling the spatial and temporal gaps by leveraging satellite derived indices and climate variables
- Maximum SIF observed in both original OCO-2 and L3 SIF data



Li and Xiao, et al., Remote Sensing, 2019

OCO-3 Based L3 Global Diurnal SIF Products

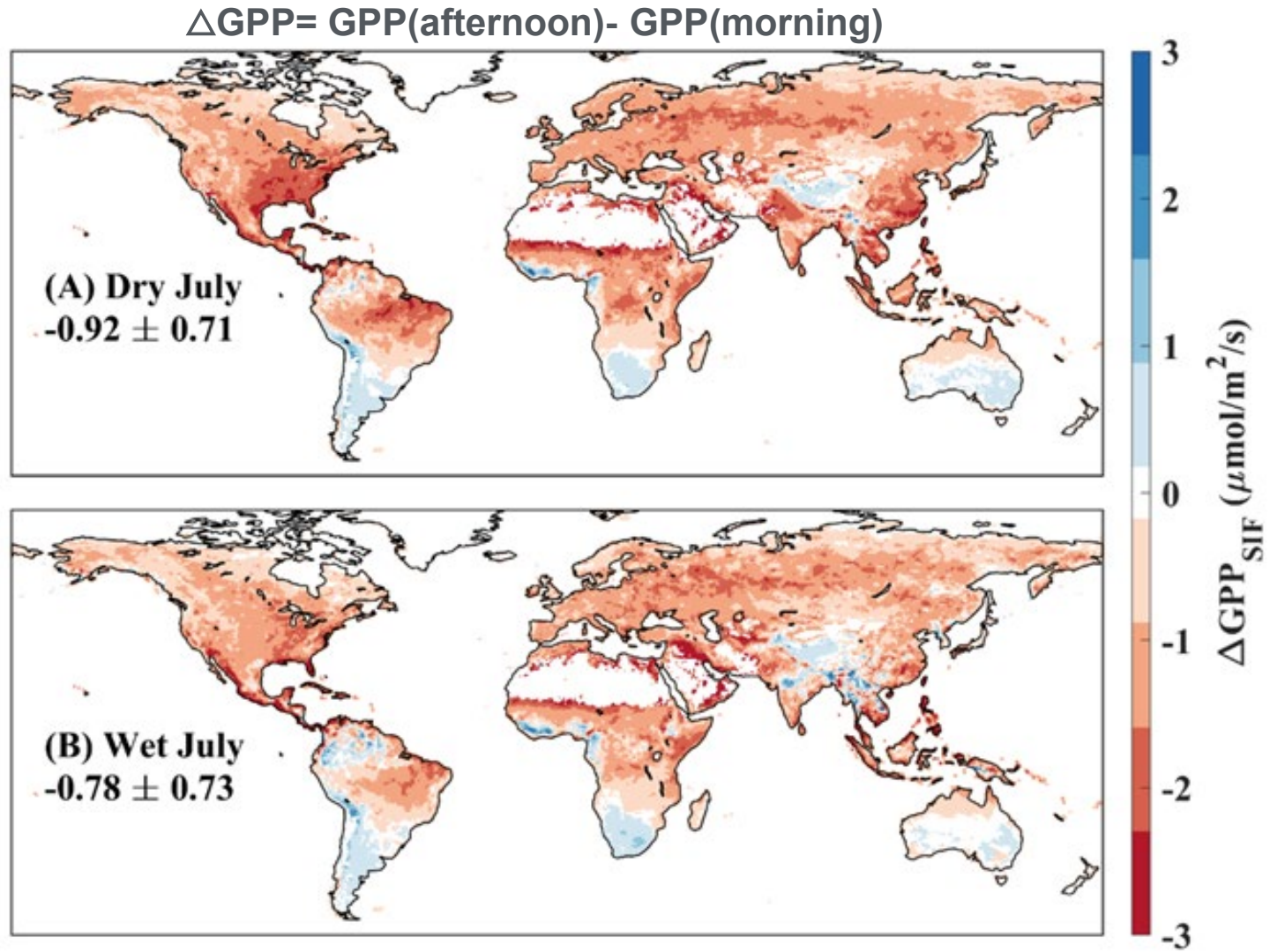


Credit: Z. Zhang

- Data available at: hourly SIF and GPP (6:00am to 18:00pm at 0.5 x 0.5 resolution) https://doi.org/10.5281/zenodo.15382965 Zhang et al., RSE, 2023

Example: Gross Primary Productivity (GPP) Diurnal Cycle Based on L3 OCO-3 Derived SIF Product

- In both wet and dry years, photosynthesis decreases in the afternoon.
- The decrease is more obvious in the afternoon in dry years compared to wet years.

