Jet Propulsion Laboratory
California Institute of Technology

Solar Induced Fluorescence

Chlorophyll Fluorescence and Soil Moisture Observations to Characterize Terrestrial Vegetation Photosynthesis and Biosphere C Uptake in N America

Nicholas Parazoo, Nima Madani: *JPL, CalTech*

Xi Yang, Atticus Stovall: *University of Virginia*

Jochen Stutz, Ulrike Seibt, Katja Grossmann, Zoe Pierrat: *UCLA*

Christian Frankenberg, Philipp Koehler, Troy Magney: *CalTech*

Gretchen Keppel-Aleks, Zachary Butterfield: *Univ of Michigan*

John Kimball, Zhihua Liu, Lucas Jones: *Univ of Montana*

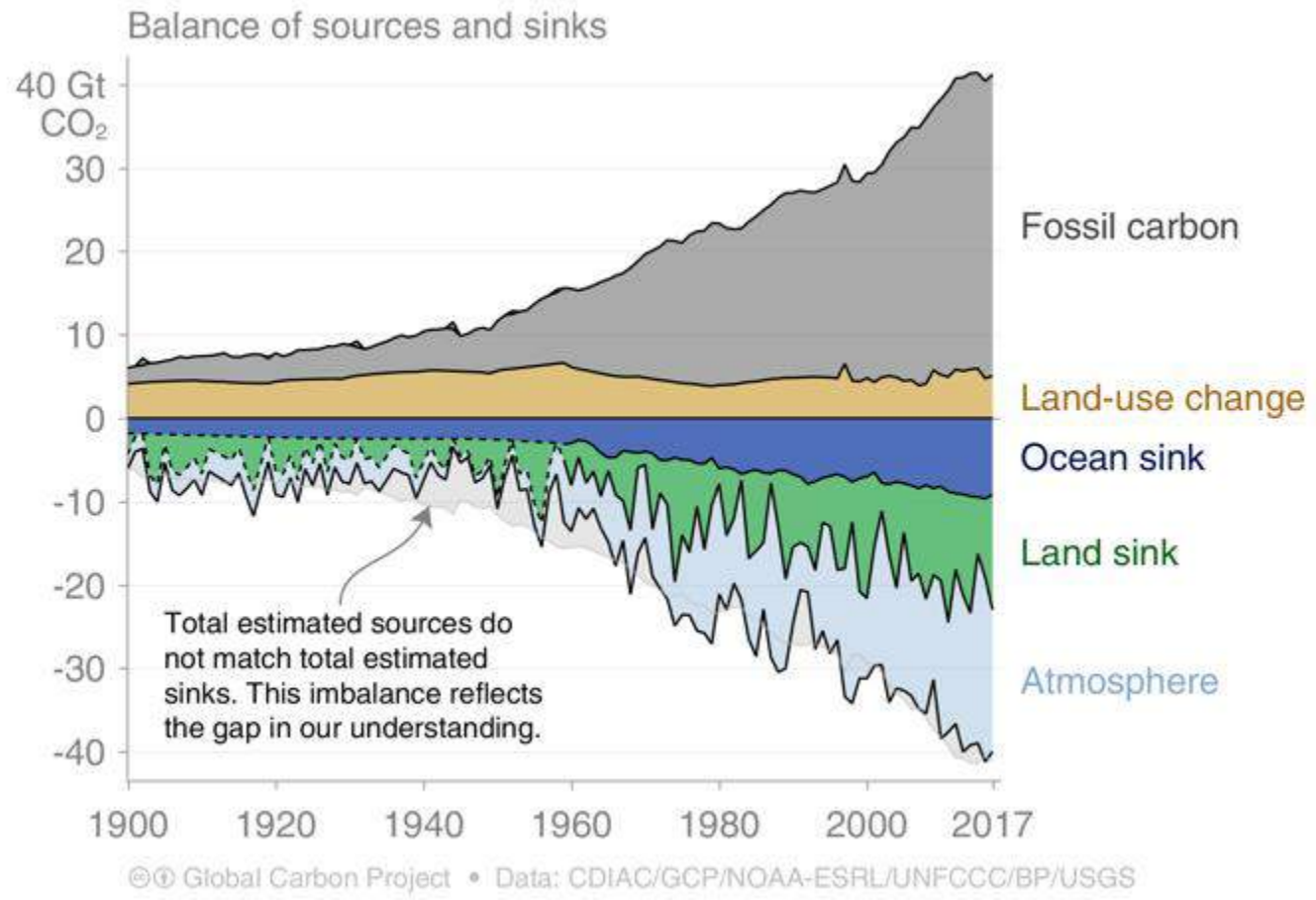
Eugenie Euskirchen: *University of Alaska - Fairbanks*

