

Simulating canopy-level solar induced fluorescence with CLM-SIF 4.5 at a sub-alpine conifer forest in the Colorado Rockies

Brett Raczka¹, H. Duarte², C. Frankenberg^{3,4}, M. Garcia¹, K. Grossmann^{4,5}, P. Köhler⁴, J. E. Lee⁶, J. Lin², T. Magney^{3,4}, J. Stutz^{4,5}, X. Yang⁷, L. Zuromski², D. Bowling¹

¹Department of Biology, University of Utah

²Department of Atmospheric Sciences, University of Utah

³ NASA Jet Propulsion Laboratory

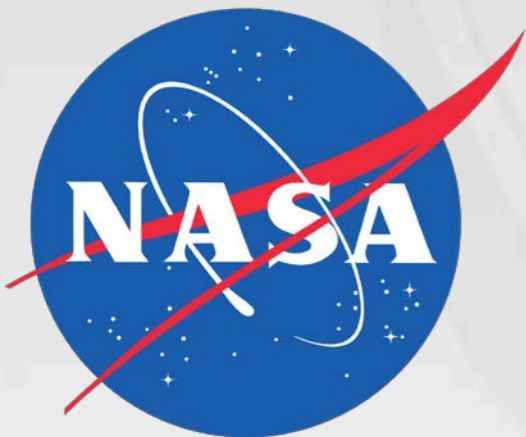
⁴California Institute of Technology

⁴Joint Institute For Regional Earth System Science and Engineering,
University of California Los Angeles

⁵Department of Atmospheric and Oceanic Sciences, University of
California Los Angeles

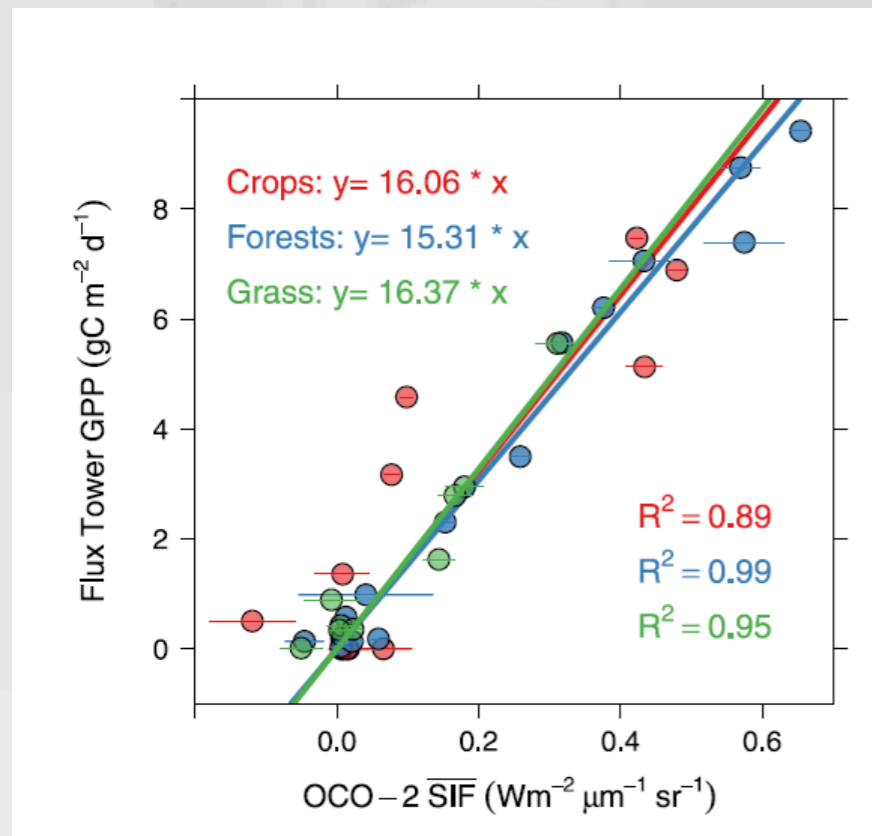
⁶Environmental and Planetary Sciences, Brown University

⁷Department of Environmental Sciences, University of Virginia



Solar Induced Fluorescence (SIF) is a robust indicator of GPP

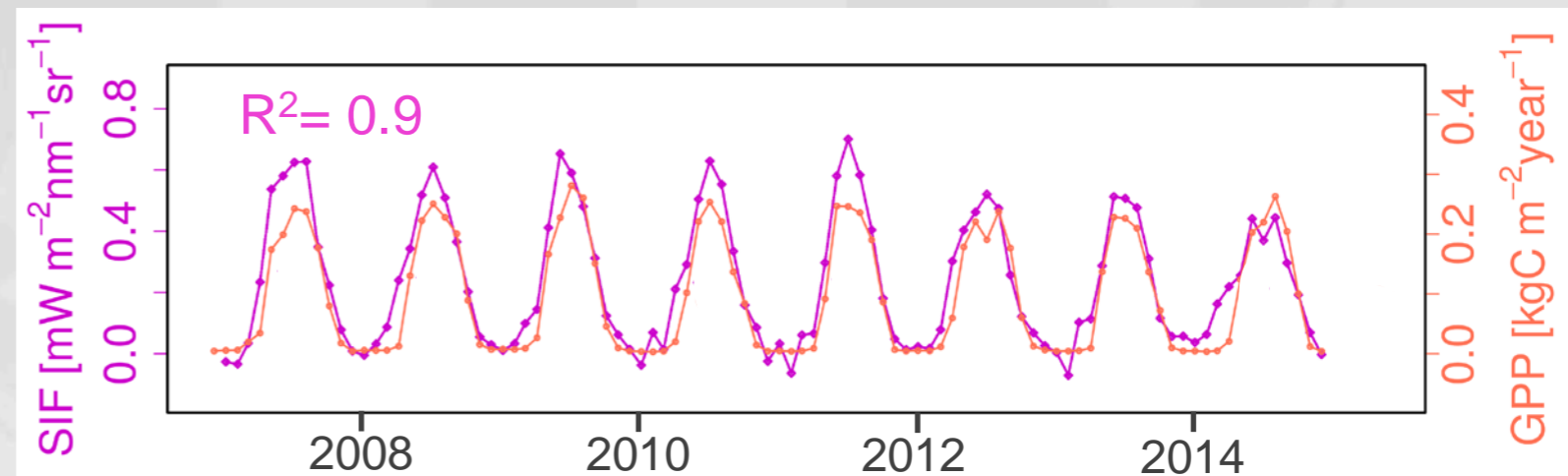
Crops, grass, deciduous forest sites



Sun et al. (2017)

Daily averages at multiple biome types (OCO-2)