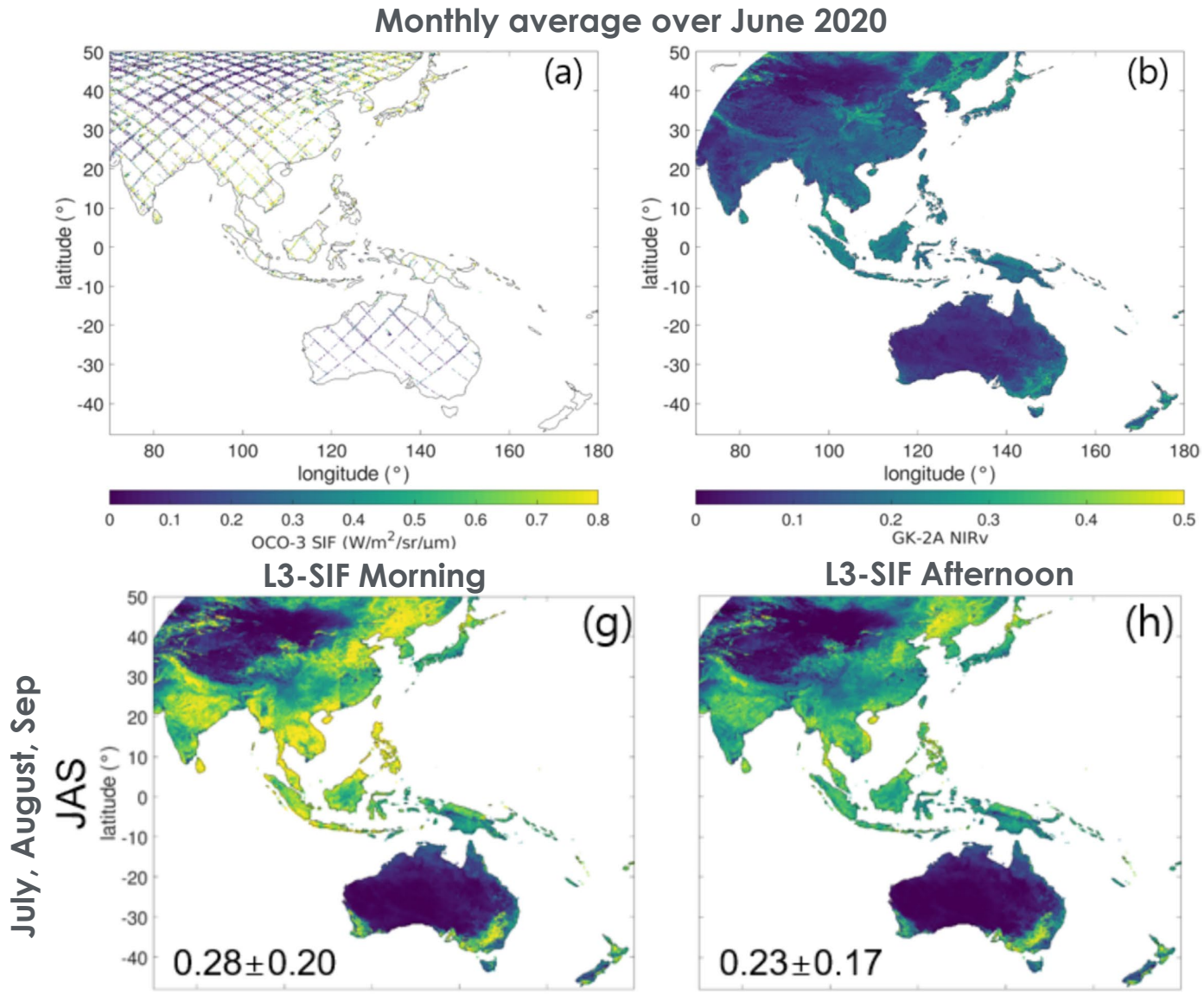


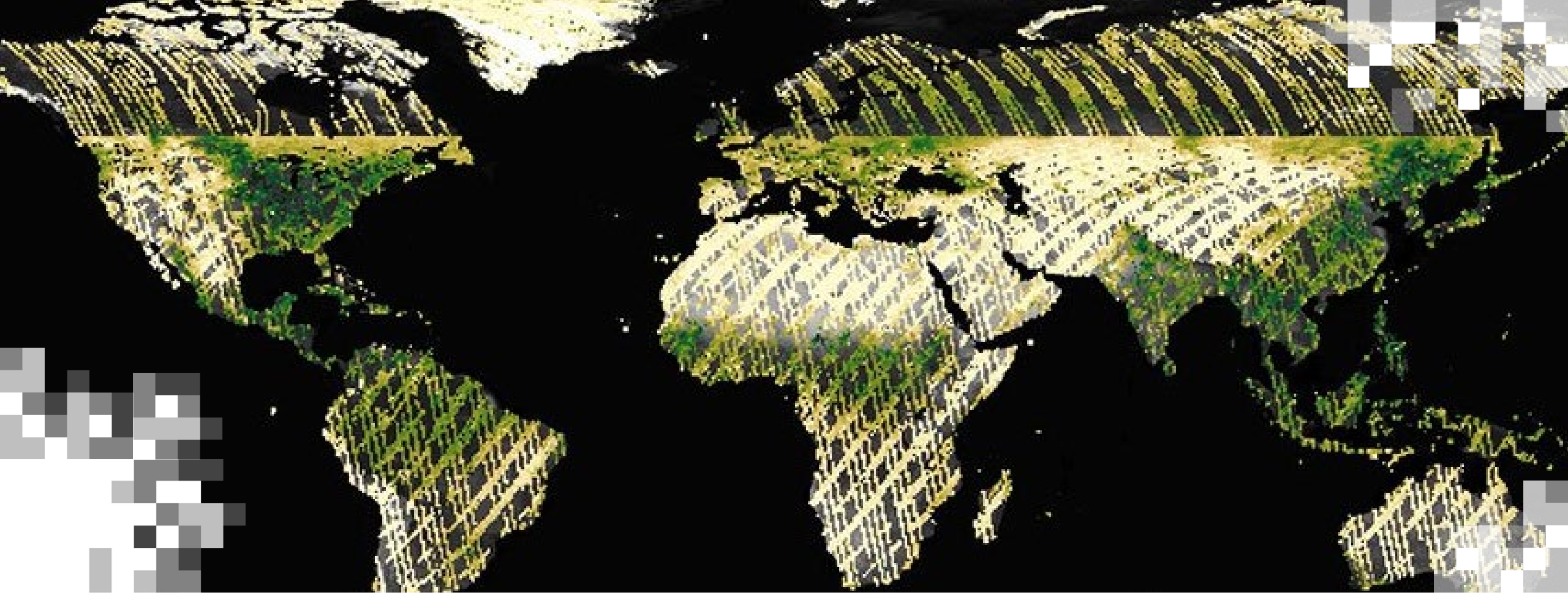
Zhang et al., RSE, 2023

GEOSIF: Combination of OCO-3 SIF and Geostationary Satellite GK-2A over Eastern Asia and Oceania