NASA Terrestrial Ecology Meeting

September 23, 2019

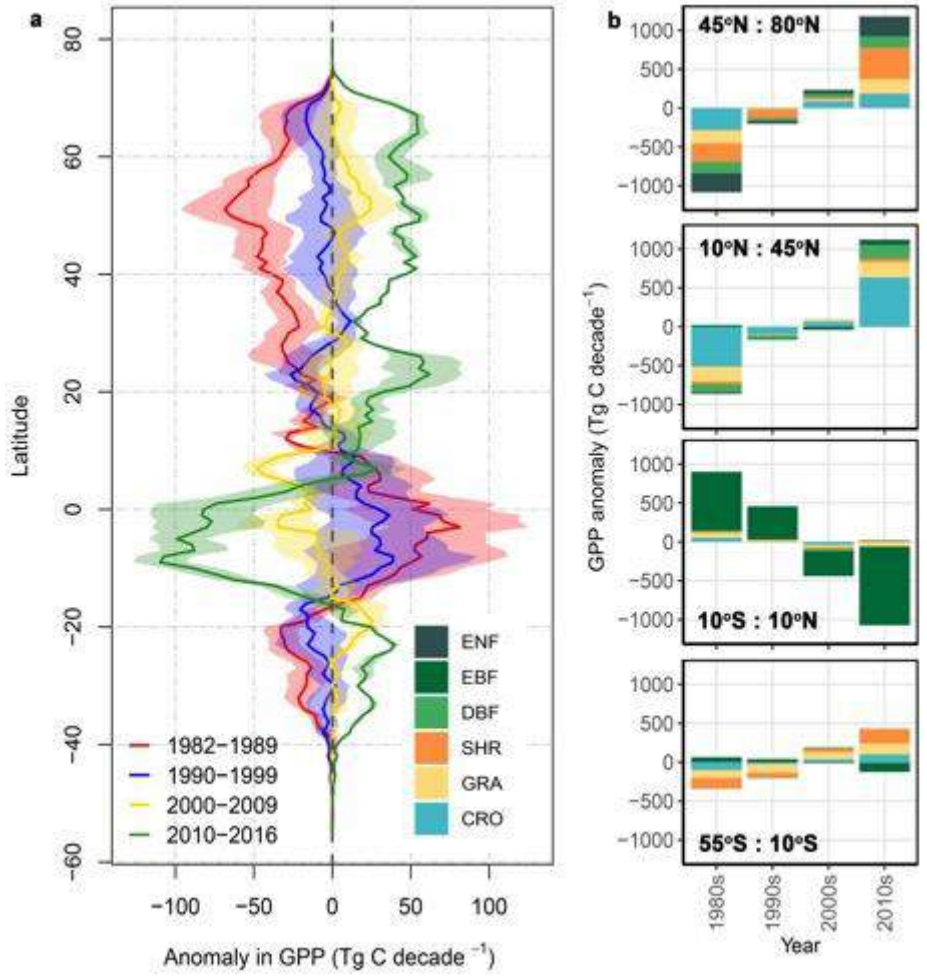
Strong Negative Feedbacks

- Both ocean and land act as strong and increasing CO2 sinks
- Sinks have historically grown stronger in rough proportion to emissions
- Earth system subsidy of ~ 50% of fossil fuel emissions



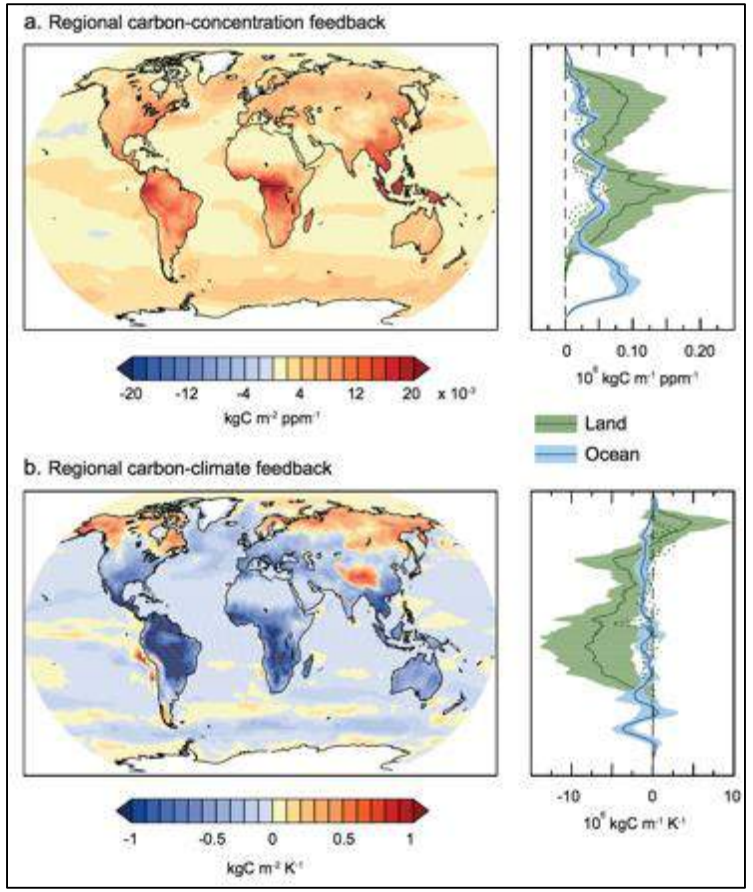
Increasing Carbon Sink in Northern High Latitudes (NHL)

