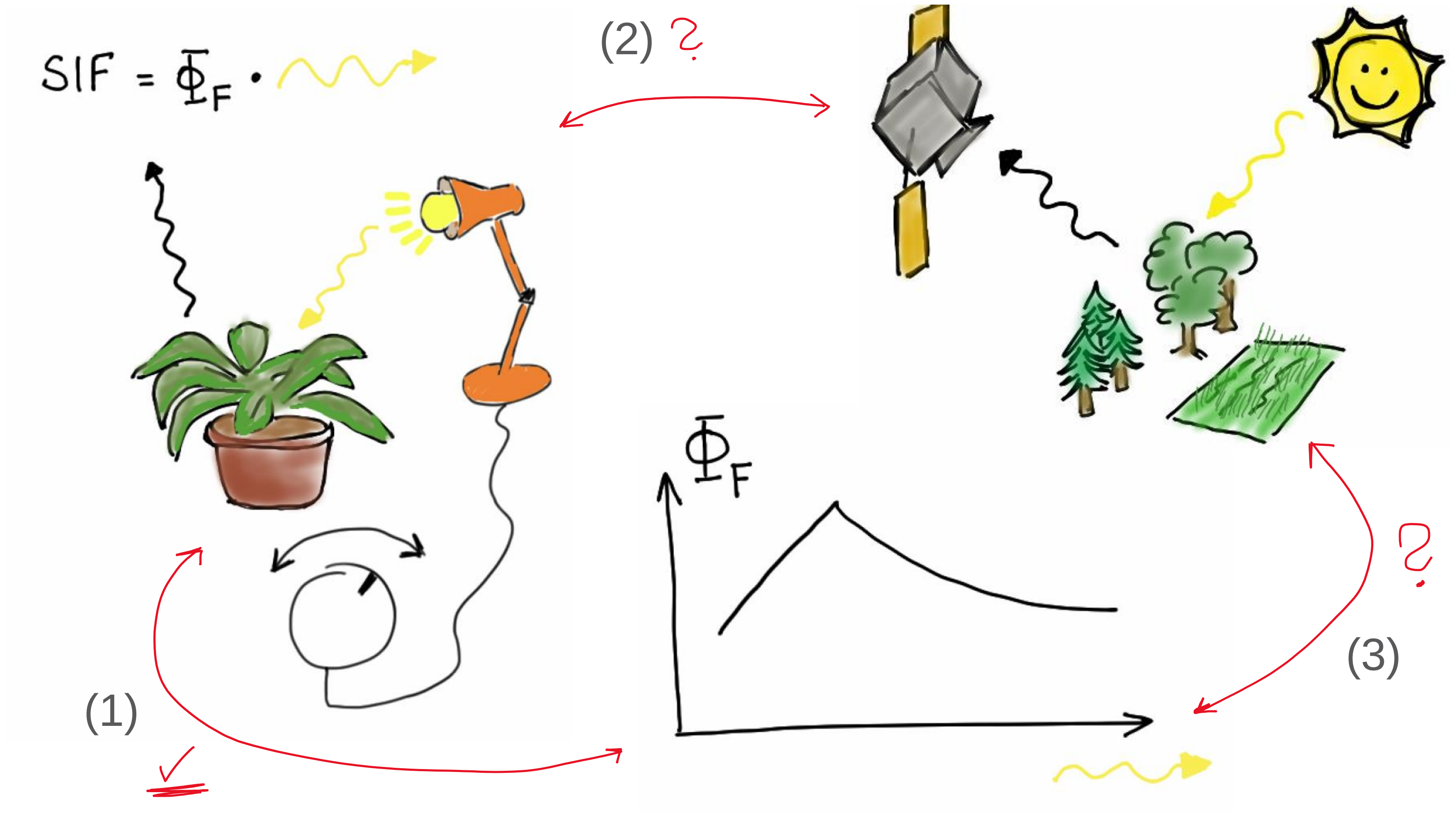
Assessing the viability of measuring the light response of solar-induced chlorophyll fluorescence (SIF) from space