- GK-2A: Geostationary satellite over Eastern Asia and Oceania
- Reflectance, shortwave radiation and VPD derived from GK2A
- GEOSIF: hourly SIF at 2km resolution
- GEOSIF captures reduction of productivity in the afternoon especially during summer.

Jeong et al., RSE, 2024



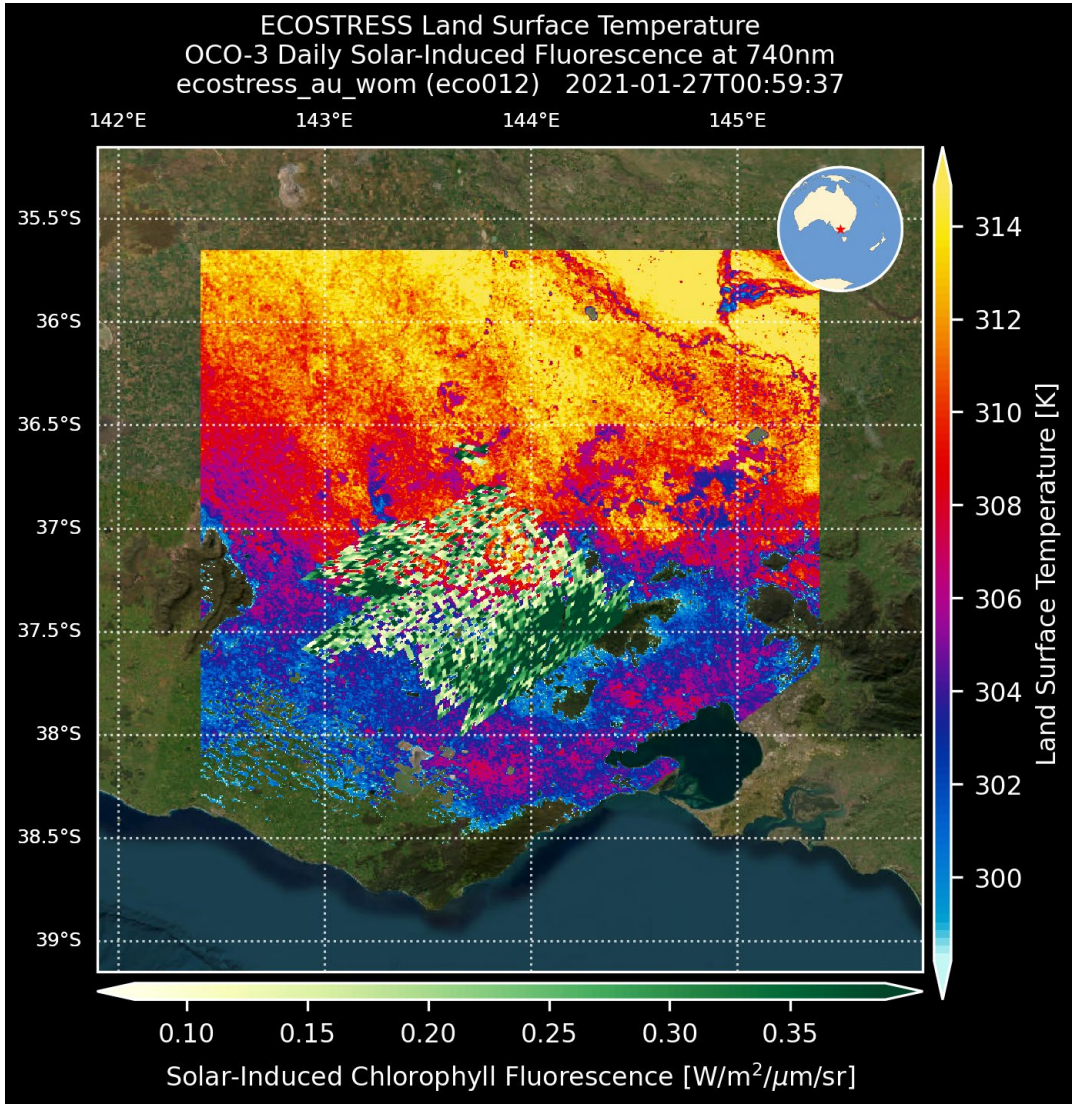


Synergistic Use of OCO-3 SIF and ECOSTRESS Data

Co-Located OCO-3 and ECOSTRESS Product to Understand Ecosystem Response to Water Availability

- ECOSTRESS instrument on the International Space Station (ISS)
- Spatial resolution：~70m × 70m
- Swath：384km
- Higher land surface temperature corresponds to lower evapotranspiration (ET) and lower productivity.
- Quantify water use efficiency (WUE):
  - the ratio between productivity (e.g., SIF) and evapotranspiration
  - how effectively ecosystems convert water to productivity.