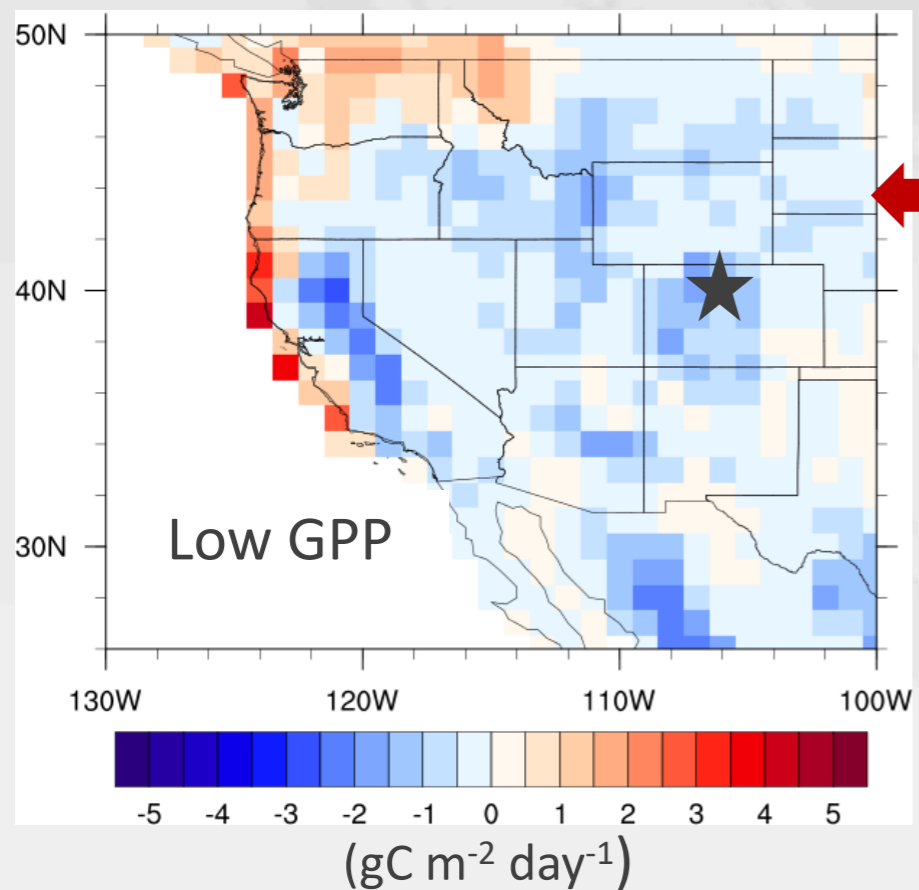
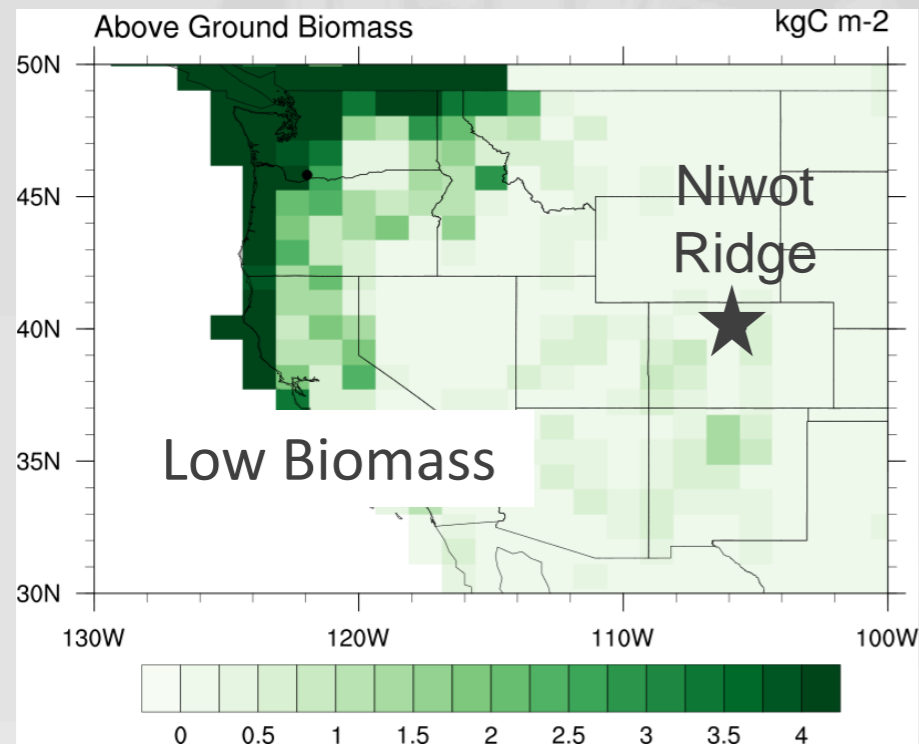
Evergreen needleleaf, Niwot Ridge, CO



'Greenness' indices: NDVI ($R^2=0.46$) EVI ($R^2=0.41$)

SIF (GOME-2) is a better indicator of GPP than reflectance or greenness indices at Niwot Ridge

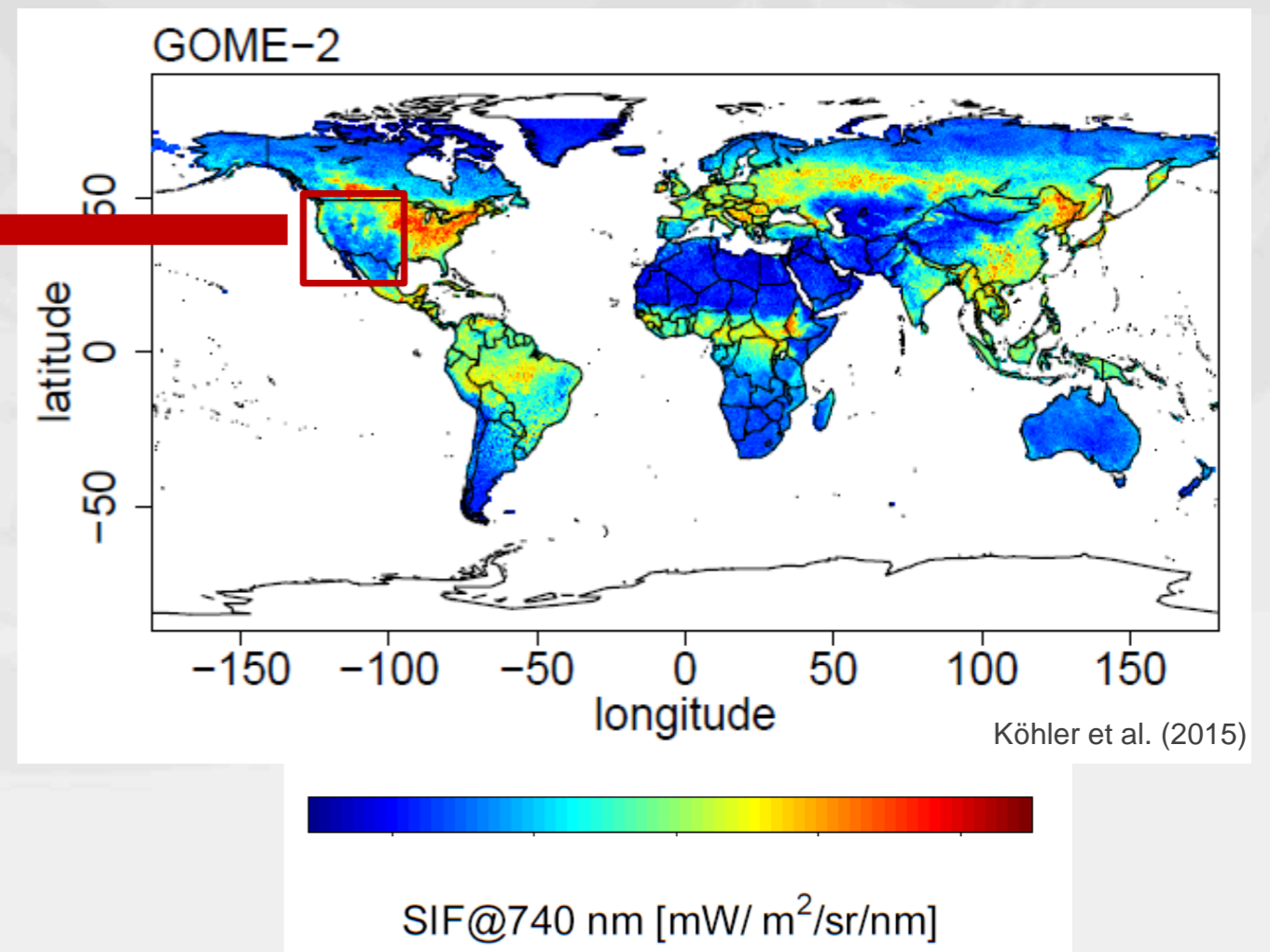
Constrain simulated GPP with remotely-sensed SIF



GPP Bias: Upscaled Flux Tower obs
Jung et al. (2010)

- Some Improvement with:
- High resolution surface maps/met
 - Accurate meteorology (dry bias)
 - Parameter calibration