Historical (1982-2016)



Madani et al., ERL, in review

Projection (2100)



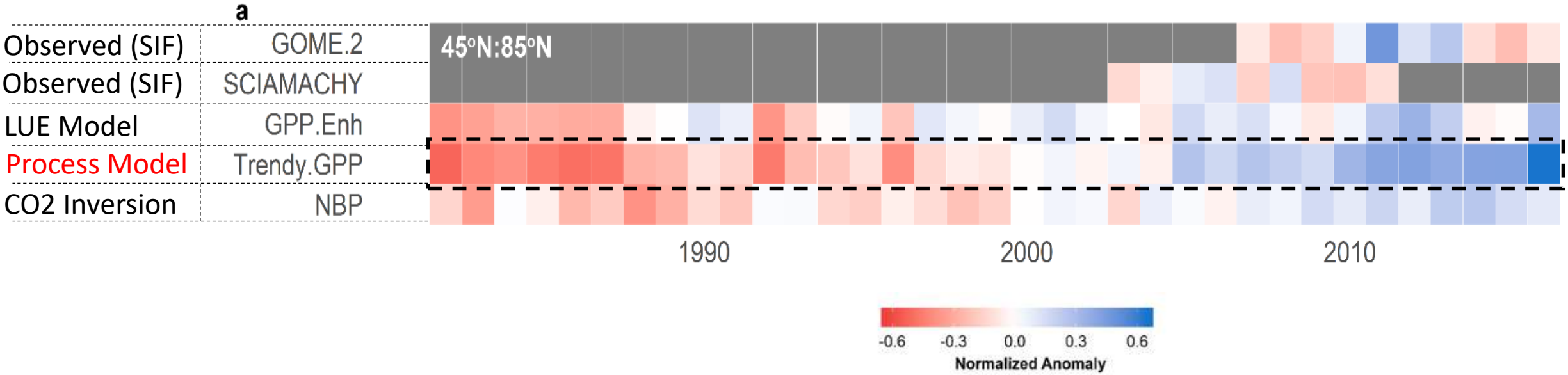
CO2 Fertilization

Climate

IPCC AR5, Ch 6

Models Overestimate NHL Sink

NHL's = 45N – 85N



Does this mean models are overestimating the future sink (in 2100)? Yes and No

Madani et al., ERL, in review

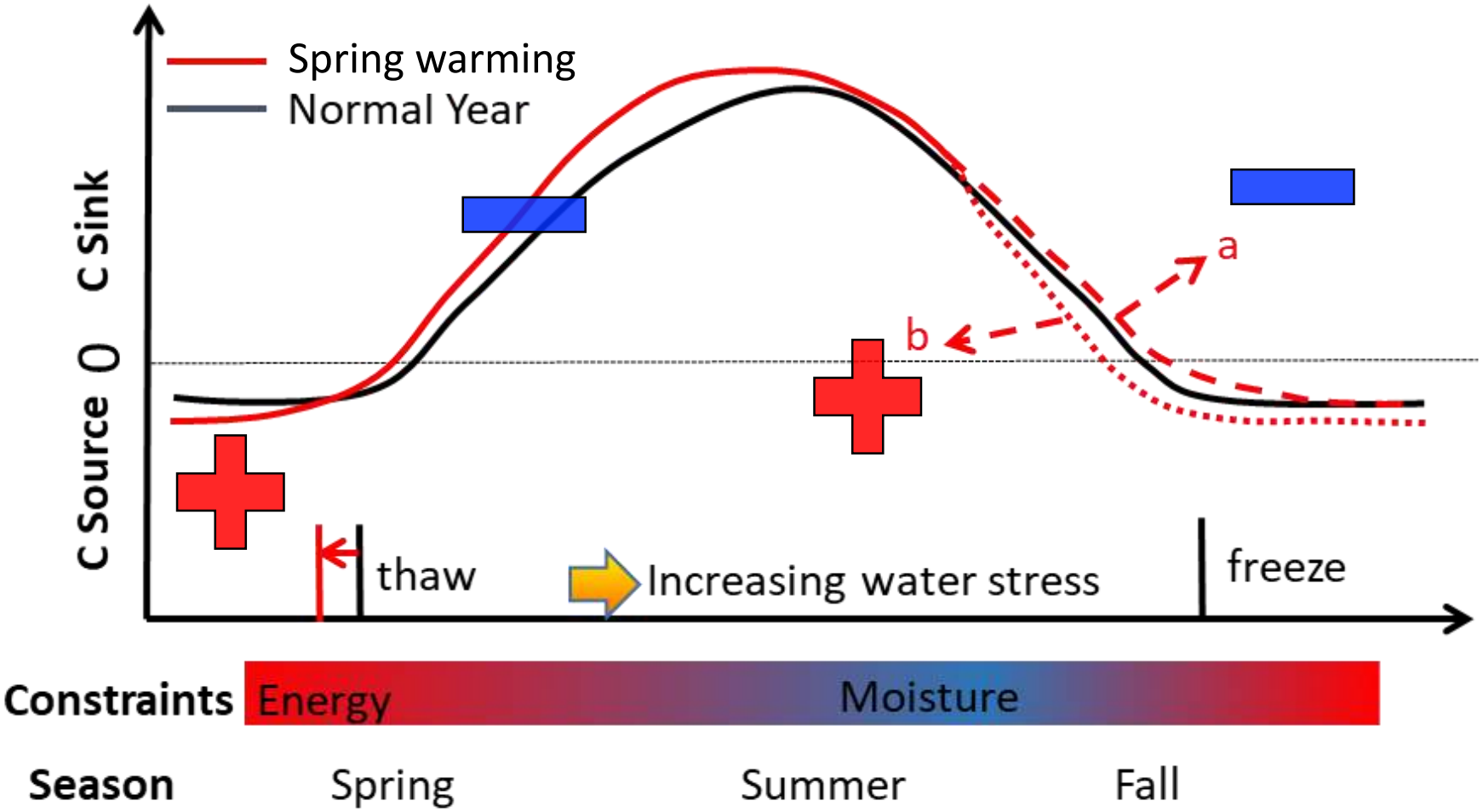
Questions

1. Why do models overestimate NHL sink?
2. How can we use remote sensing for:
   a) Process Attribution?
   b) Model Improvement?

Questions

1. **Why do models overestimate NHL sink?**
2. How can we use remote sensing for:
   a) Process Attribution?
   b) Model Improvement?