- Link: Co-located ECOSTRESS and OCO-3 data product

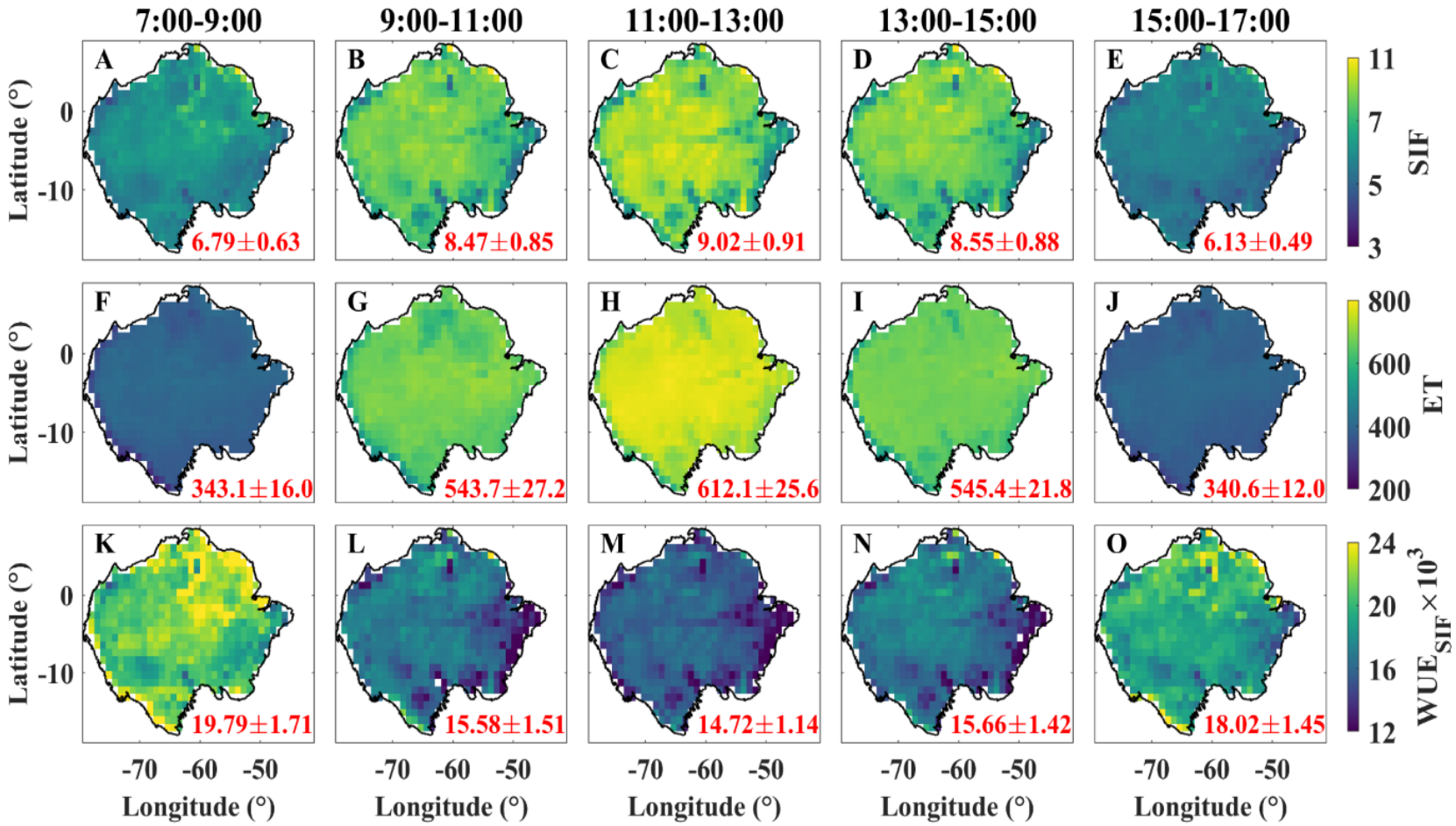


Z. Pierrat et al. (*in prep.*)

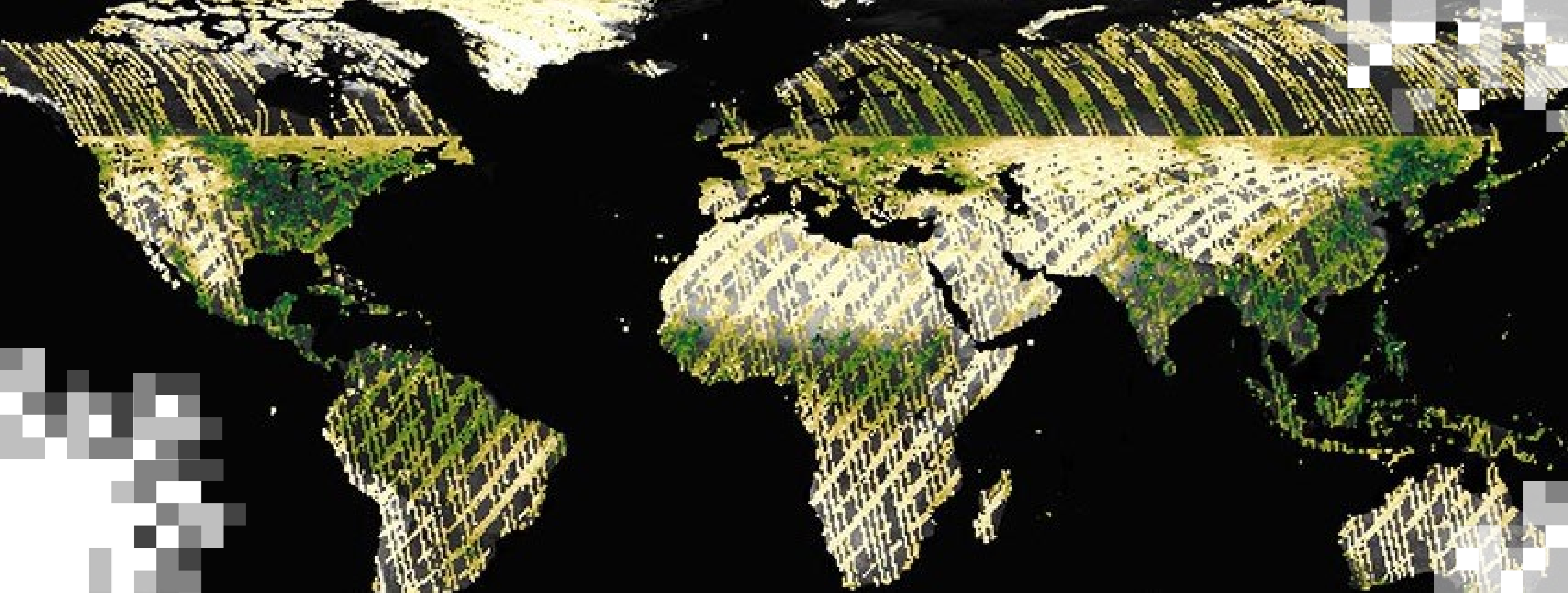
Example: Investigating the Diurnal Patterns of Vegetation Photosynthesis and Evapotranspiration