P. Somkuti, CIRA, Colorado State University – peter.somkuti@colostate.edu
J. E. Johnson, Dept. Global Ecology, Carnegie Institute - jjohnson@carnegiescience.edu



- Motivation: fluorescence yield as function of incident radiation (PAR) understood at laboratory conditions (1)
- Long term goal: relate lab and space-based observations (2)
- Our approach: design observing system simulation experiment (OSSE) to understand when/where/how well light response can be recorded from space (3)

Observing System Simulation Experiment (OSSE): Framework for SIF investigations

- 3-component Ansatz:
  - Abstract instrument
    "I want **this instrument** to look at **that place** on Earth and measure SIF"
    (e.g. OCO-2, OCO-3, GOSAT, future missions, OCO-X in different orbit etc., ..)
  - Abstract spatial aggregation
    "I want my SIF measurements to be spatially aggregated into **arbitrary groups**"
  - (e.g. 2° x 2° grid cells, or PFT/land cover-based collection, ..)
  - Abstract temporal aggregation
    "I want my SIF measurements to be aggregated in **some arbitrary intervals**"
    (e.g. hourly, daily, some interval in which a relevant parameter is constant, ..)

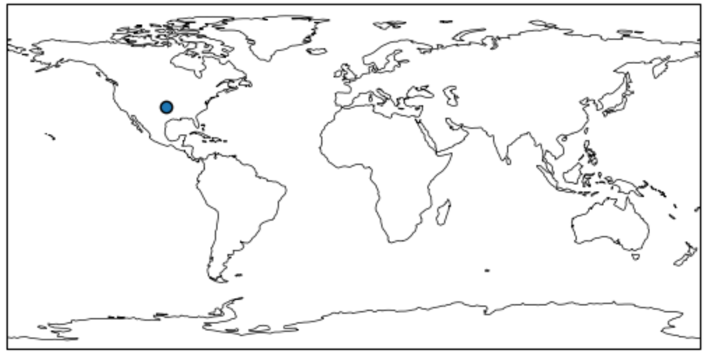
→ light response

Driven by following data/models:

- real OCO-2/3 geolocation
- VIIRS-based reflectance
  (VNP43C1, 2020 year)
  (provides NDVI, NIRv etc.)
- leaf-level SIF yield model according to Johnson & Berry (2021)
- SMARTS model
  (provides solar angle-dependent PAR)
- real, observed OCO-2/3 SIF uncertainty

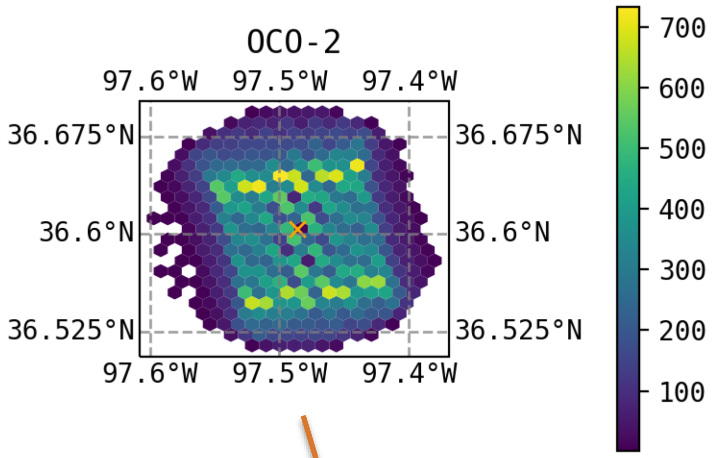
NOTE:
Cloud cover not yet included

Case study: Lamont (OK), USA



- Targeted regularly by OCO-2 and OCO-3 due to TCCON ground instrumentation
  - Good choice for demonstration: many OCO-2/3 overpasses
- Pick 10km-radius ROI around TCCON instrument location