Remotely Sensed SIF

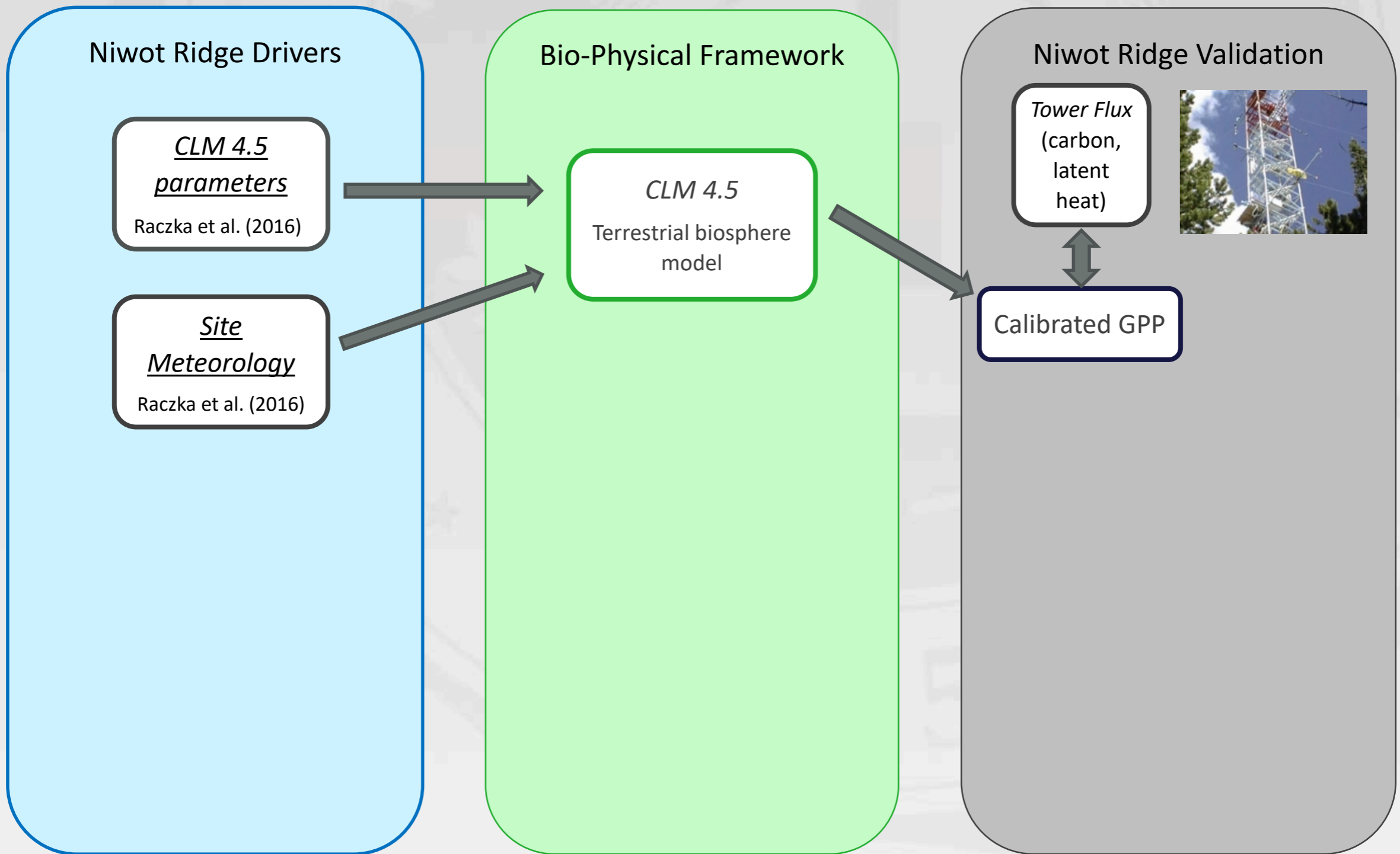


Overall Goal : Simulate canopy fluorescence across the Western US, and use SIF satellite observations (e.g. OCO-2; GOME-2) to help constrain GPP (carbon exchange)

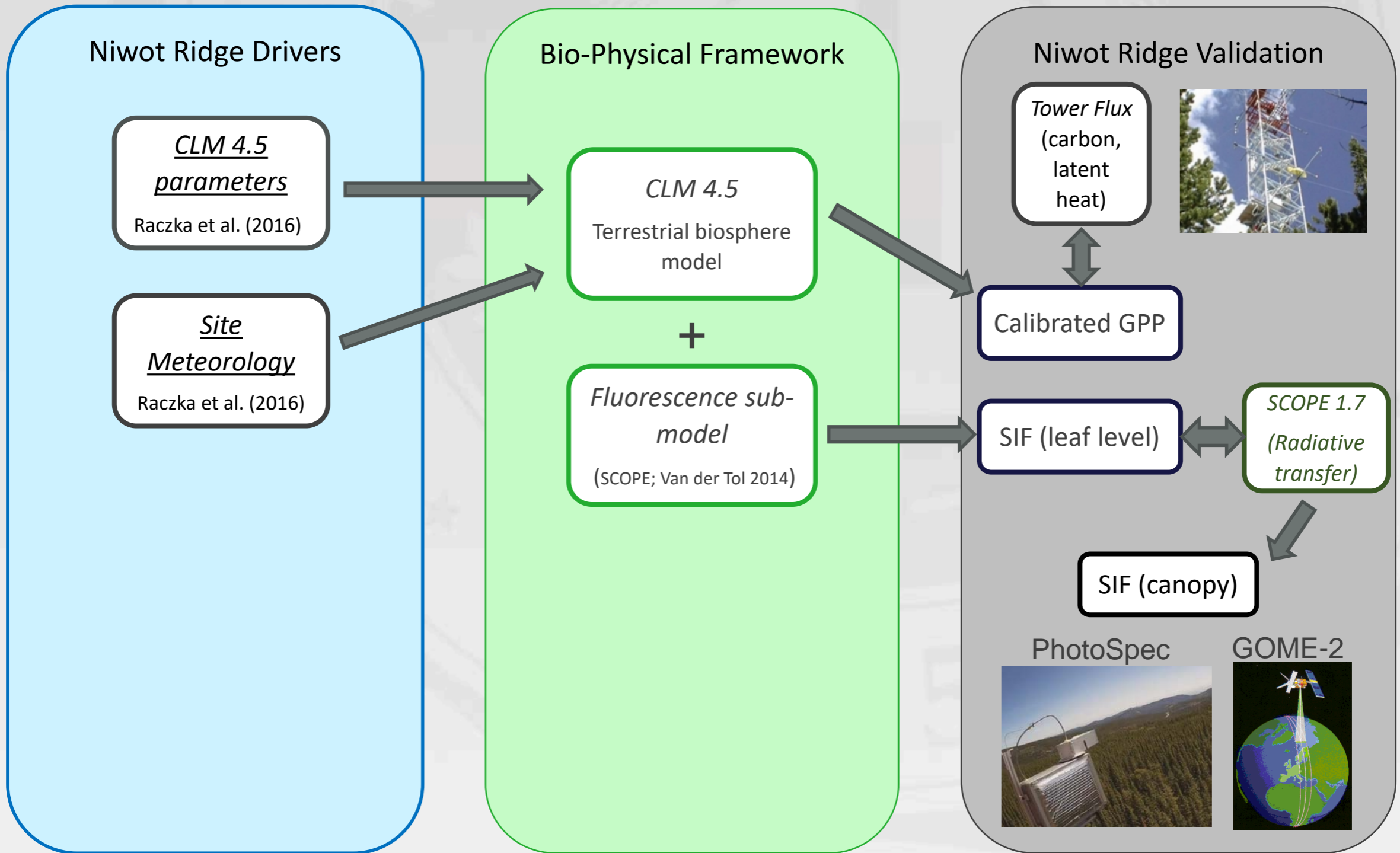
Immediate Objective: Implement a fluorescence sub-model within the Community Land Model (CLM-SIF 4.5) and simulate canopy fluorescence at Niwot Ridge.

- Can CLM simulate seasonal changes in SIF as measured by a tower-mounted scanning spectrometer (PhotoSpec)?