- L3 SIF and ET derived from OCO-3 SIF and ECOSTRESS
- Productivity and ET increase toward noon, but WUE decreases

Coupling between productivity and water stress in the Amazon



Zhang et al., Science Advances, 2023

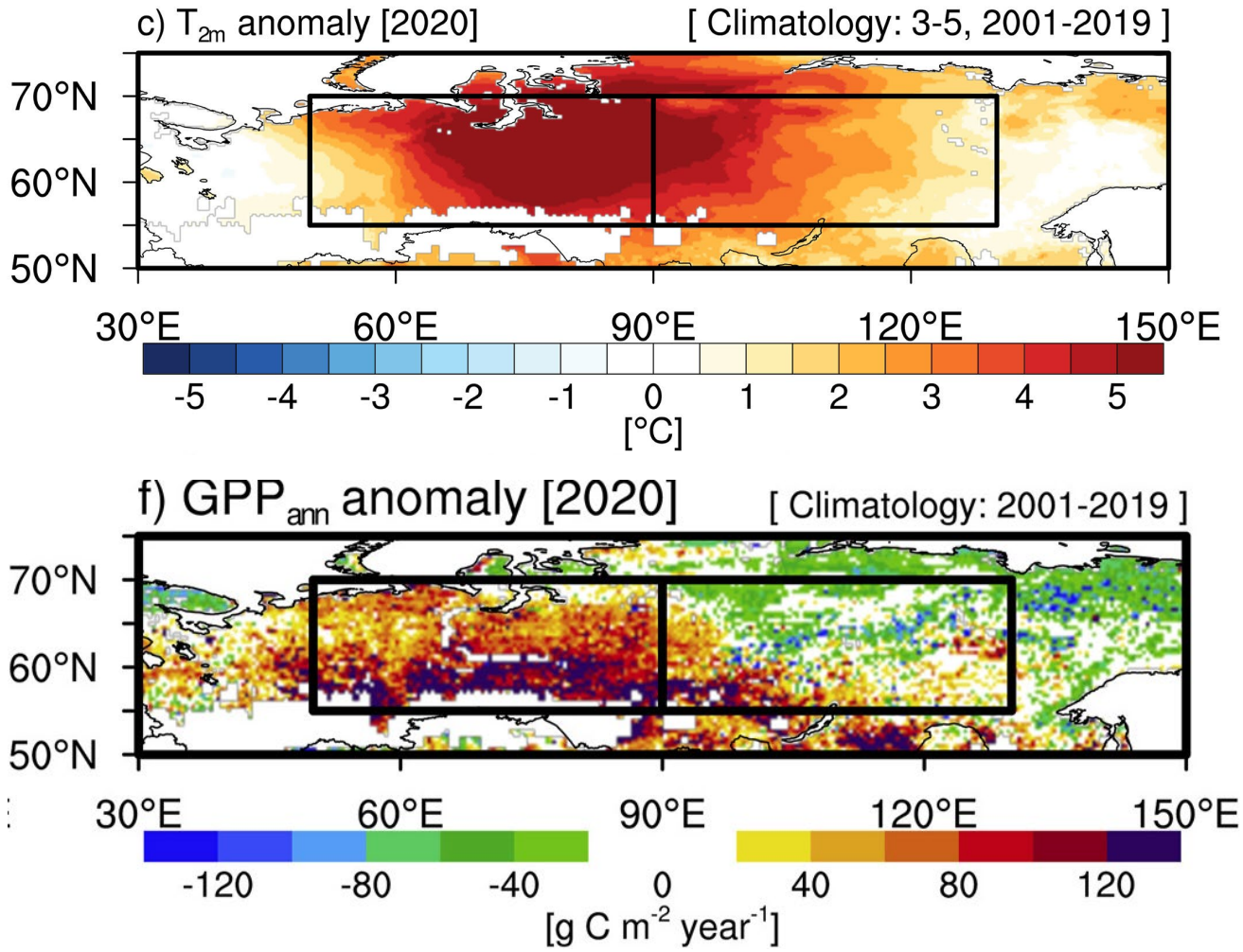


SIF Applications

Response to Climate Anomalies: 2020 Heatwave in Siberia

