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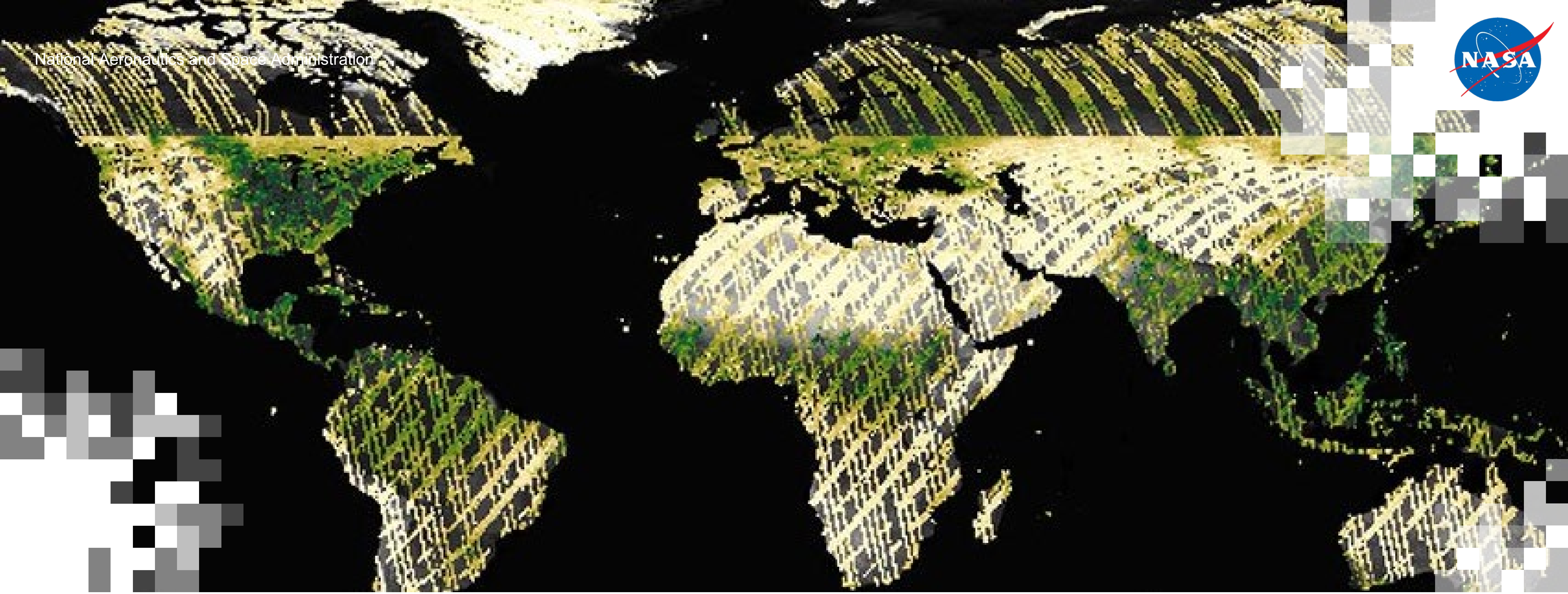

Solar Induced Fluorescence (SIF) Observations for Assessing Vegetation Changes Related to Floods, Drought, and Fire Impacts

Session 3: Working with Gap-Filled SIF Products

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 29, 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 22, 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 3 – Trainers

Dr. Erika Podest

Scientist

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Data Visualization Developer

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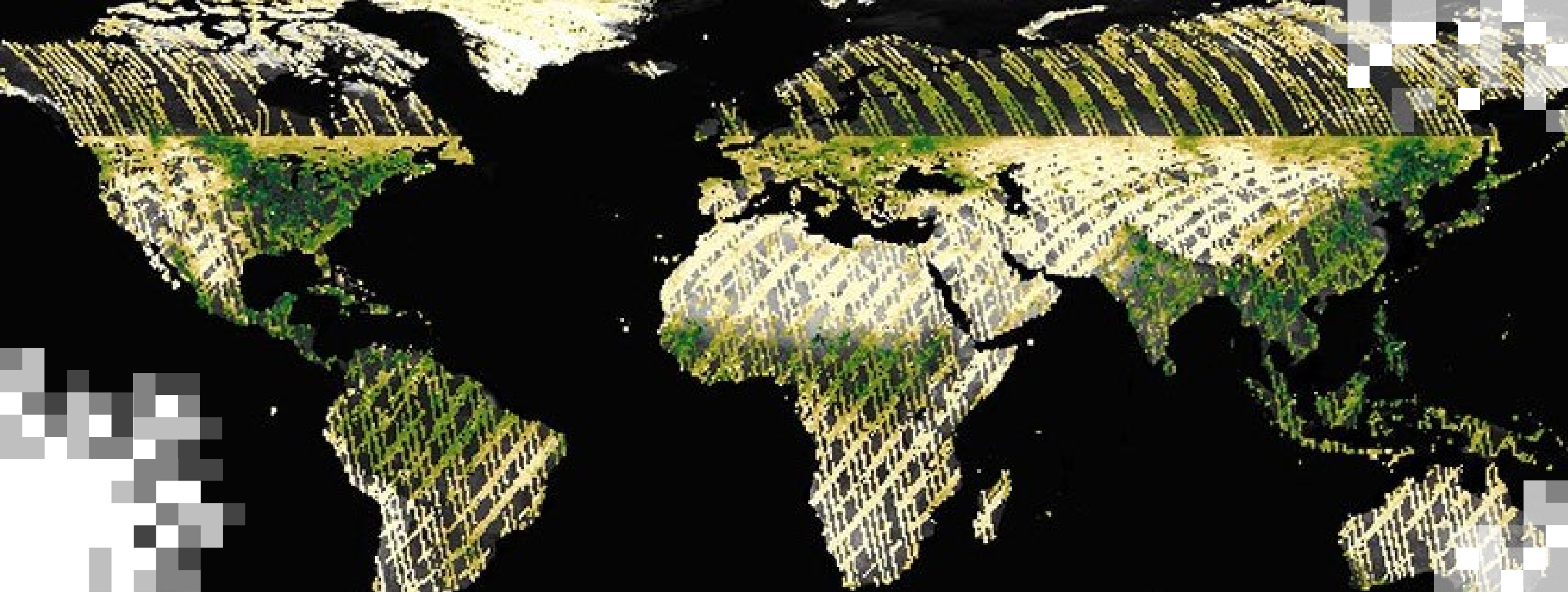
How to Ask Questions

- 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.