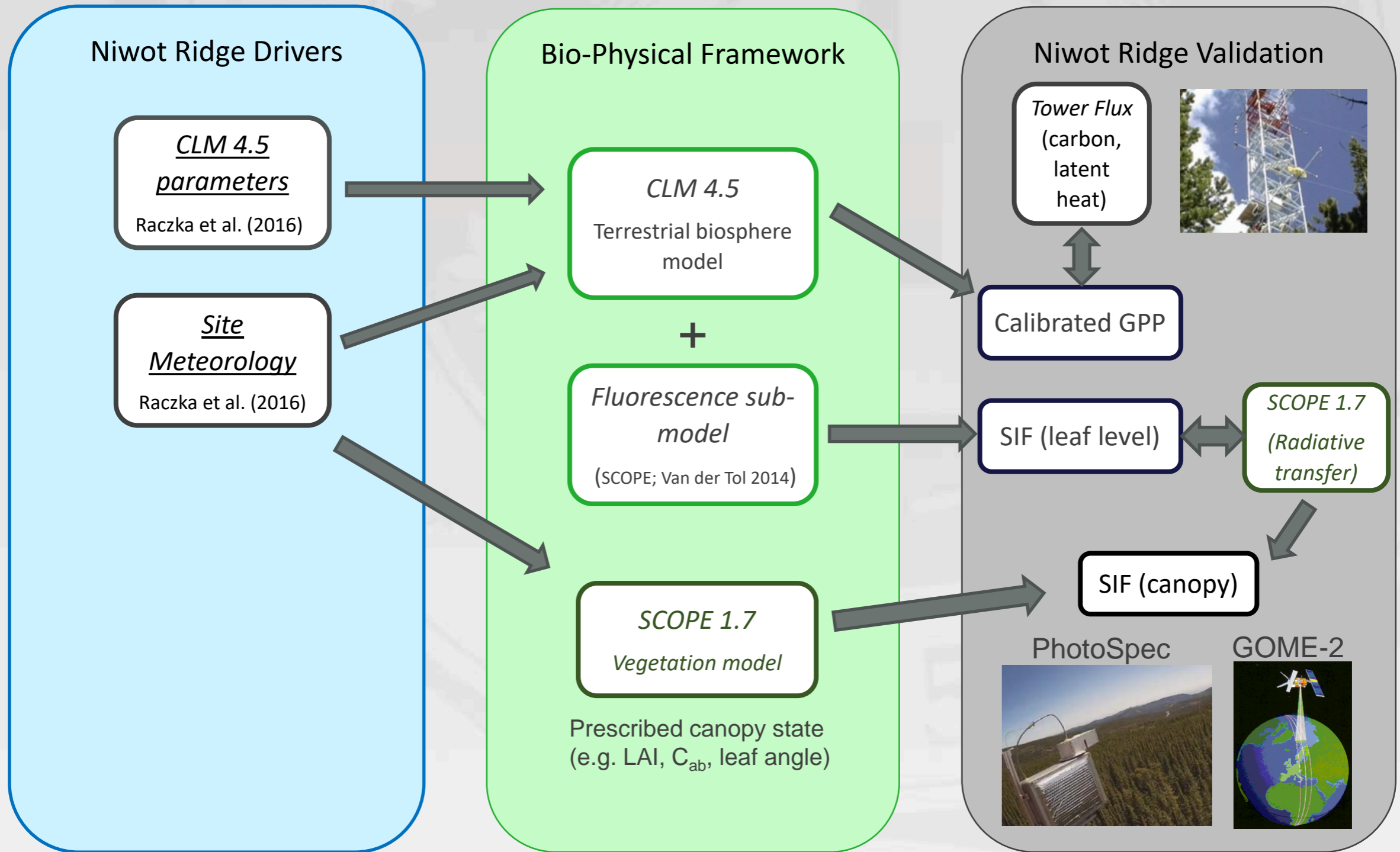
Methodological Approach



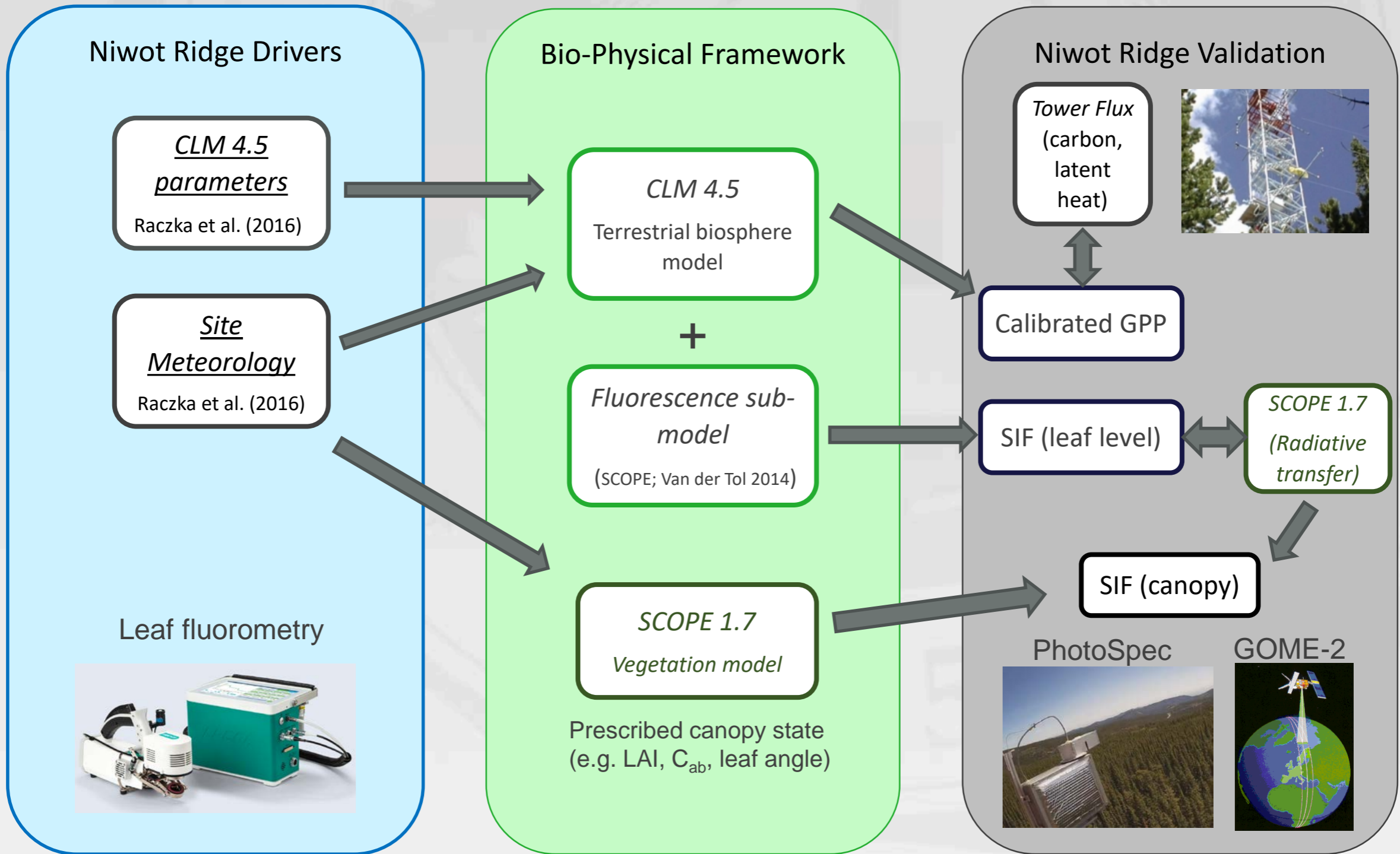
Methodological Approach



Methodological Approach



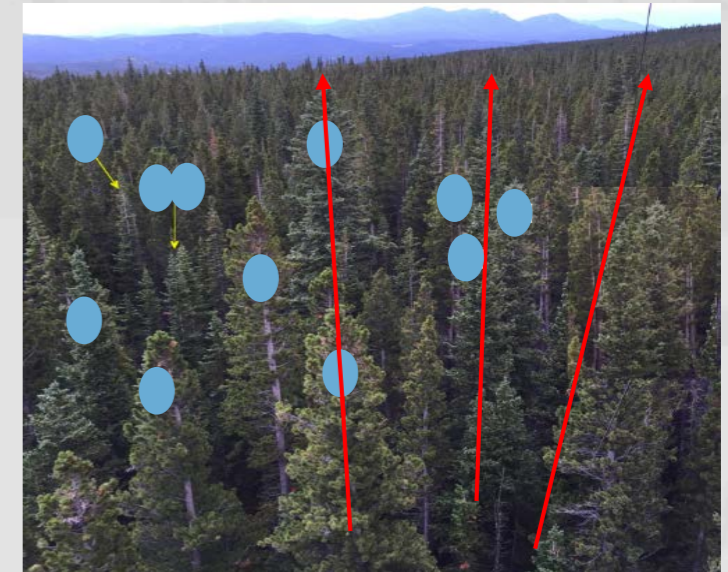
Methodological Approach



Observations of Fluorescence

PhotoSpec: Tower-mounted scanning spectrometer

- Tower-based canopy fluorescence is filtered average of PhotoSpec 'target' and 'elevation' scans (preliminary)