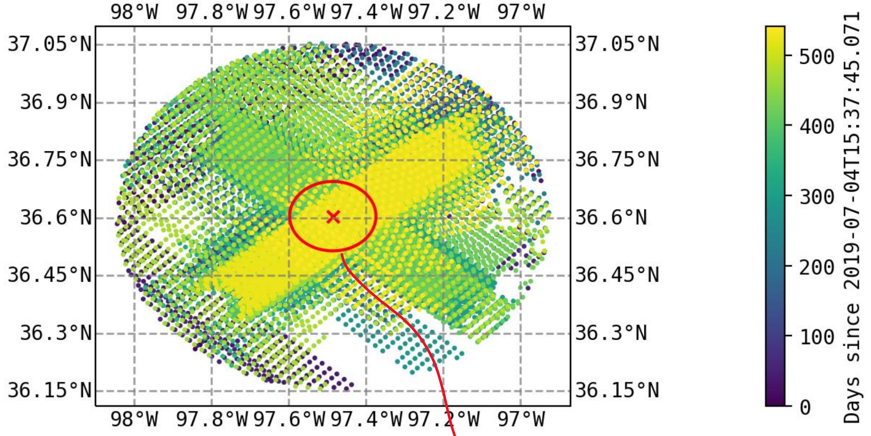
OCO-2/3 measurement density



We collect both target mode measurements (rapid collection, ~9min) as well as regular nadir+glint overpasses

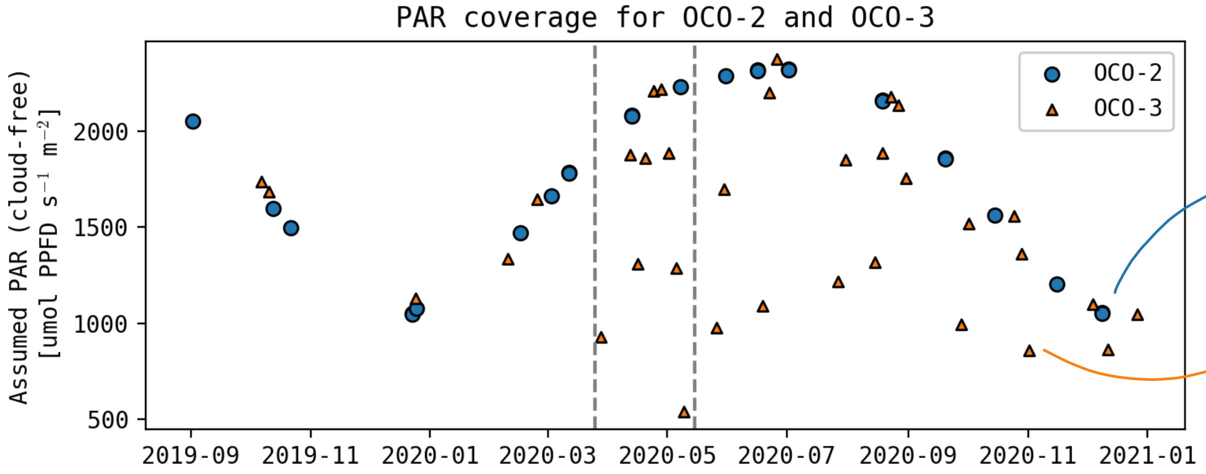
We collect all OCO-3 measurement modes (target, land nadir)

OCO-3 overpasses



Case study: Lamont (OK), USA

- Due to the different orbits, OCO-2 and OCO-3 cover a different range of solar irradiance (→ photosynthetically available radiation, PAR, calculated from solar position via SMARTS)