Session 3: Working with Gap-Filled SIF Products

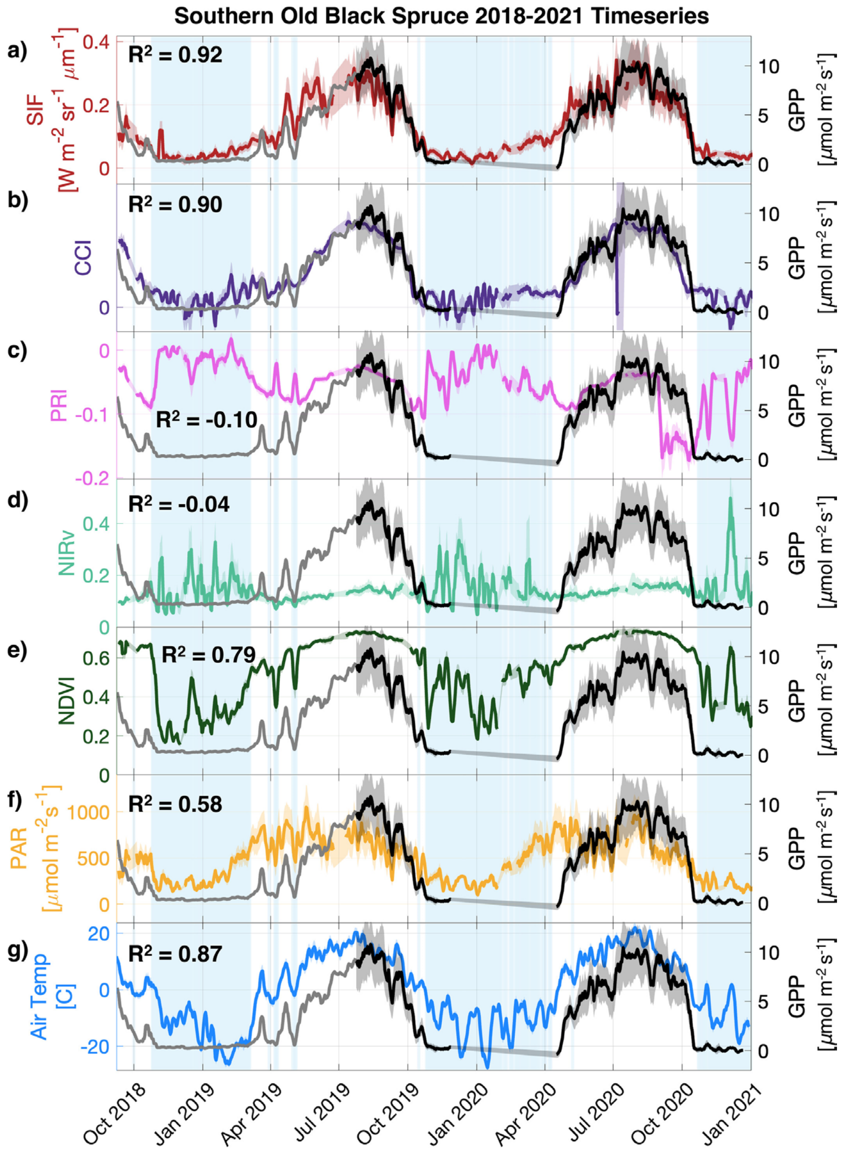
Session 3: Objectives

1. Identify additional SIF products from spacecraft other than OCO-2 and 3
2. Identify advantages of using gap-filled SIF products for vegetation analysis
3. Compare several approaches to data fusion with SIF and other spacecraft data
4. Retrieve and visualize a specific gap-filled SIF product, GOSIF
5. Analyze two case studies within the US corn belt using GOSIF data:
    a. 2019 Midwestern US flooding, discussed in [Yin et al., 2020]
    b. 2012 drought and heat wave

Landsat OLI images over Platte, Missouri from March 2018 (*Left*) and March 2019 (*Right*)
Credit: NASA Goddard Spaceflight Center

Review: Why use SIF as Opposed to Other Measurements?

- Common measurements used for vegetation assessment:
  - Enhanced Vegetation Index (EVI)
  - Normalized difference vegetation index (NDVI)
  - Near Infrared Reflectance of Vegetation (NIRv)
- GPP
  - Measures carbon fixation for vegetation health
  - Hard to measure directly
- NDVI
  - Primarily a measure of "brownness" or "curing index"
  - Easy to measure even with COTS
  - Lagging indicator
- Chlorophyll Carotenoid Index (CCI)
  - Closely tracks GPP but is primarily applicable to evergreen ecosystems

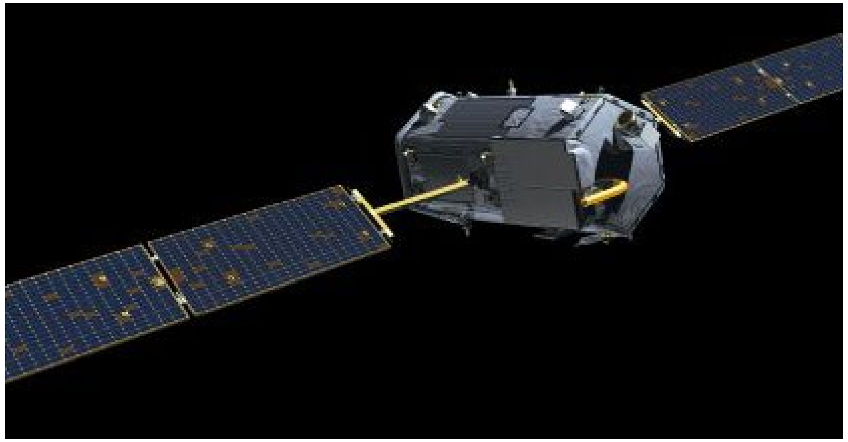


Right: Comparison of various vegetation indices with GPP data for a boreal forest tower site in Canada. *Credit: Z. Pierrat, et al. 2022*

Background: SIF Observational Record

- These are all the spacecraft offering direct SIF observations through multispectral imaging:
  - EU EUMETSAT's GOME-2 instruments onboard MetOp-A/B (SIF: 2007-2018)
  - JP JAXA's **GOSAT** or Ibuki (2010 – Present) and **GOSAT-2** (2018 – Present)
  - US NASA's **OCO-2** (2014 – Present) and **OCO-3** onboard ISS (2019 – Present)
  - EU ESA's **TROPOMI** instrument onboard Sentinel-5P (2018 – Present)
  - CN CAST's TECIS or **Goumang** (2022 – Present)

GOSAT-2 Satellite
(Credit: Mitsubishi Electric)