Seasonal Compensation: A Spectrum of Feedbacks

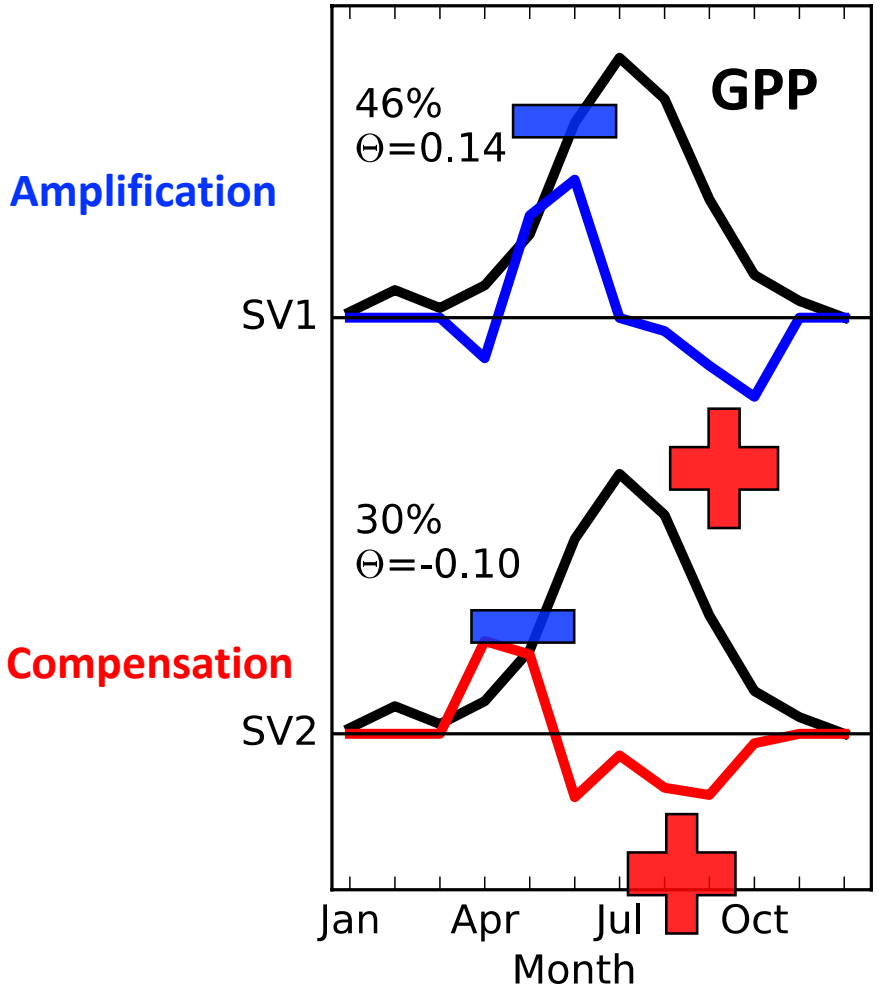


Zhihua Liu
Poster 49
Mon, 4-5 PM

Liu et al., Global Change Biology, Accepted

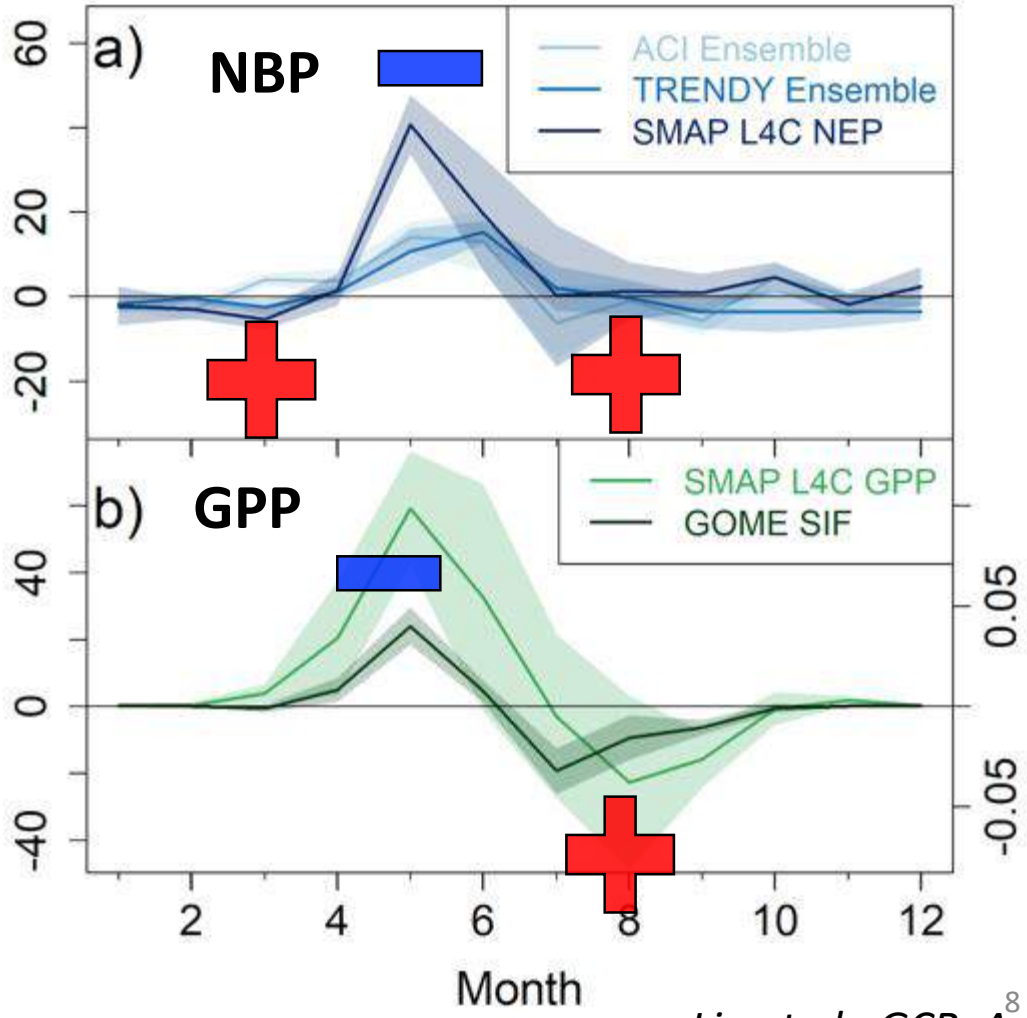
Tower and Regional Data Support Compensation Effect