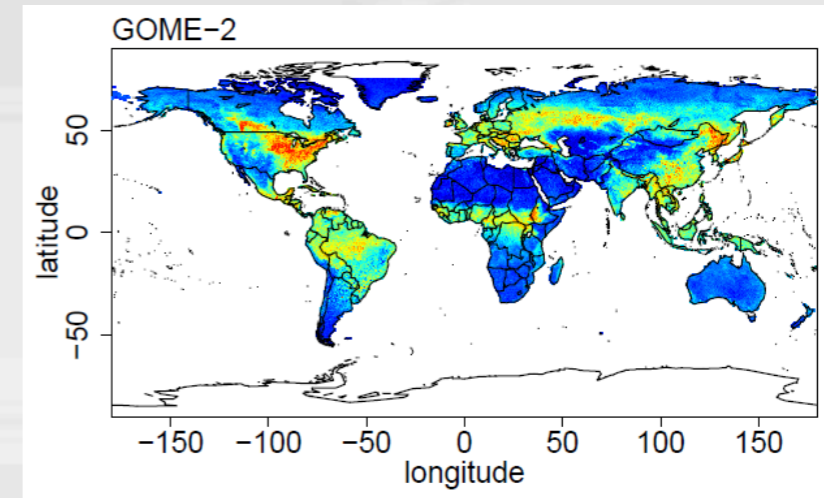
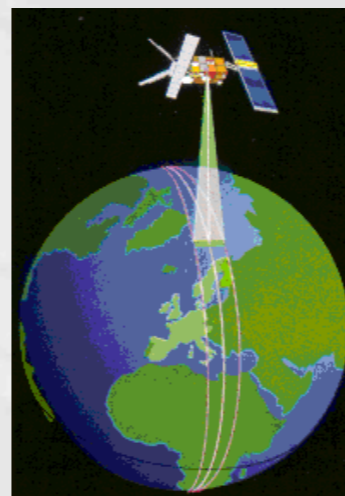


Photospec team: K. Grossmann, T. Magney, J. Stutz, C. Frankenberg

GOME-2 Satellite-derived fluorescence:

- NASA-Level 3; (Joiner et al. 2013)
- GFZ; (Köhler et al. 2015)

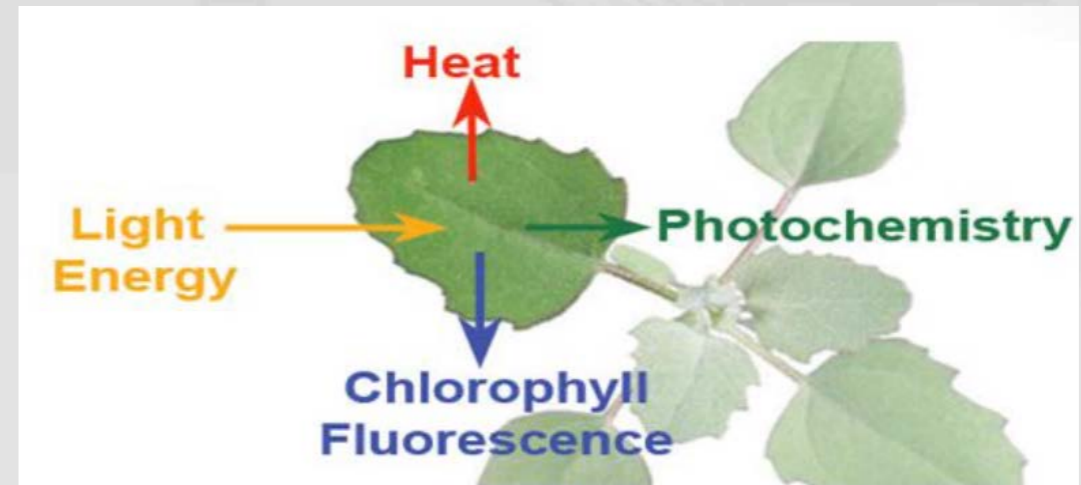
Spatial mismatch: 40 km² vs 1 km²



Model Representation of Fluorescence

Fate of absorbed photons; expressed in yields (ϕ) :

$$\phi_{Photo} + \phi_{Fluor} + \underbrace{\phi_N + \phi_D}_{\text{NPQ: heat dissipation}} = 1$$
$$\underbrace{\phi_{light\ adaptive} + \phi_{sustained}}$$



Model Representation of Fluorescence

Fate of absorbed photons; expressed in yields (ϕ) :

Genty et al. (1989); Van der Tol (2014)

NPQ: heat dissipation

$$\phi_{Photo} + \phi_{Fluor} + \phi_N + \phi_D = 1$$

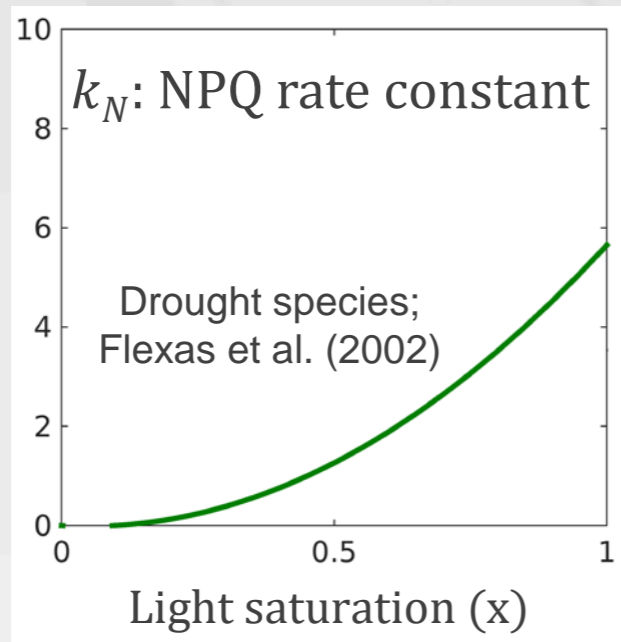
$\phi_{light\ adaptive} + \phi_{sustained}$