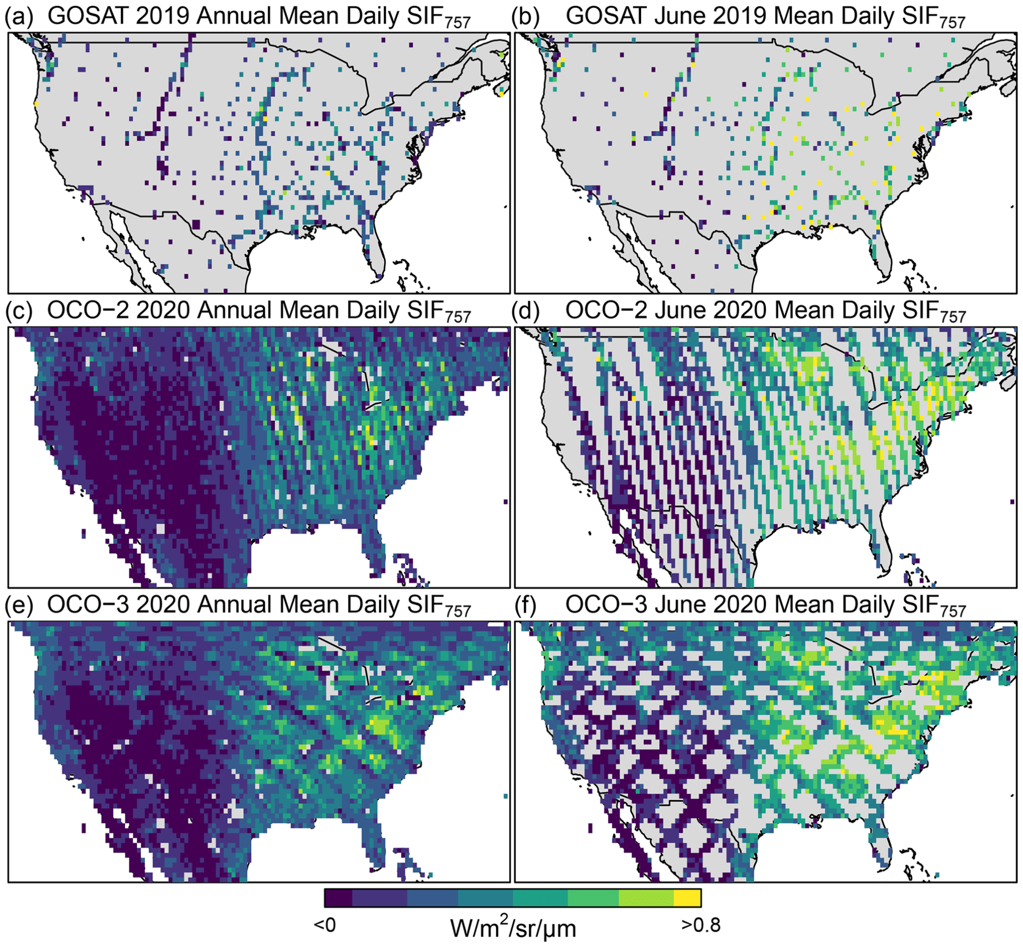


OCO-2 Satellite
(Credit: NASA/JPL)

Sentinel-5P Satellite
(Credit: ESA)

GOSAT

- Source of the first global SIF remote sensing observations from space when launched in 2009
- GOME-2 SIF is slightly older but was derived later
- Sun-synchronous orbit, 3-day revisit times
- ~10 km diameter circular footprint for observations (82 km^2), about 0.1 degrees
- SIF is derived from O_2-A band spectrometer data at 755nm and 770nm
- Further reading:
  - J. Joiner, et al. 2011 https://doi.org/10.5194/bg-8-637-2011
  - C. Frankenberg, et al. 2011 https://doi.org/10.1029/2011GL048738
- Dataset link:
  - https://climatesciences.jpl.nasa.gov/sif/download-data/level-2/

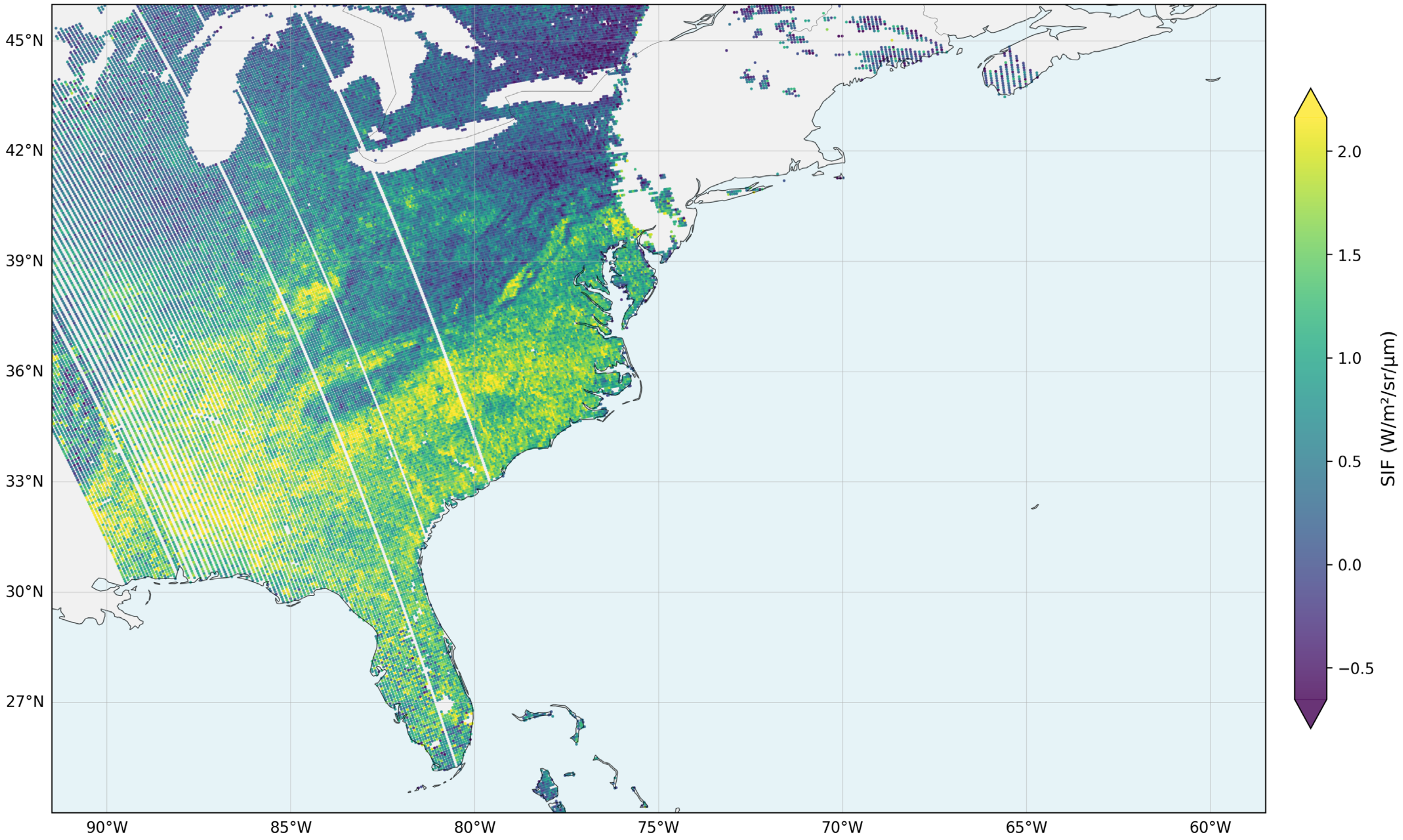


0.5-degree gridded SIF over the CONUS over annual (a, c, e) and monthly (b, d, f) periods
Credit: R. Doughty, et al. 2022