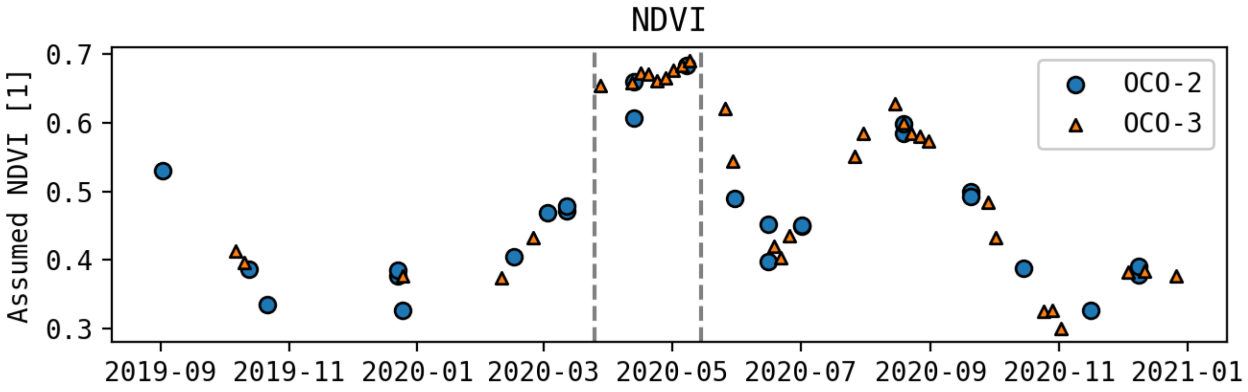


OCO-2 observed PAR changes with season due to Earth's axis tilt

OCO-3 observed PAR is a mix of both seasonal and diurnal component (ISS orbit not sun-synchronous!)

Each point represents a full ROI aggregate for one day (only one overpass per day for both OCO-2 and OCO-3)

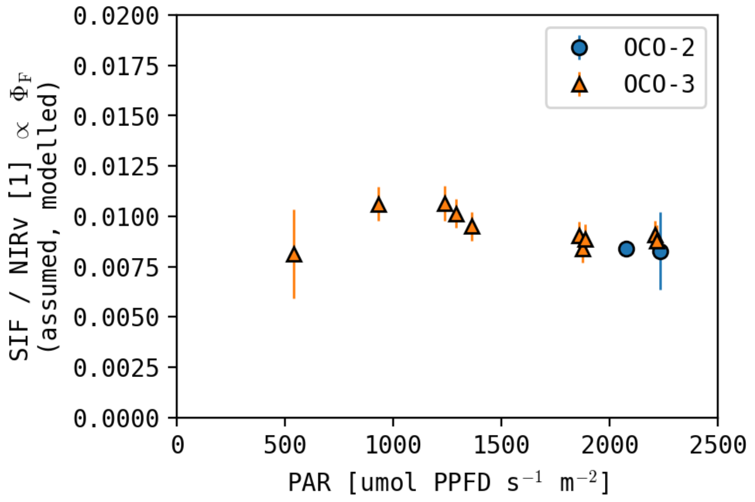
NDVI (derived using measurement locations sampled from VNP43C1, 2020 year), gives us "*first guess*" of when vegetation is "stable", so we focus on the period indicated by vertical grey bars (March 15th to June 1st)



Case study: Lamont (OK), USA

http://ou.edu/geocarb

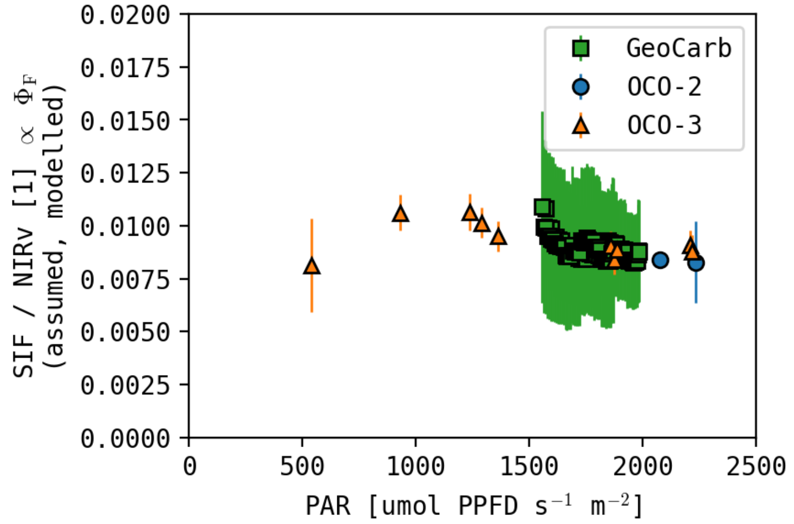
- Ratio of interest: SIF / NIRv $\propto \phi_F$
  NIRv = NDVI · NIR (reflectance) · NIR (radiance)
- SIF retrieval uncertainties propagated through
  - assumption: aggregate uncertainty = standard error



- Low uncertainty due to large number of scenes – no systematic biases considered (yet)!
  (~200 to ~300 scenes per OCO-3 aggregate)
- OCO-3 provides good coverage of PAR thanks to overpasses at different times of day!