$$\phi_{Fluor} = \phi_{Fm'}(k_N(x)) * (1 - \phi_{Photo}(x));$$

$\phi_{Fm'}$: maximum ϕ_{Fluor} ; ϕ_{Photo} : photochemical yield

k_N : NPQ rate constant

x : Light saturation

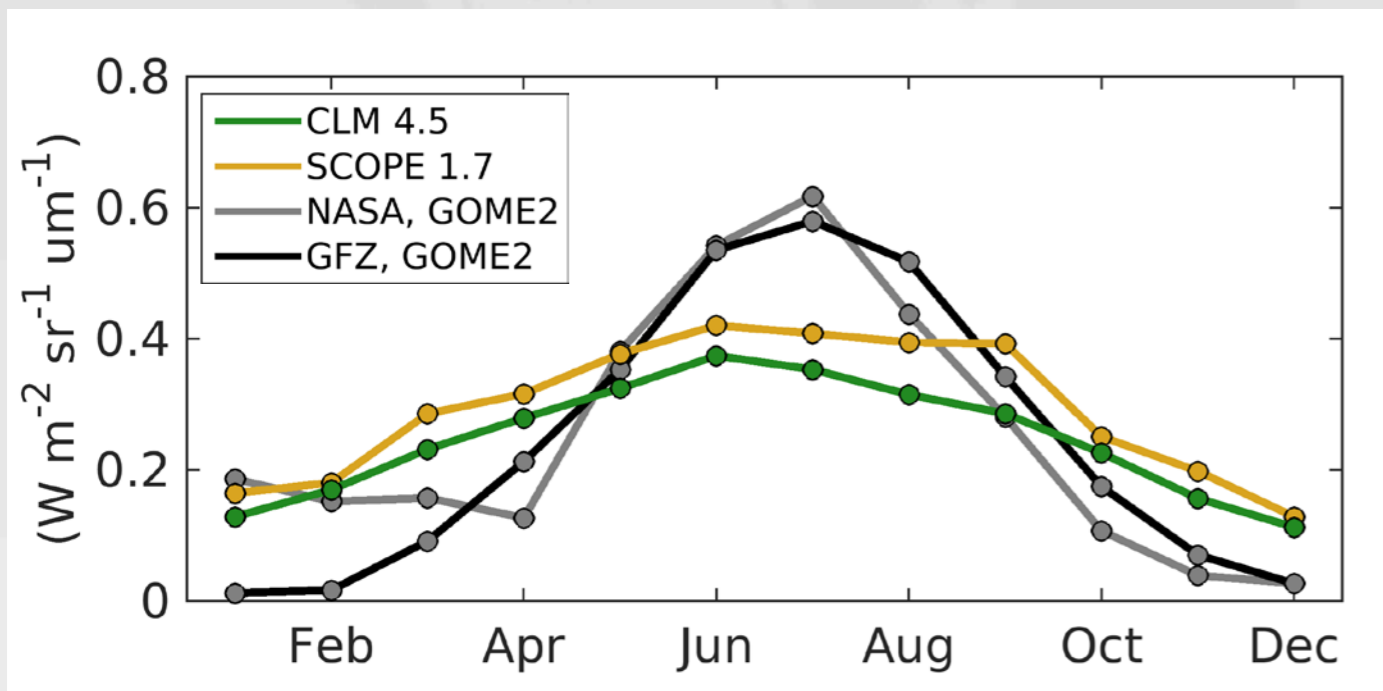


CLM 4.5/SCOPE
Terrestrial biosphere model

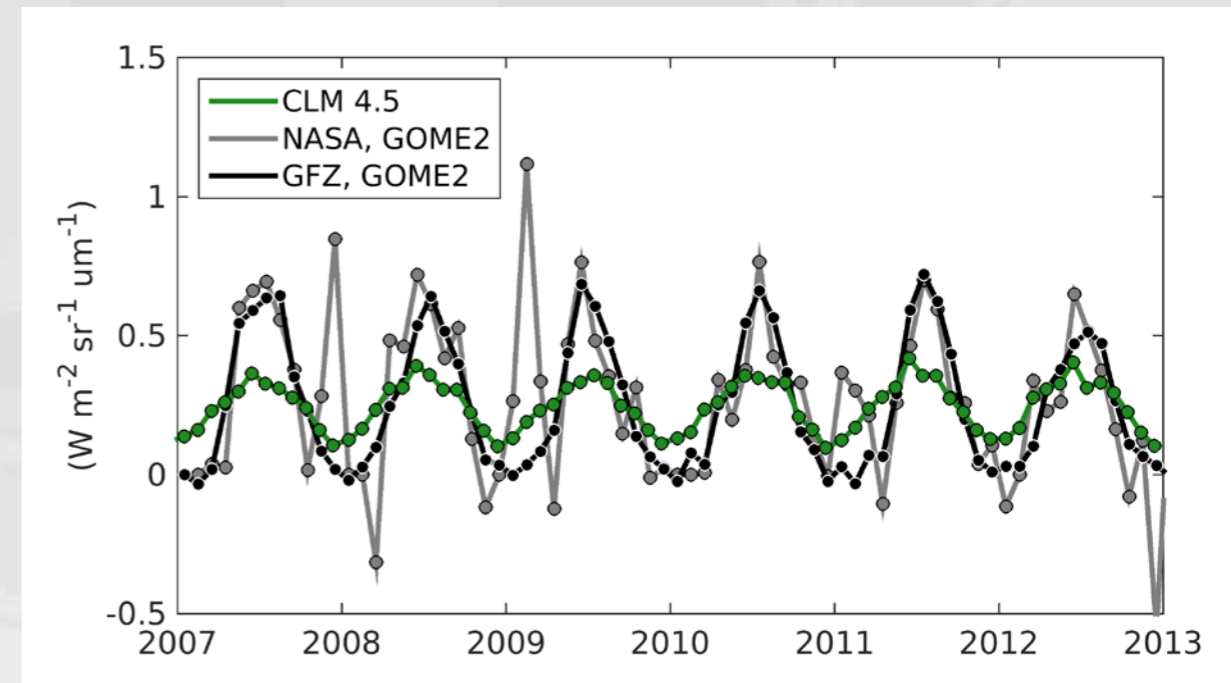
More photochemistry ← → more NPQ

SIF model simulations underestimate satellite fluorescence at Niwot Ridge in summer, overestimate in winter

Canopy SIF (740 nm) 1999-2013 average



Canopy SIF (740 nm), all years

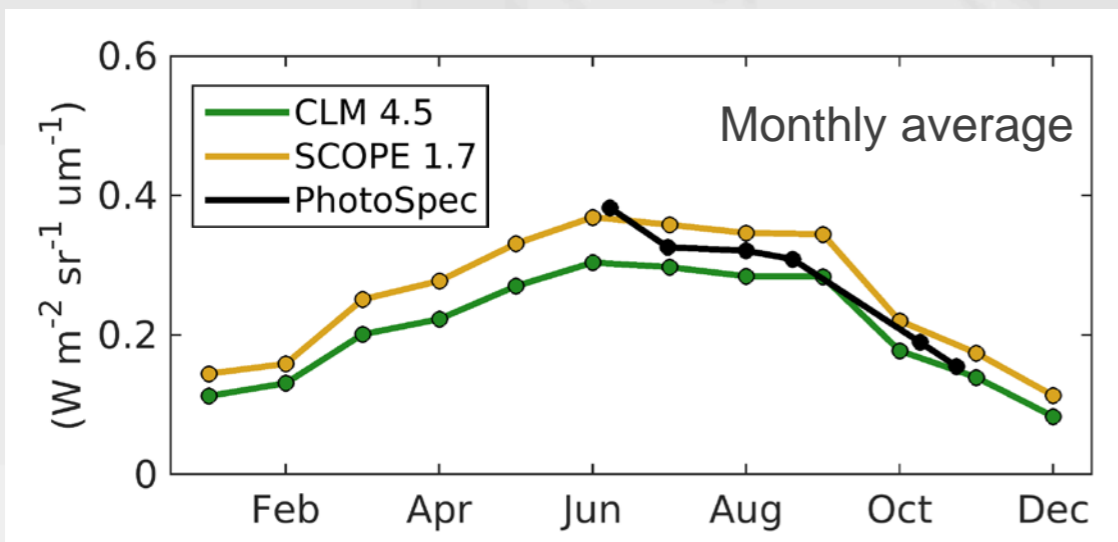
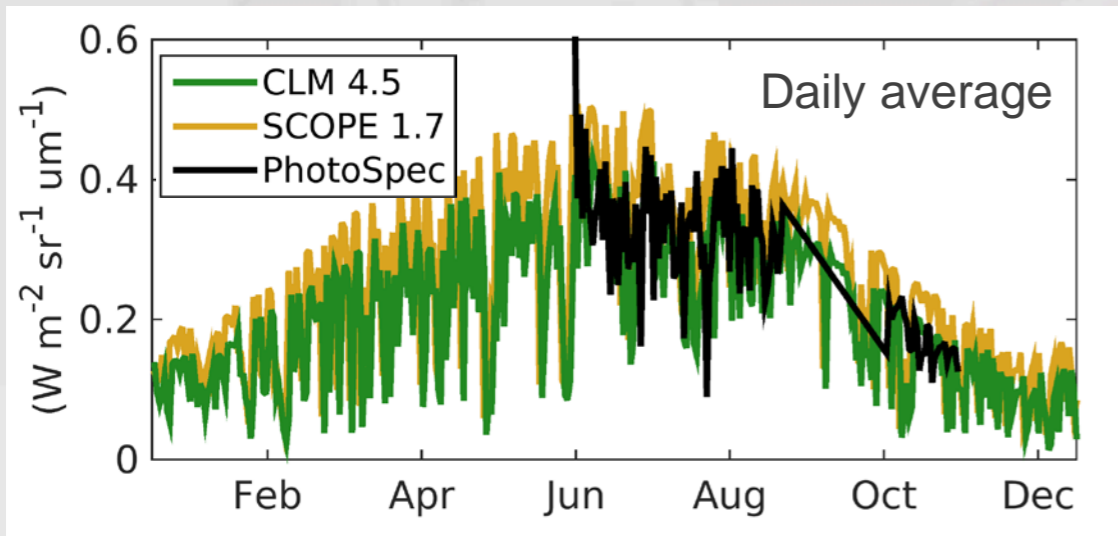


**SCOPE simulation for year 2010 only

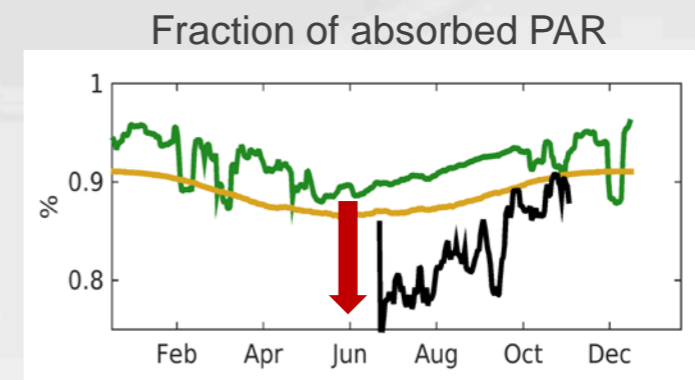
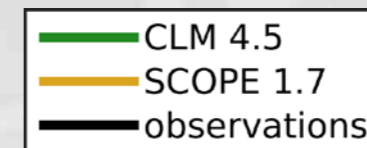
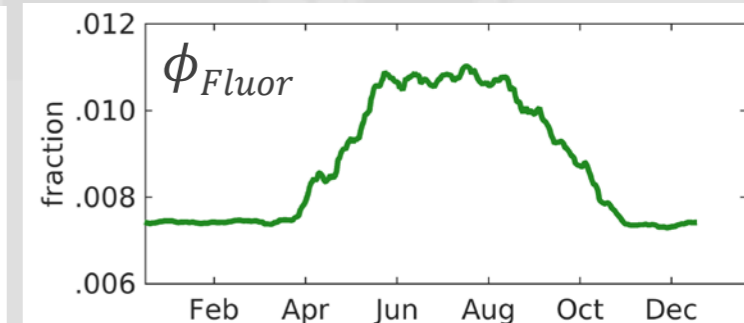
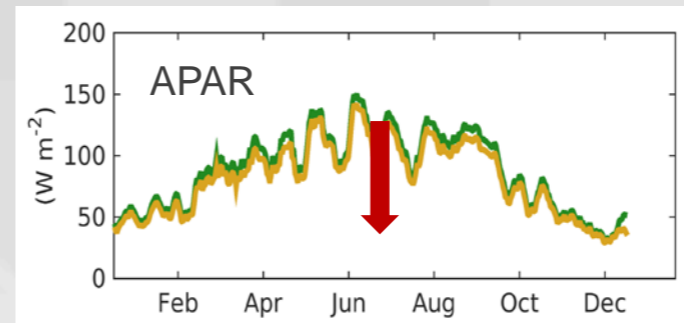
CLM/satellite mismatch is similar across years