Single Flux Tower (CA-OBS) -> IAV



Butterfield, Keppel-Aleks, in prep

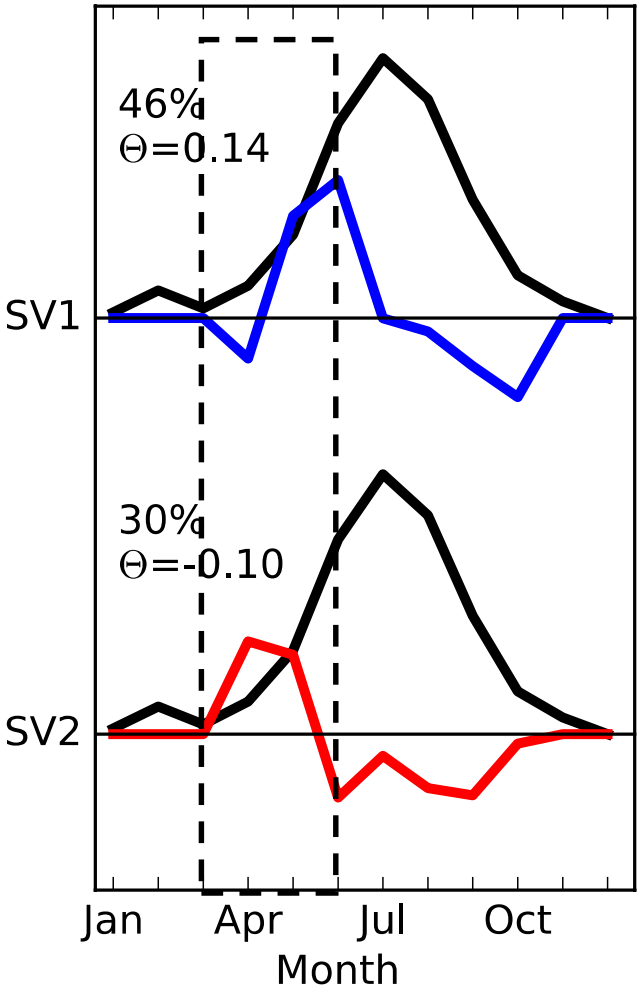
Regional Synthesis (ABoVE domain) -> ENSO



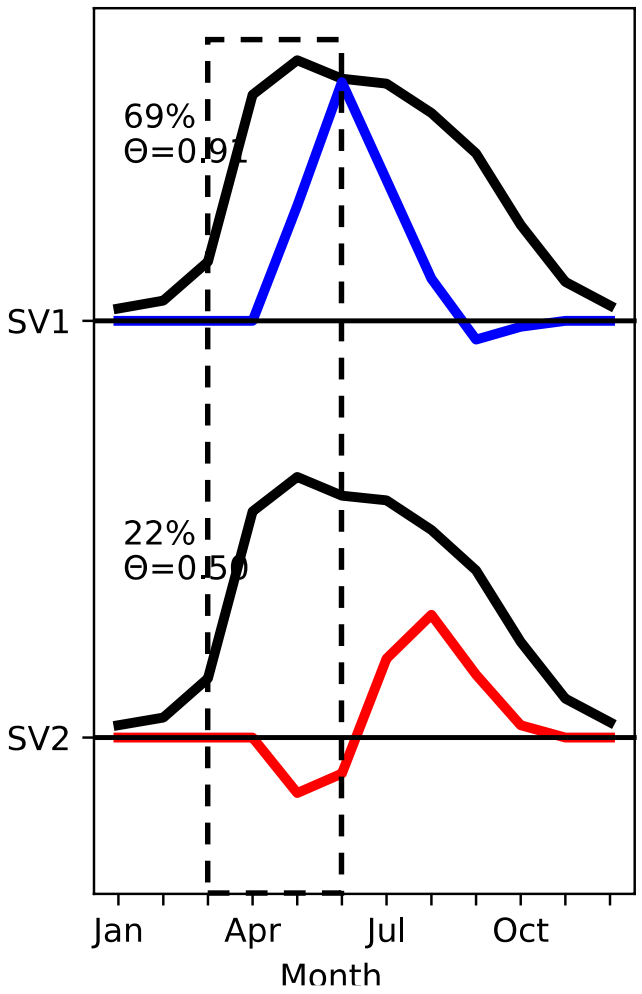
Liu et al., GCB, Accepted

Model bias

Tower Observed



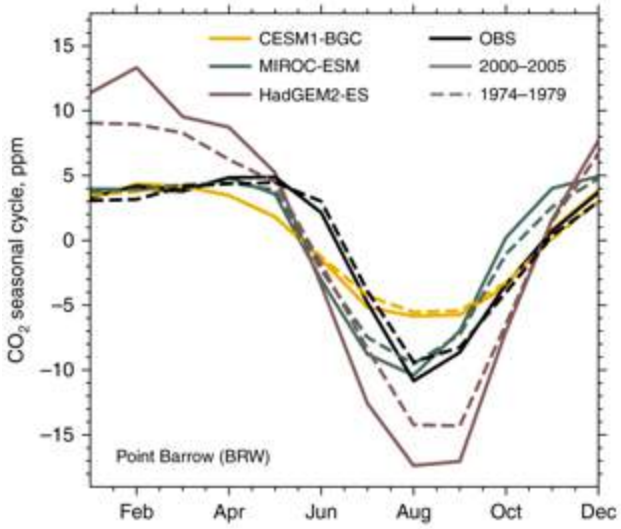
CLM5 Predicted



Butterfield, Keppel-Aleks, in prep

- Early spring (**good!**)
- Weak seasonal compensation (**bad!**)
- Strong Amplification (**bad!**)

Persistent Grow Seas bias in models



Winkler et al., 2019, Nature

Questions

1. Why do models overestimate NHL sink?
2. **How can we use remote sensing for:**
   a) **Process Attribution?**
   b) Model Improvement?