TROPOSIF

- Current best dataset for using TROPOMI SIF measurements
- Derived from 743 nm – 758 nm radiances

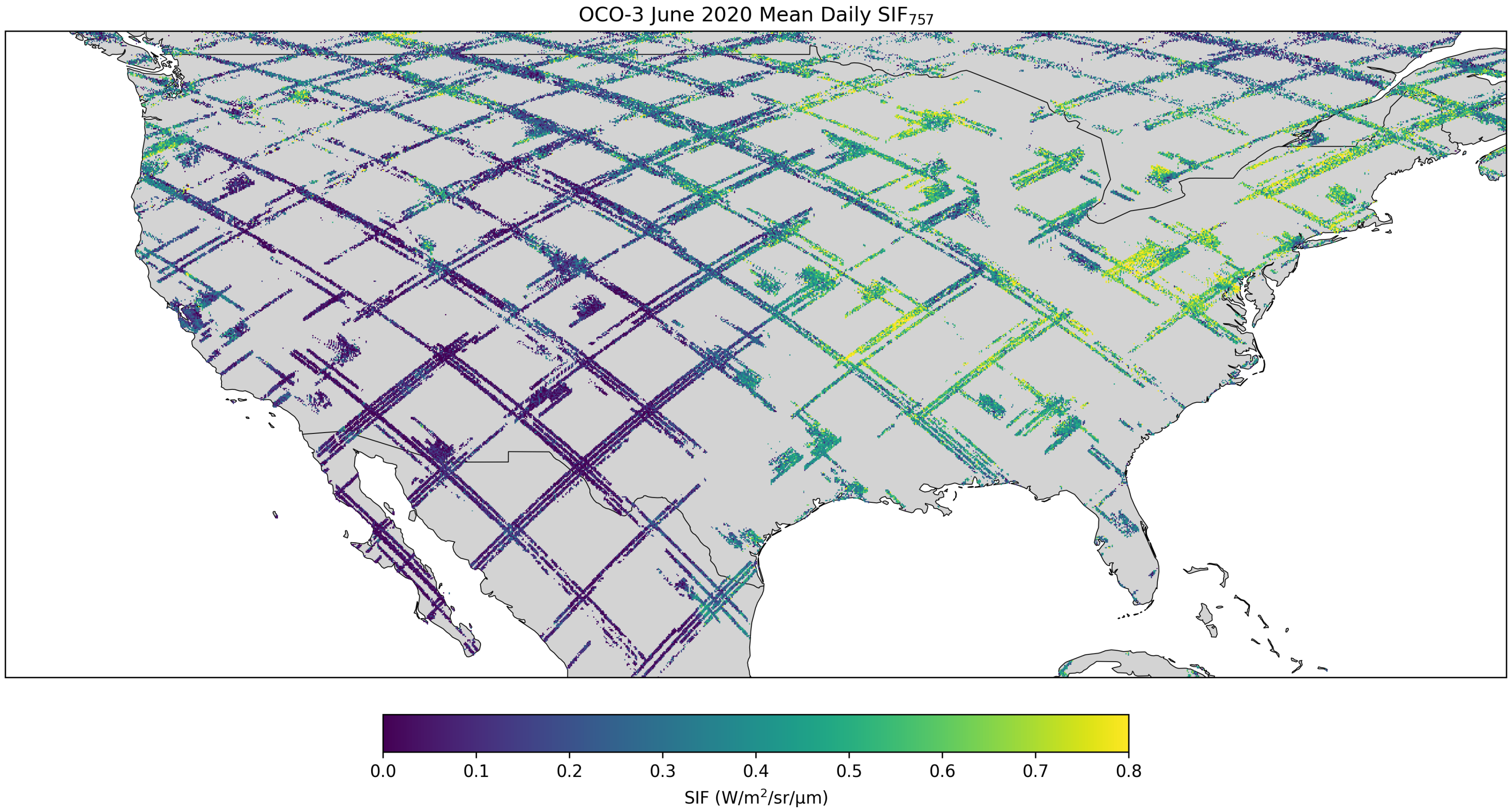
- Further reading:
  - L. Guanter, et al. 2021 https://doi.org/10.5194/essd-13-5423-2021
- Dataset link:
  - https://doi.org/10.5270/esa-s5p_innovation-sif-20180501_20210320-v2.1-202104



Subdaily TROPOSIF product over the eastern US for April 30, 2018
Credit: Copernicus/ESA

What are the Limitations of OCO-2 and OCO-3 Data?

- Limited spatial coverage, even when averaging over longer time periods
- Biases in revisit times due to ISS orbit (OCO-3)
- Limited range of latitudes (OCO-3)
- Relatively short observational record (at most ~11 years)