SIF model simulations are consistent with PhotoSpec

Canopy SIF (745-758 nm)



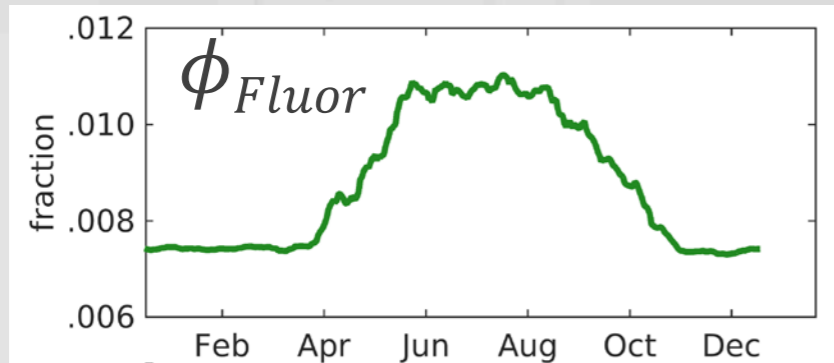
$$Canopy\ SIF \propto APAR \times \phi_{Fluor}$$



Positive Bias in APAR

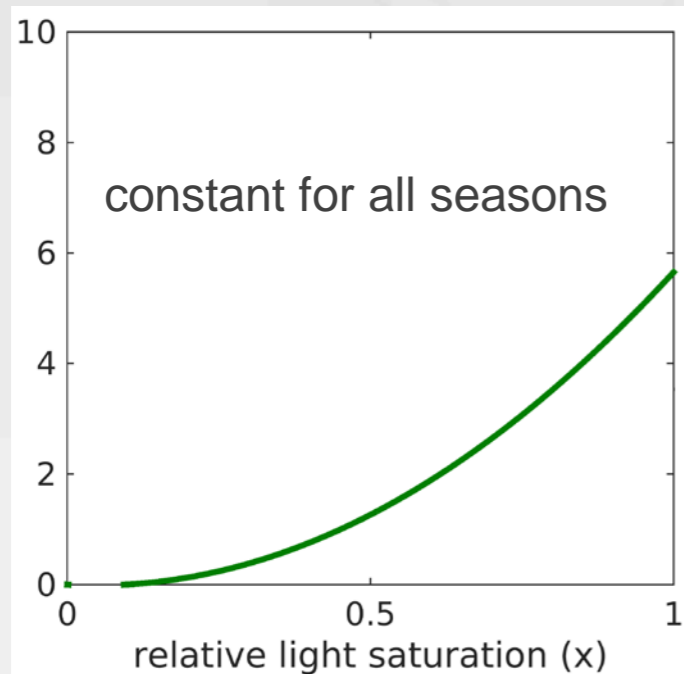
**CLM/SCOPE: Year 2010; PhotoSpec: Year 2017

Is fluorescence yield modeled correctly?

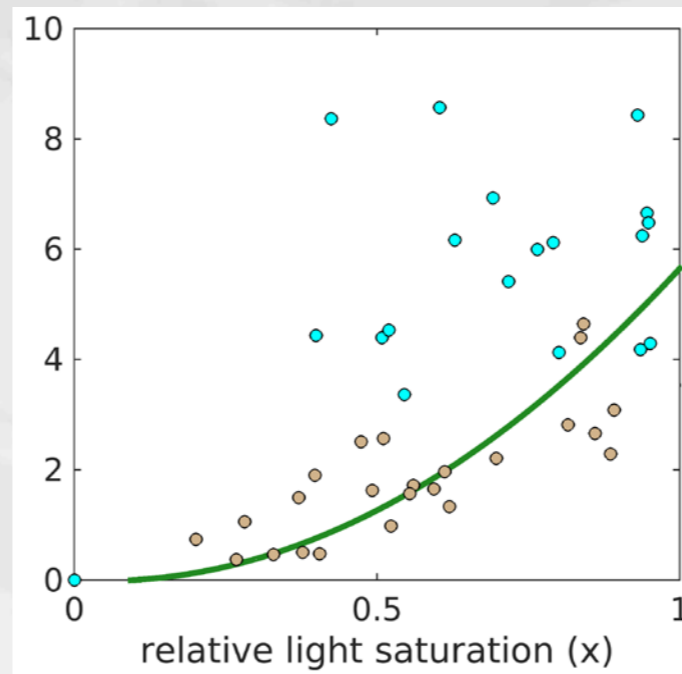


Does k_N change with season ?

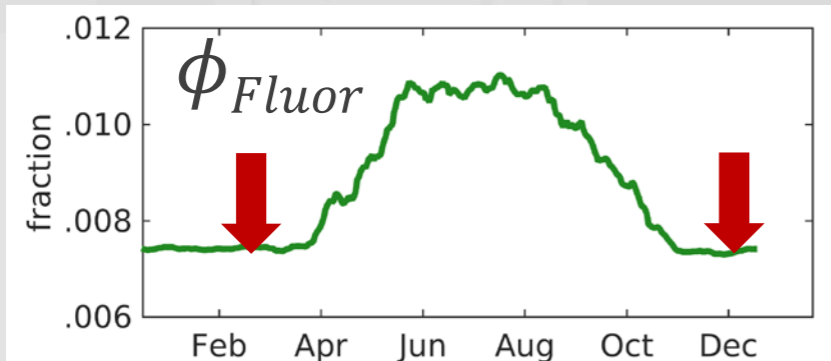
NPQ rate constant (k_N : drought species)



k_N : Niwot Ridge

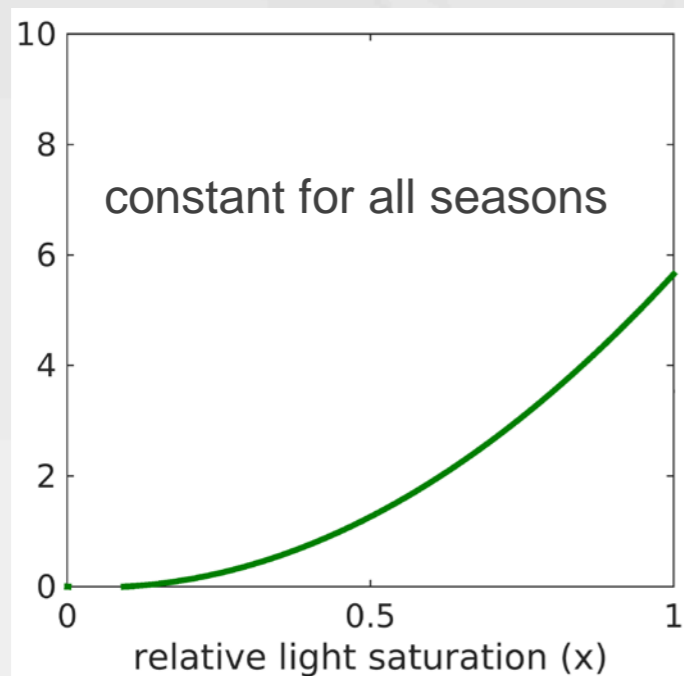


Is fluorescence yield modeled correctly?