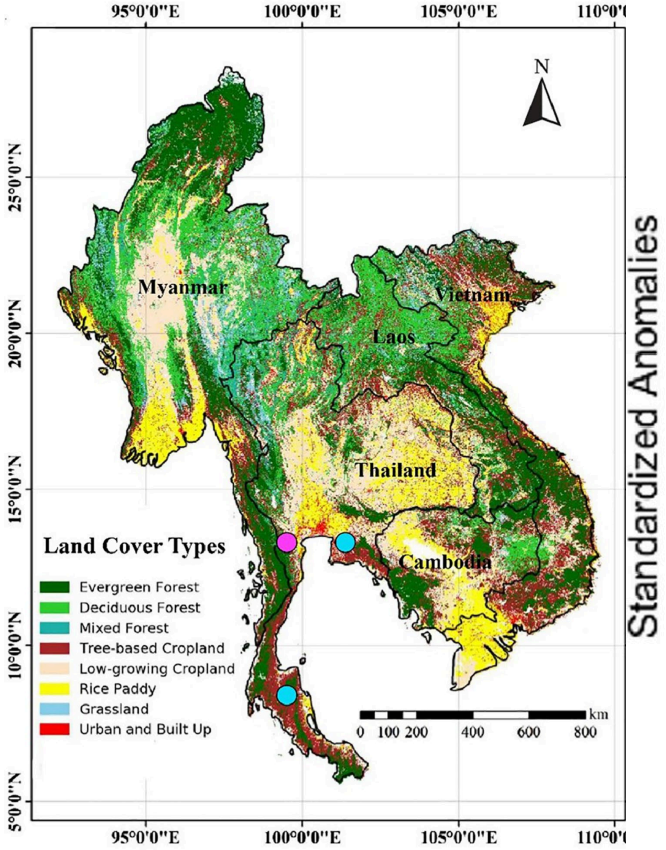
- Top panel: temperature anomalies in March-May in 2020;
- Bottom panel: GPP anomalies during the same period.
- Warmer temperature in spring and early summer over high latitudes promotes plants growth.

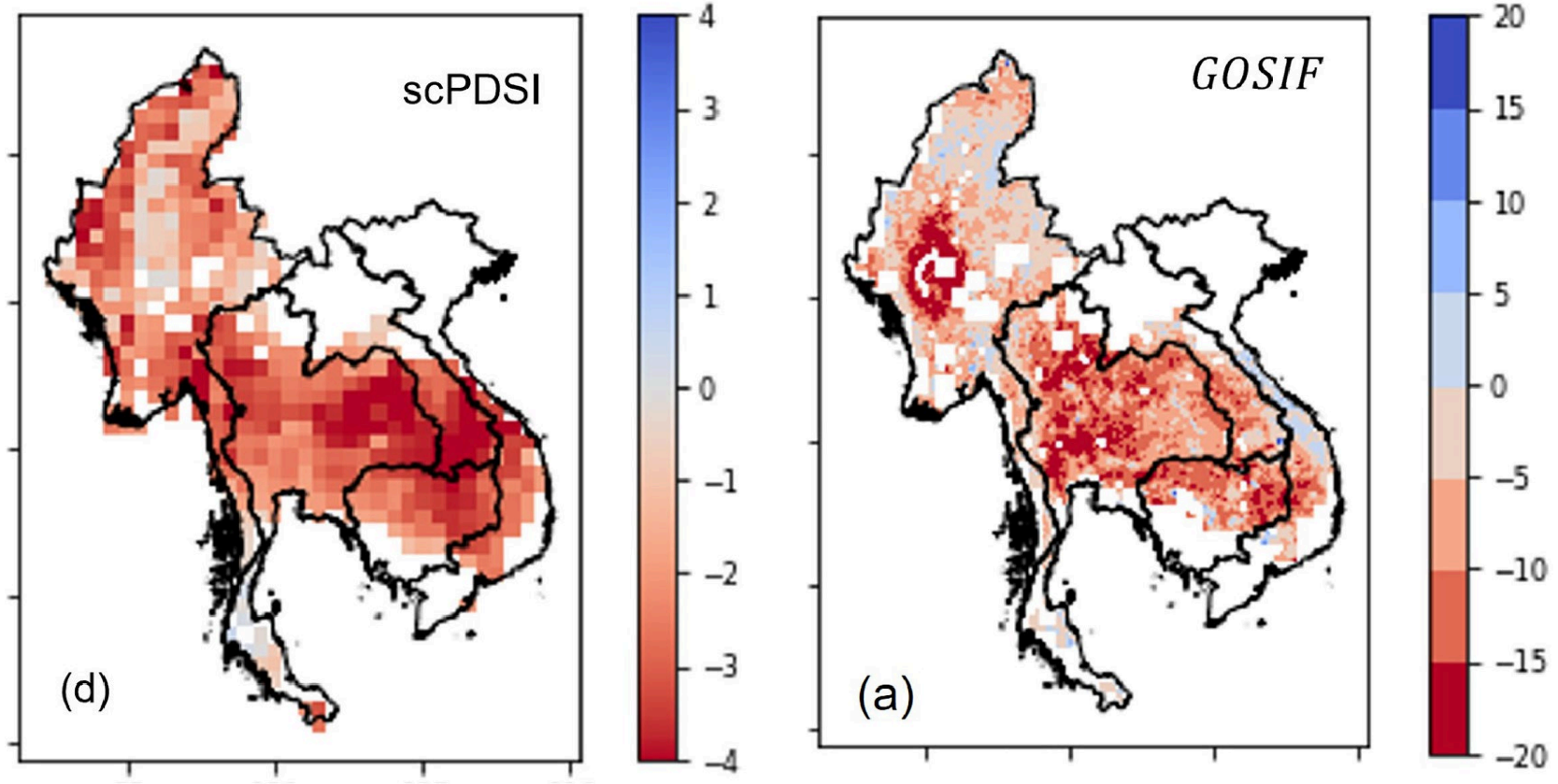
Temperature anomalies in March, April, and May