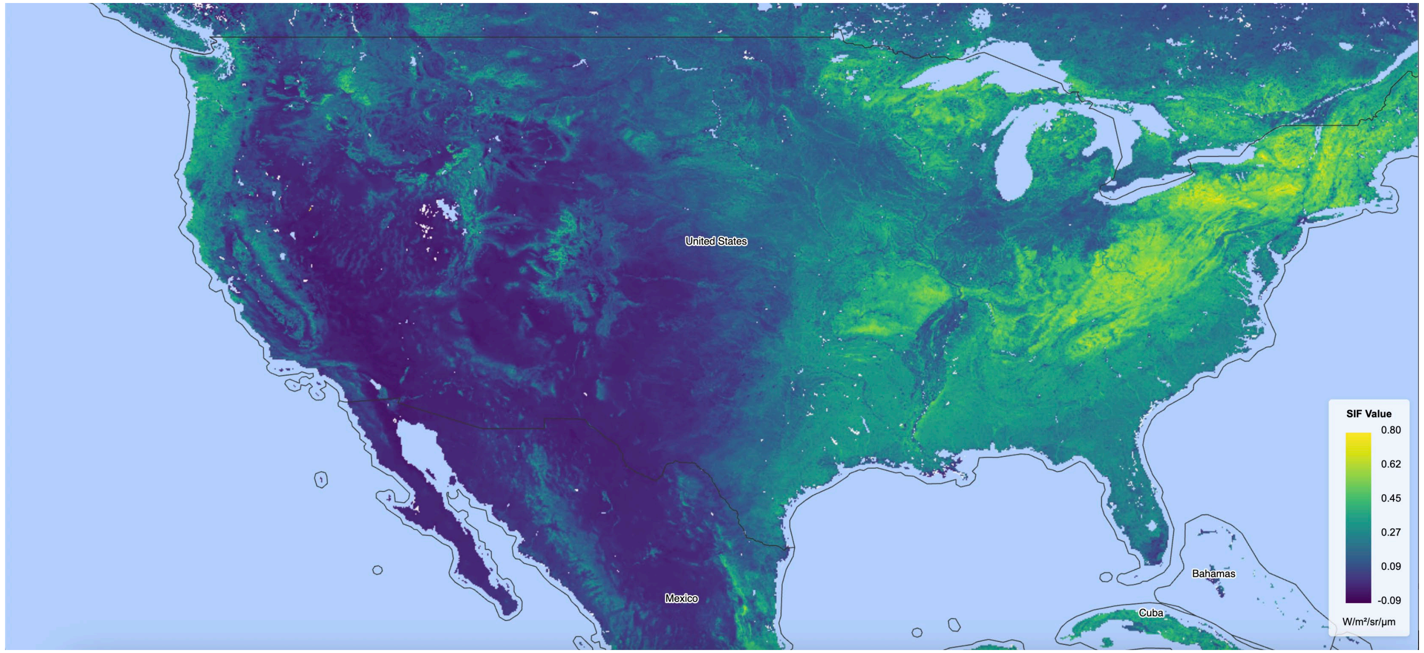
One month (June 2020) of OCO-3 SIF soundings gridded and temporally averaged over North America, centered on CONUS.
Credit: NASA/JPL

What is Gap-Filling?

- Train a model using a data-driven or machine-learning approach to predict the value of a measurement
  - **Labels:** SIF Values
  - **Predictors:** Can include Land Cover (LC), surface reflectance, vapor pressure deficit (VPD), air temperature, downwelling shortwave radiation (DSR), and/or photosynthetically active radiation
  - Spatial and temporal resolution of predictor data sets the limit on resolution of output dataset
- Example: MODIS data is up to 500m/pixel, surface reflectance able to be calculated at 8-day time interval at best due to requirements for creating a bidirectional reflectance distribution function (BRDF) product
- By training the model to map how the predictor variables correlate with observed SIF, we can estimate what SIF might be when observations are not available
- Many different techniques available, the product we will be using is based on a Cubist regression tree model

GOSIF Dataset

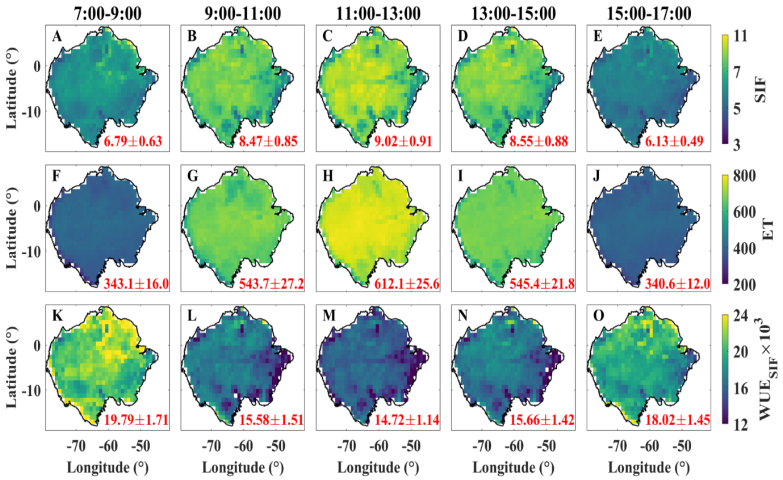
- Developed by Xing Li and Jingfeng Xiao in 2019
- Fuses OCO-2 data with MODIS surface reflectance to estimate SIF at 0.05-degree resolution and 8-day temporal cadence
- Also available in monthly and annual average versions
- By using MODIS as the predictor dataset, enables coverage back to 2000
- Further reading:
  - https://doi.org/10.3390/rs11050517
- Dataset link:
  - https://data.globalecology.unh.edu/data/GOSIF_v2/



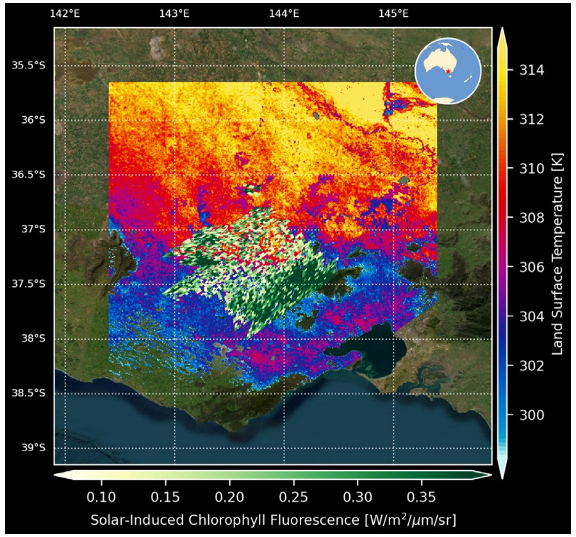
June 2020 monthly averaged SIF estimated by the GOSIF model over the CONUS.
Credit: Li & Xiao 2019, Plot: NASA/JPL, SIF-ARSET

Other Gap-Filled Products and Current Research

- Zhang, et al. have developed a diurnal 0.5-degree SIF product that demonstrates the afternoon depression in photosynthesis on hot days
- ECO-OCO3 fuses land surface temperature (LST) measurements from ECOSTRESS with OCO-3 SAMs to provide additional context on vegetation health. For example, can be used for estimating water use efficiency (WUE)
- Jeong, et al. have developed the GEOSIF product by fusing Korean GK-2A geostationary weather satellite data with OCO-3 to create a diurnal SIF product
- Downscaling and sub-daily gap-filling techniques can improve resolution of data, better accounting for clouds