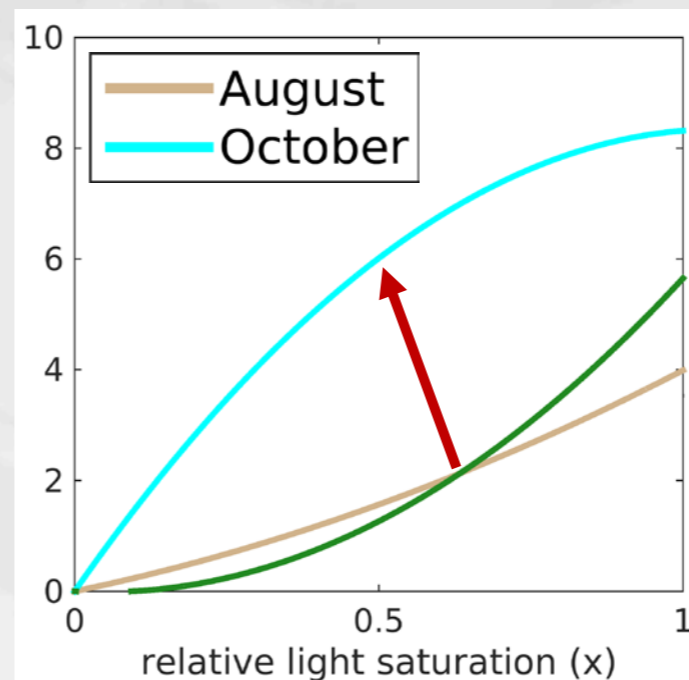


Does k_N change with season ?

NPQ rate constant (k_N : drought species)



k_N : Niwot Ridge



Yes, it appears that k_N increases towards winter.

winter k_N



winter ϕ_{Fluor}

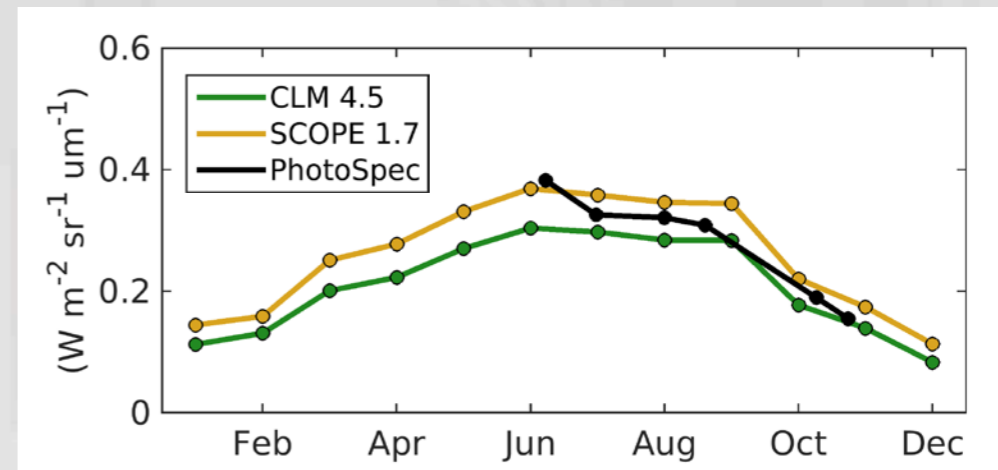


winter SIF



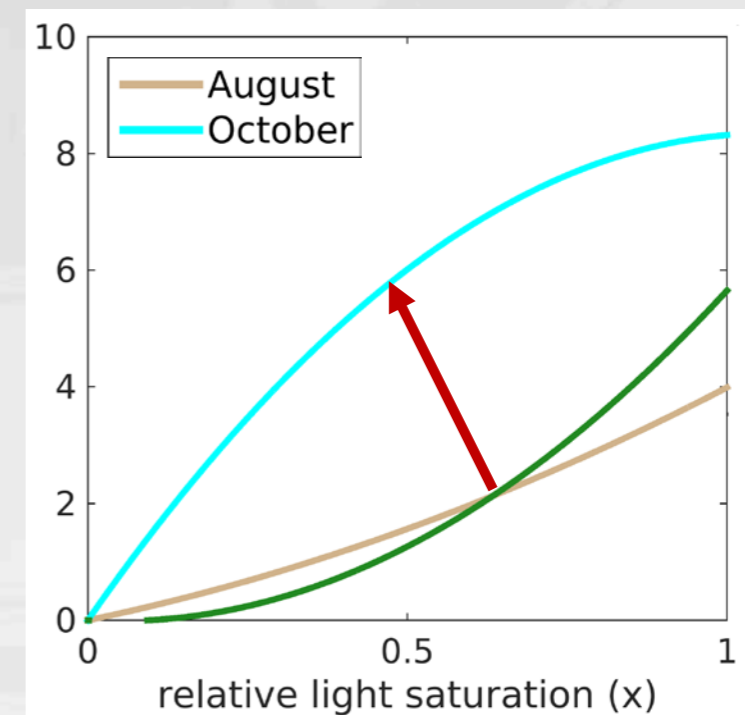
Conclusions

- Seasonal simulations of SIF at Niwot Ridge are more similar to the PhotoSpec, than the satellite SIF products.



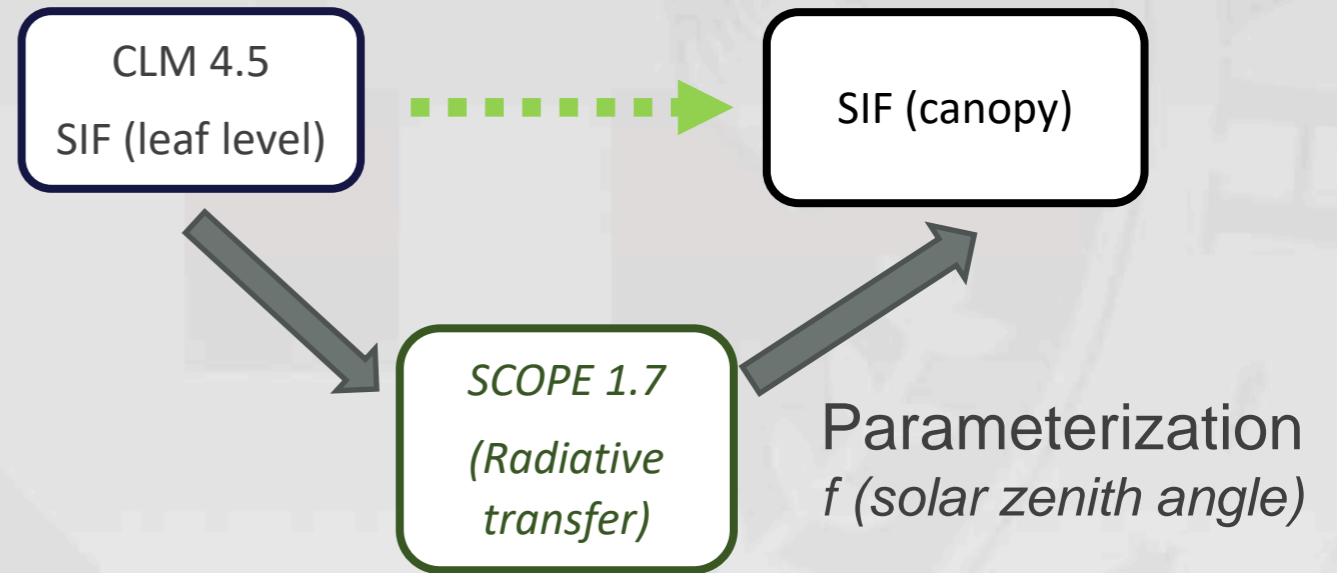
The models (with non-site specific SIF parameterization) work well so far, but the fit may be gratuitous:

- Need better calibration of APAR, and implementation of k_N (season). This will change the seasonal SIF.
- Need to evaluate the observed GPP-SIF relationship against the modeled GPP-SIF at Niwot Ridge to validate model performance.



Longer Term Goals

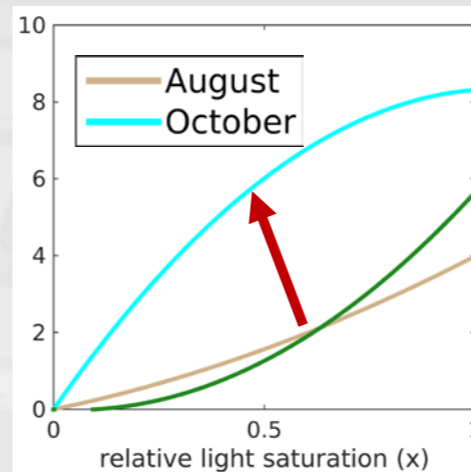
- Add explicit representation of fluorescence radiative transfer within CLM.



- Add prognostic representation of NPQ rate constant

empirical k_N

prognostic k_N



Environmental drivers
 k_N (eg. *temp, daylength*)

Acknowledgements

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Citations

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