Park et al., 2025: https://doi.org/10.1029/2024JG008487

Response to Climate Anomalies: Drought Impact



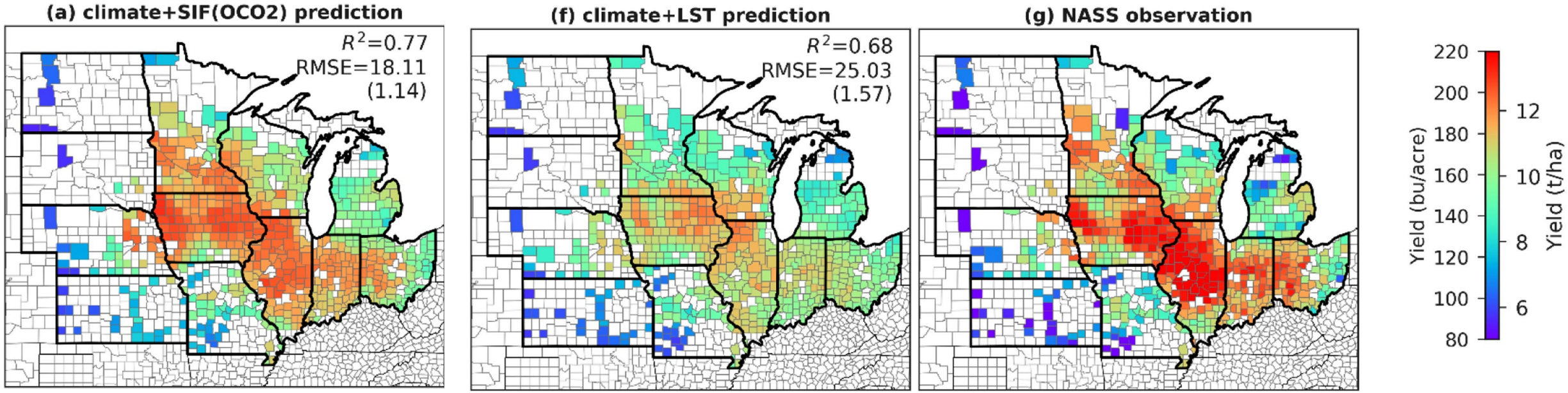


Drought index (Sep 2014-Aug 2016)

Spatial patterns of SIF change (%) drought (Sep 2014–Aug 2016) compared to non-drought condition (Sep 2016–Aug 2018)

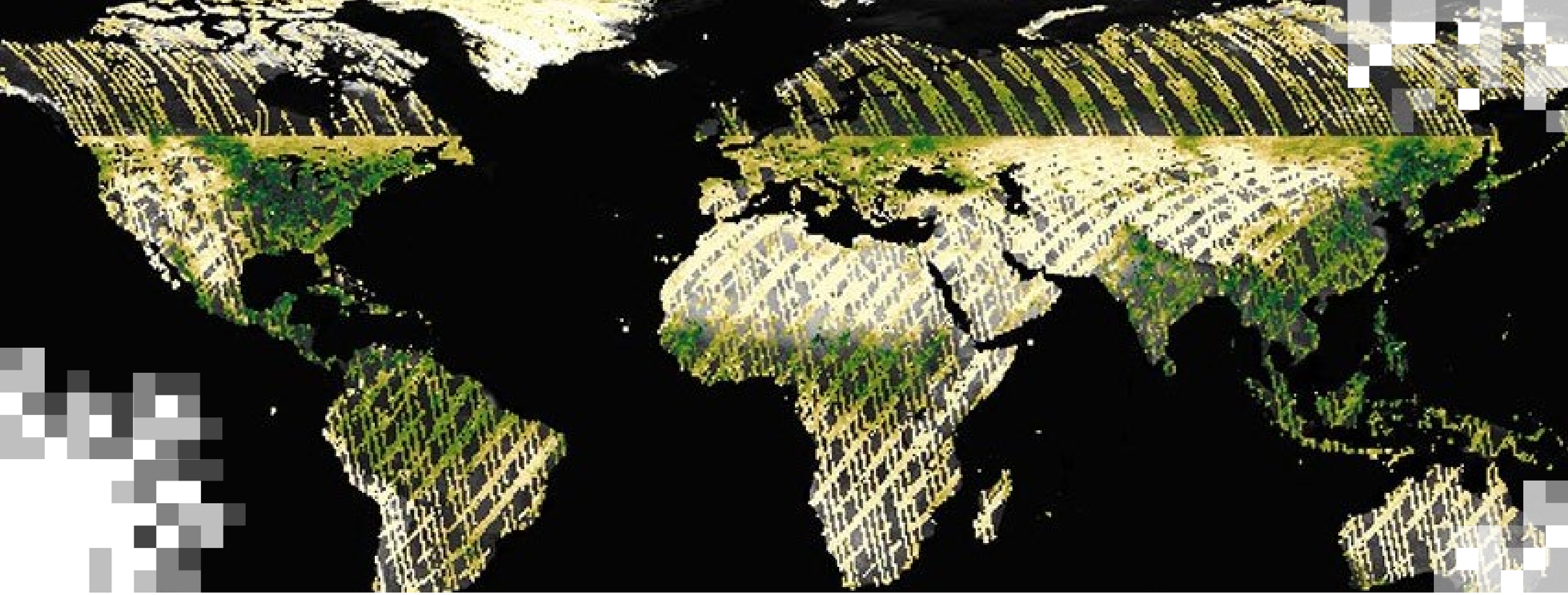
Wang et al., 2023: https://doi.org/10.1016/j.agrformet.2023.109591

Applications: Crop Yield Predictions



- NASS: (USDA) National Agricultural Statistics Service (NASS)
- Maize prediction
- Crop yield predictions based on climate + OCO-2 SIF better capture spatial distributions of NASS observations than predictions based on climate + LST.