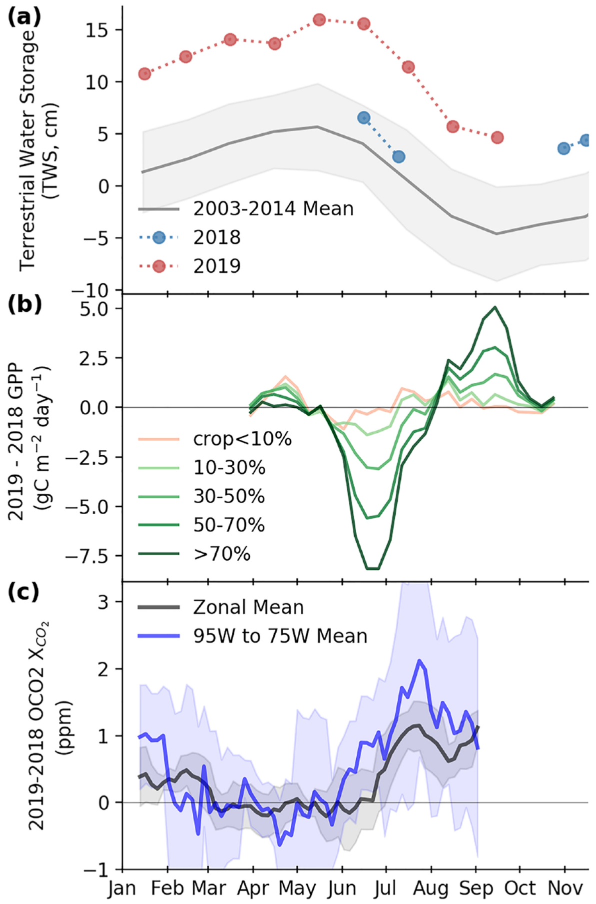
Left: Afternoon depression of SIF enables better water use efficiency in the Amazon rainforest
Credit: Zhang et al., Science Advances, 2023



Right: OCO-3 SAM SIF is overlayed on land surface temperature to enable WUE estimation in Melbourne, Aus.
Credit: Z. Pierrat et al. (in prep.)

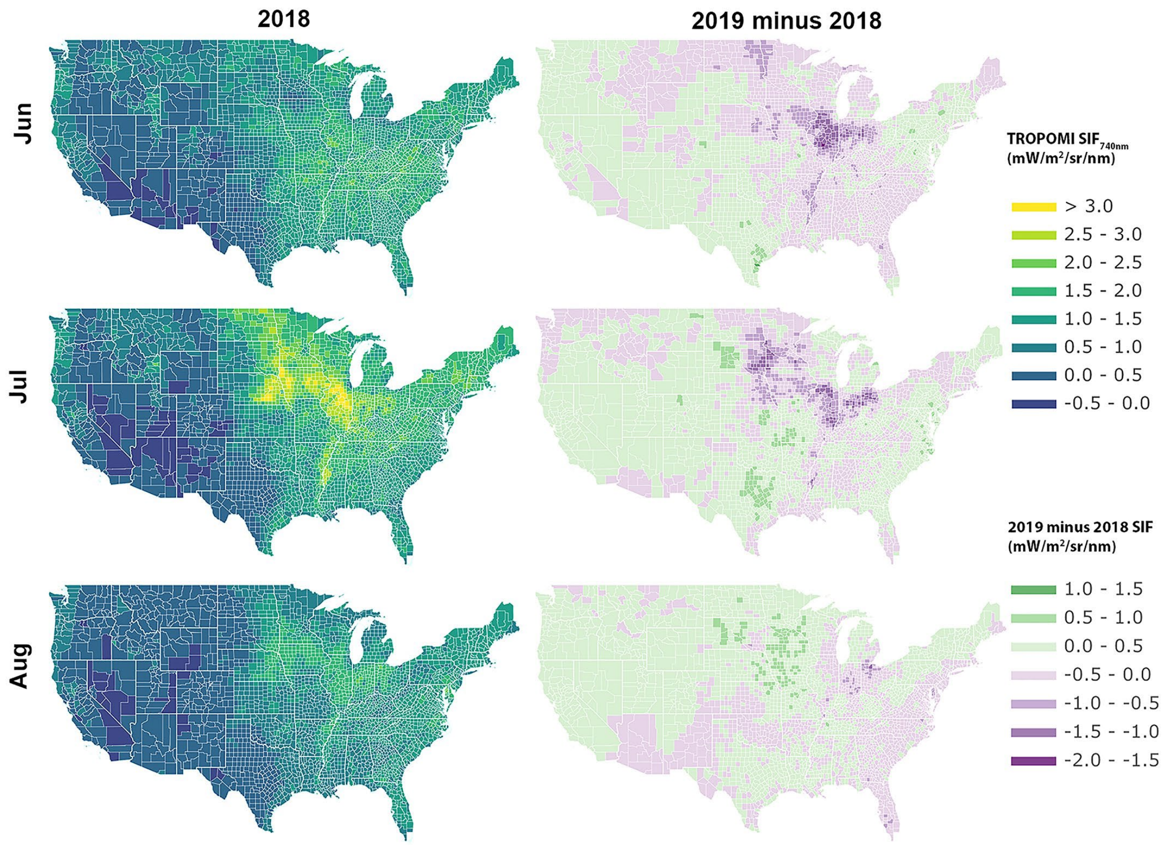
Case Study Overview: 2019 Midwestern US Floods

- 1 million acres of farmland across 9 states flooded due to significantly above average precipitation from January to May 2019
- Terrestrial Water Storage (TWS) observed by GRACE-FO mission was over 2x standard deviation over decadal average in summer 2019, indicates significantly above average water in soil during growing season
- Overall impact on crop yields was about 15% reduction as compared with 2018
- Flooding impact was partially compensated by 3 weeks delayed planting and delayed peak in growing season
- Y. Yin, et al. 2020 studied OCO-2 & TROPOMI SIF alongside XCO_2 from Act-America airborne campaign and GRACE-FO TWS data
- In this exercise, we will use GOSIF to study this event with broader spatial context