SIF Remote Sensing

Spaceborne + Airborne + Tower

FluoSpec2

CFIS

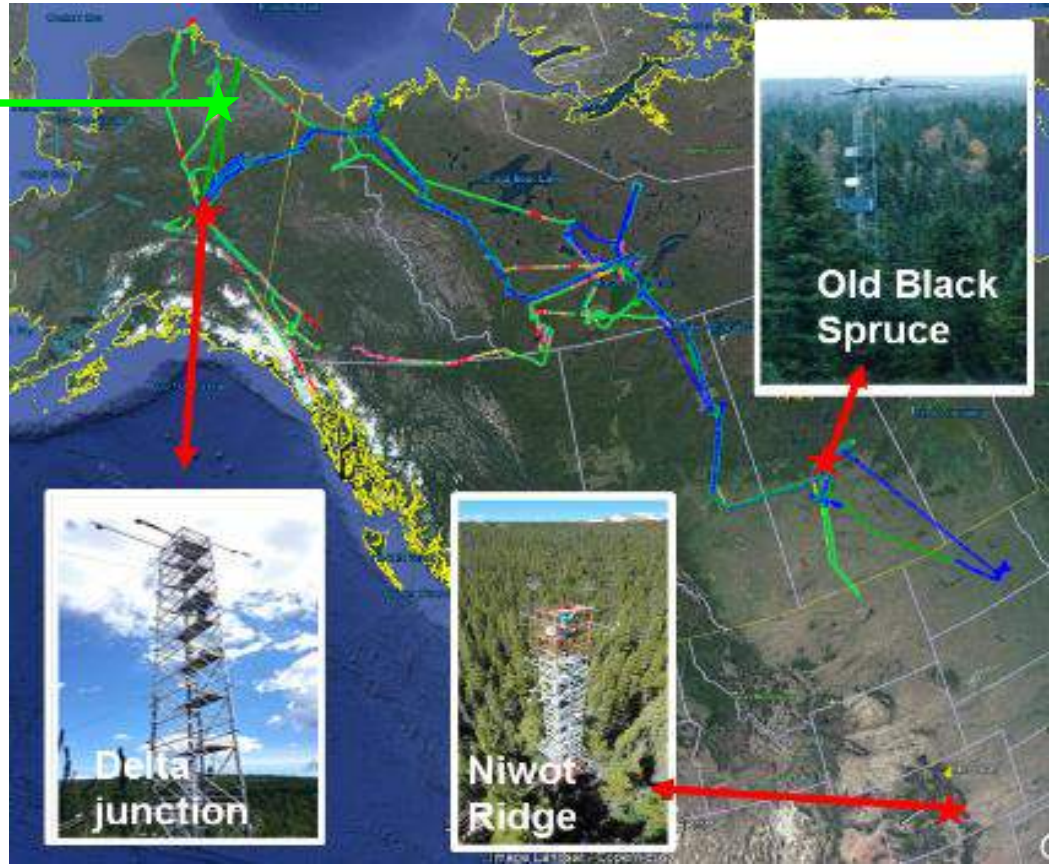


Fig. 10: Three tower field locations indicated by red stars. ABoVE flight lines (Green = AVIRIS, blue = CFIS)