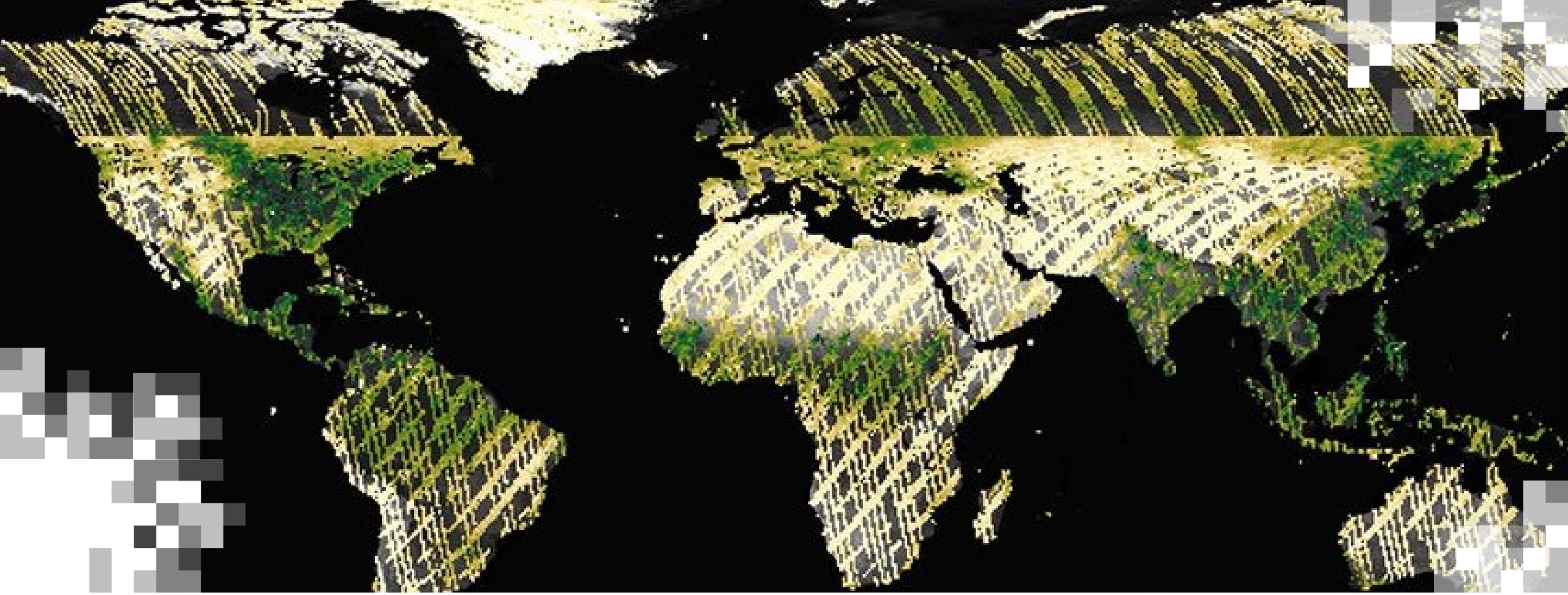
Peng et al., 2020, https://doi.org/10.1016/j.jag.2020.102126



OCO-3 Snapshot Area Map (SAM) Mode Demonstration

Demo Outline

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



Session 2
Summary

Summary

- OCO-2 has global coverage, and OCO-3 has observations at different times of day.

The L2 and L3 SIF data can be used for:

- Understanding the impact of climate perturbations on vegetation health
- Drought monitoring
- Crop yield prediction

Resources

- Website: OCO3-SAM
- Co-located ECOSTRESS and OCO-3 data product
- Main L3-SIF products include:
  - Hourly SIF and GPP (6:00am to 18:00pm at 0.5 x 0.5 resolution) based on OCO-3 https://doi.org/10.5281/zenodo.15382965.
  - GOSIF: (Li and Xiao et al., Remote Sensing, 2019), 8-day, monthly, and annually at 0.05 x0.05 resolution and the corresponding GPP products (2000–onward)
  - CSIF: (Zhang et al., Biogeosciences, 2018b), 4-day 0.05 x0.05 resolution (2000–onward)
  - SIF(OCO2-005): (Yu et al., Geophysical Research Letters, 2018), bi-weekly, 0.05 x0.05 resolution (2014–onward)

Contact Information

Trainers:

- Junjie Liu
  junjie.liu@jpl.nasa.gov
- Jackie Ryan
  jacqueline.ryan@jpl.nasa.gov
- Karen Yuen
  karen.yuen@jpl.nasa.gov

- ARSET Website
- ARSET YouTube

Looking Ahead to Session 3

- Run the lesson 3 Jupyter notebook to compare how gap-filled SIF products such as GOSIF can be used for assessing the impact of floods and droughts on cropland through specific case studies in the US Midwest.

- Using the notebook tutorials, choose another region or time frame of your choice and reproduce new products for another analysis.

- Compare SIF products aggregated in space and time using open source tools and how they can be used to study vegetation change across different regions in a variety of science and applied use cases.


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!