PRELIMINARY!

- We now consider the addition of **GeoCarb** (preliminarily positioned at 103W longitude)
- Fixed sampling
  - location is re-visited twice per day at the same time (~16h and ~21h UTC)

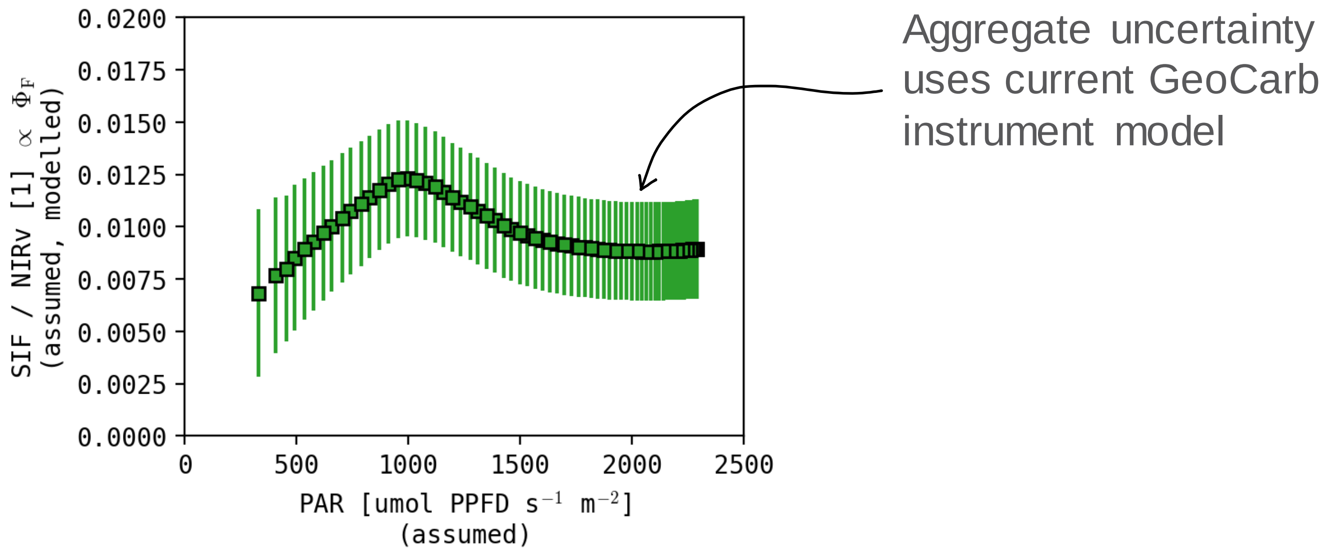


- With regular sampling pattern (meaning: as part of the scan which measures both SA and NA), GeoCarb would add to PAR coverage at higher end
  (however does not add to PAR coverage at lower values)

Case study: Lamont (OK), USA

For details on the shape of yield-vs-PAR curve, read Johnson & Berry (2021):
https://doi.org/10.1007/s11120-021-00840-4

- GeoCarb in ”intensive scan mode”
  (much flexibility due to scan mirror assembly)
- Same location is scanned repeatedly throughout the day, **~10 minute** intervals
- For the same ROI (10 km radius), we have 30 scenes per 10-minute-aggregate
- Full range of PAR is scanned in one day



Summary:
- We designed a flexible and fast OSSE framework to simulate the acquisition of a SIF light response function from space, for use with both existing and upcoming instruments (or any combination of those)
- We can already see the added value of OCO-3, as its orbit allows for much wider PAR coverage for certain target locations
- As a next effort, we will use the inverse formulation of the SIF yield model to infer underlying vegetation parameters and the relevant uncertainties!
  - **Where, when and with which current and future instruments can we perform this inversion?**