PhotoSpec

Zoe Pierrat
Poster 51
Tuesday, 4-5 PM

Troy Magney
Poster 26
Mon, 5-6 PM

Deciduous/Tundra

Toolik: June 2017 –

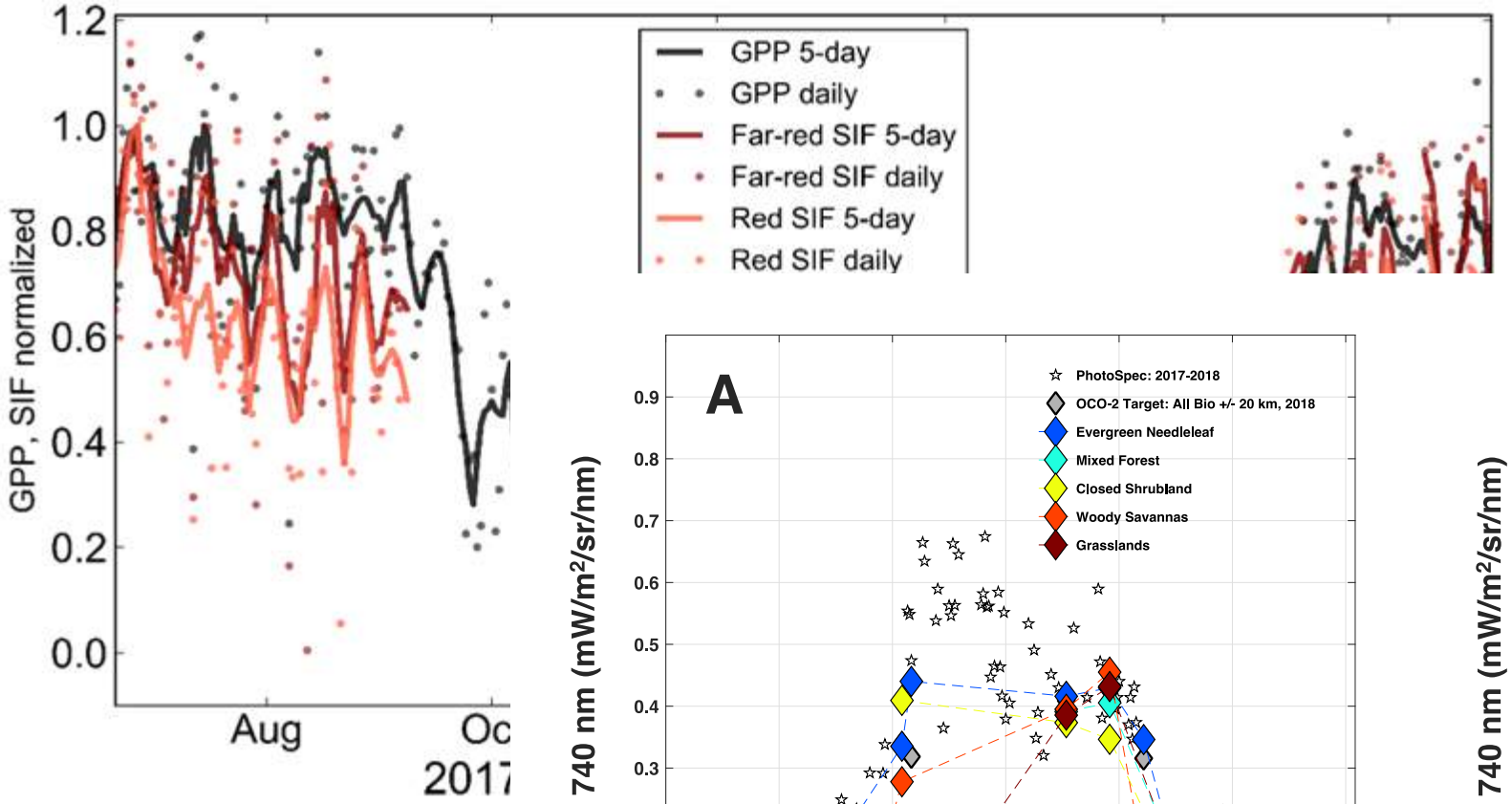
Evergreen/Boreal