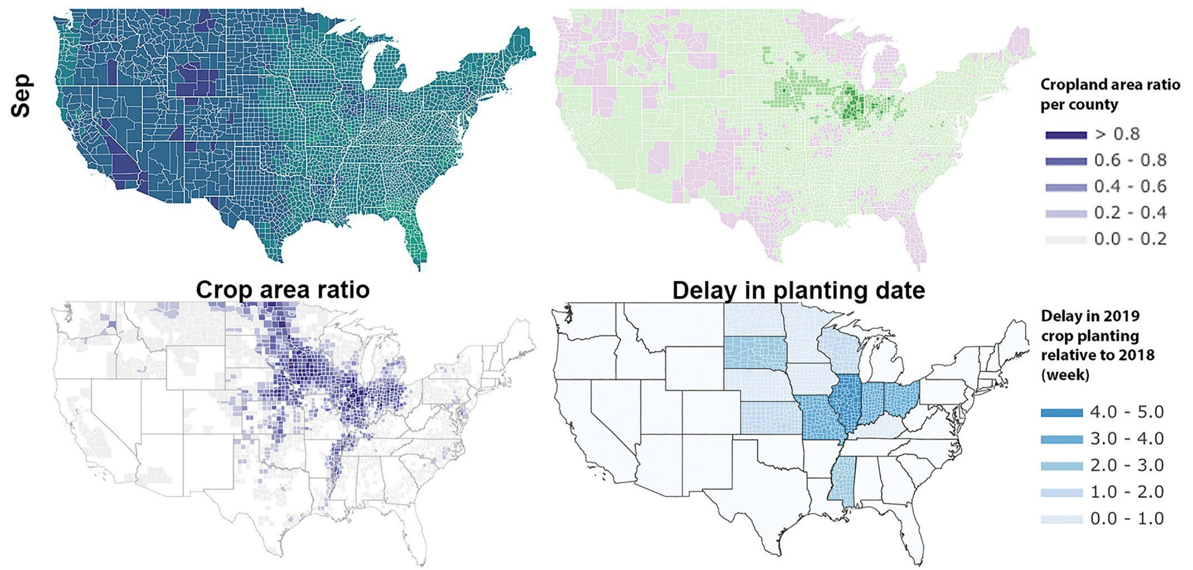


Terrestrial Water Storage (TWS) was elevated in the flood year compared to normal. *Credit: Y. Yin, et al. 2020*

Case Study: 2019 Midwestern Floods



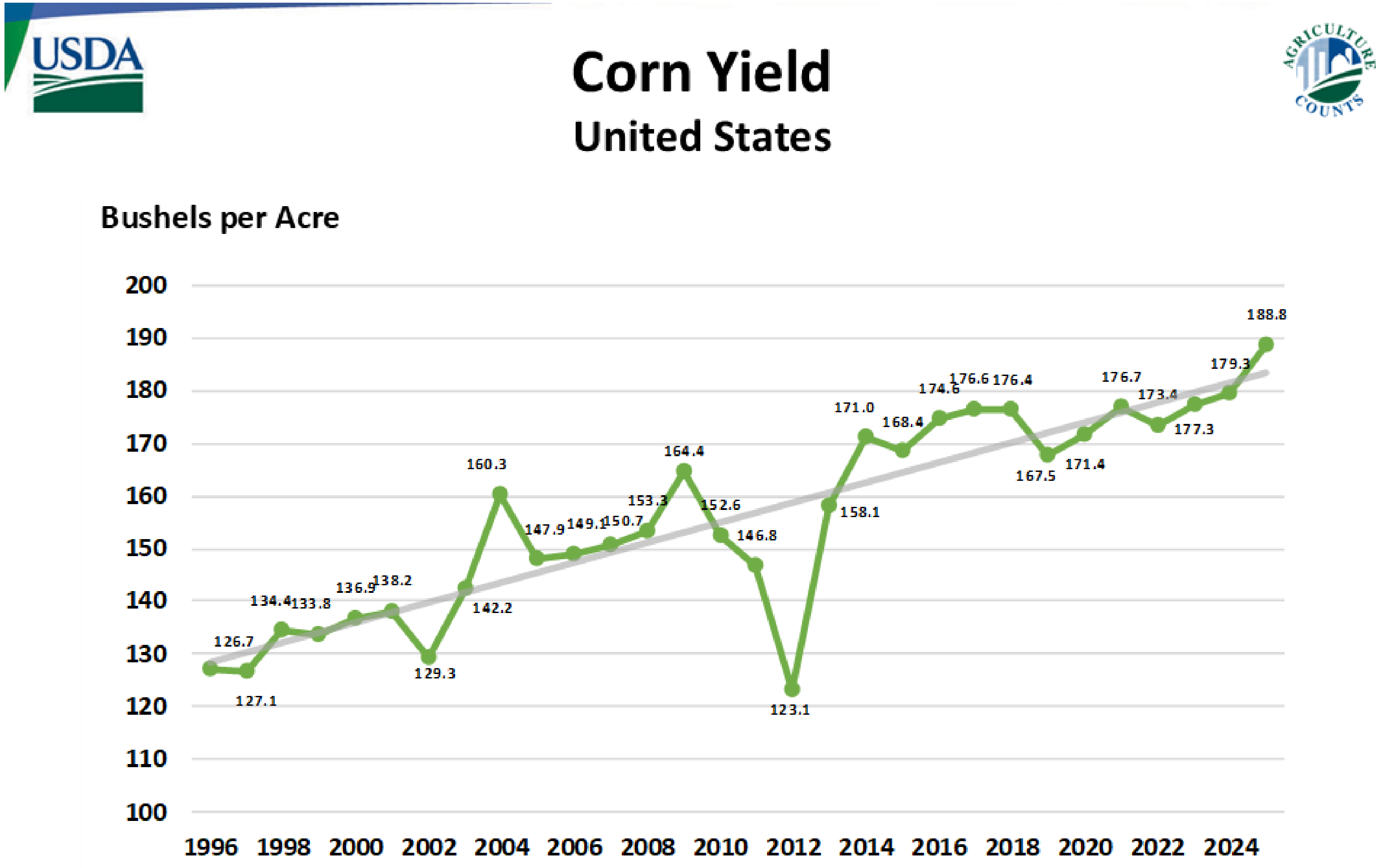
Do you expect to see similar results when comparing GOSIF data between 2018 and 2019 as was observed in the study?



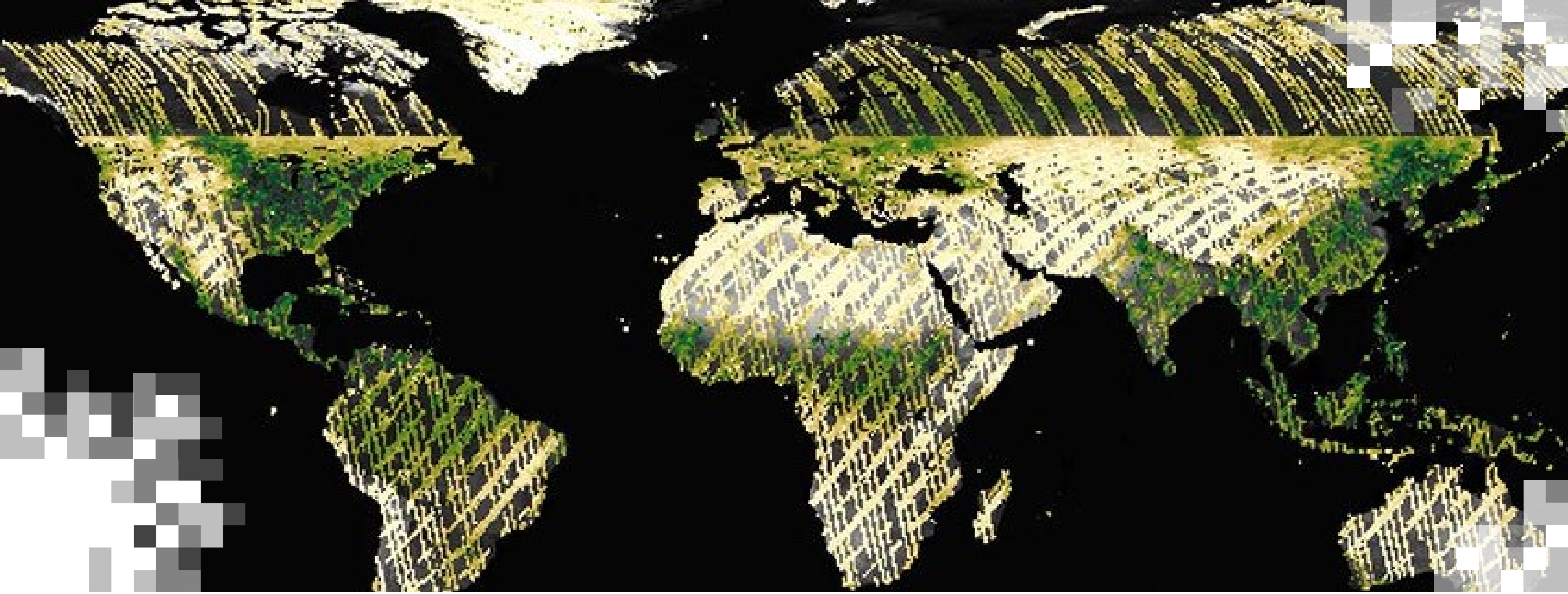
Yin et al. compared TROPOMI SIF spatially aggregated to a county level between 2018 and 2019. Note that the planting date was delayed by up to 5 weeks in some states, and that likewise the peak in SIF was was later in the year, especially in Illinois where planting was delayed the longest. *Credit: Y. Yin, et al. 2020*

Reference: Corn Yields in the U.S.

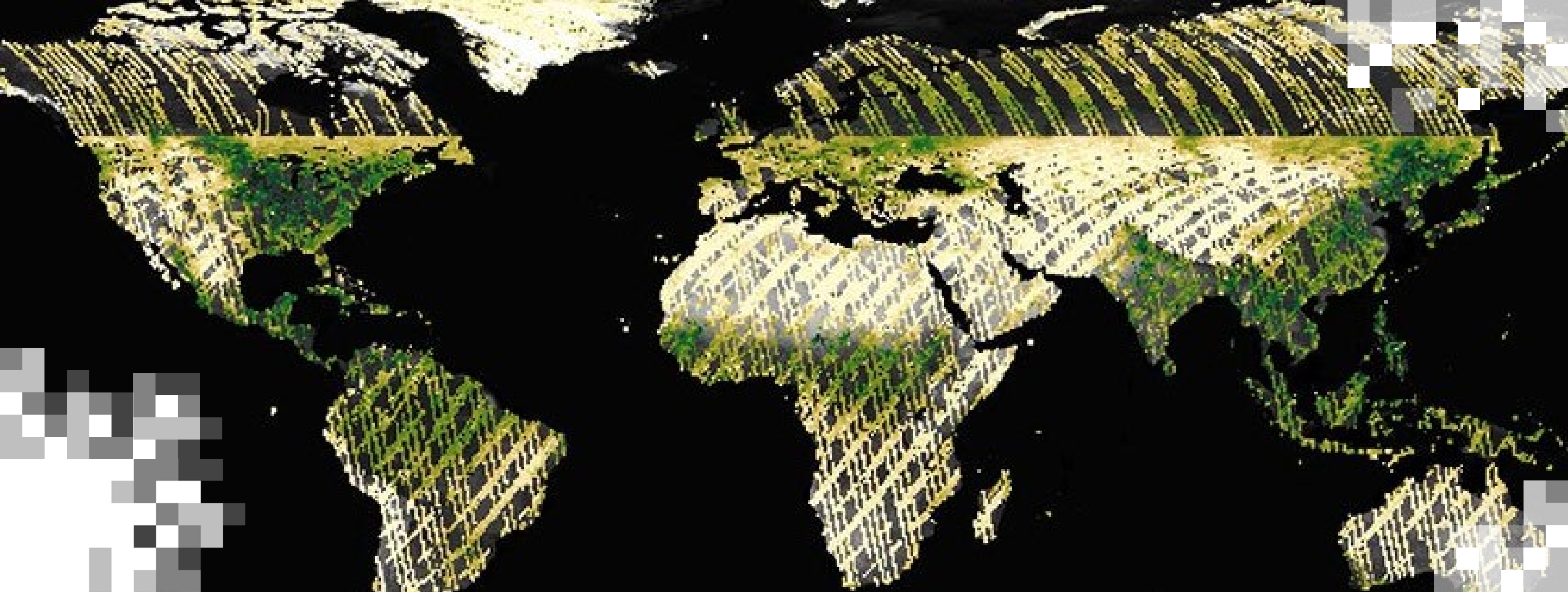
- 2019 corn yield was about 5% less than 2018
- **Case Study 2: 2012 growing season**
- Severe drought combined with extreme temperatures caused the lowest corn yields since 1995, significant due to upward trend in yield over time
- 2012 corn yield was about 22% less than 2013 (2011 was also a minor drought year)
- Dry June and Hot + Dry July combined to significantly lower crop yields
- **Is SIF data correlated with crop yield statistics?**



Corn Yields in the United States, 1996-2025
Credit: USDA National Agricultural Statistics Service (NASS)



Demonstration: 2019 Midwestern US Floods



Session 3
Summary

Summary

- SIF is an excellent metric for assessing vegetation health and stress response.
- It can be measured from several satellite platforms, each with its own trade-offs.
- OCO-2 and OCO-3 provide high-quality SIF measurements but have limited spatial coverage and a relatively short observational record (up to ~11 years).
- Gap-filling or data fusion uses data-driven models to predict SIF values and extend spatial and temporal coverage.
- GOSIF is a globally continuous SIF product with 0.05-degree (~6 km/pixel) spatial resolution and 8-day, monthly, and annual temporal resolutions, extending back to 2000.
- Floods and droughts cause vegetation stress, which reduces SIF.

Contact Information

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- ARSET Website
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Thank You!