Niwot Ridge (NR1): June 2017 –

Old Black Spruce (OBS): Sep 2018 –

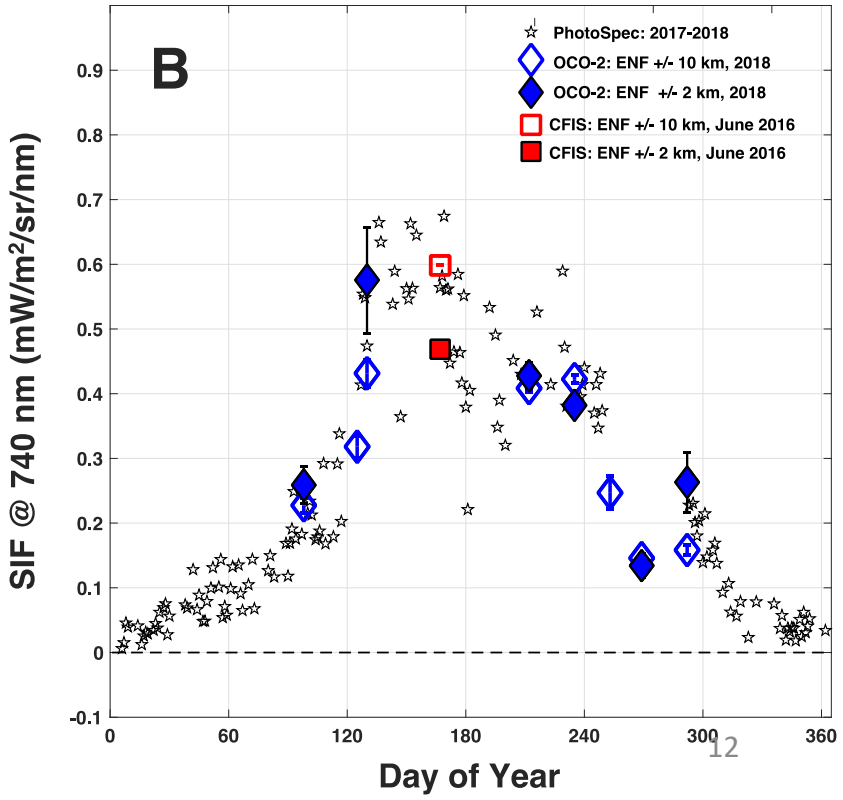
Delta Junction (DJU): Sep 2019 -

Multi-Scale SIF phenology constraint: Niwot Ridge

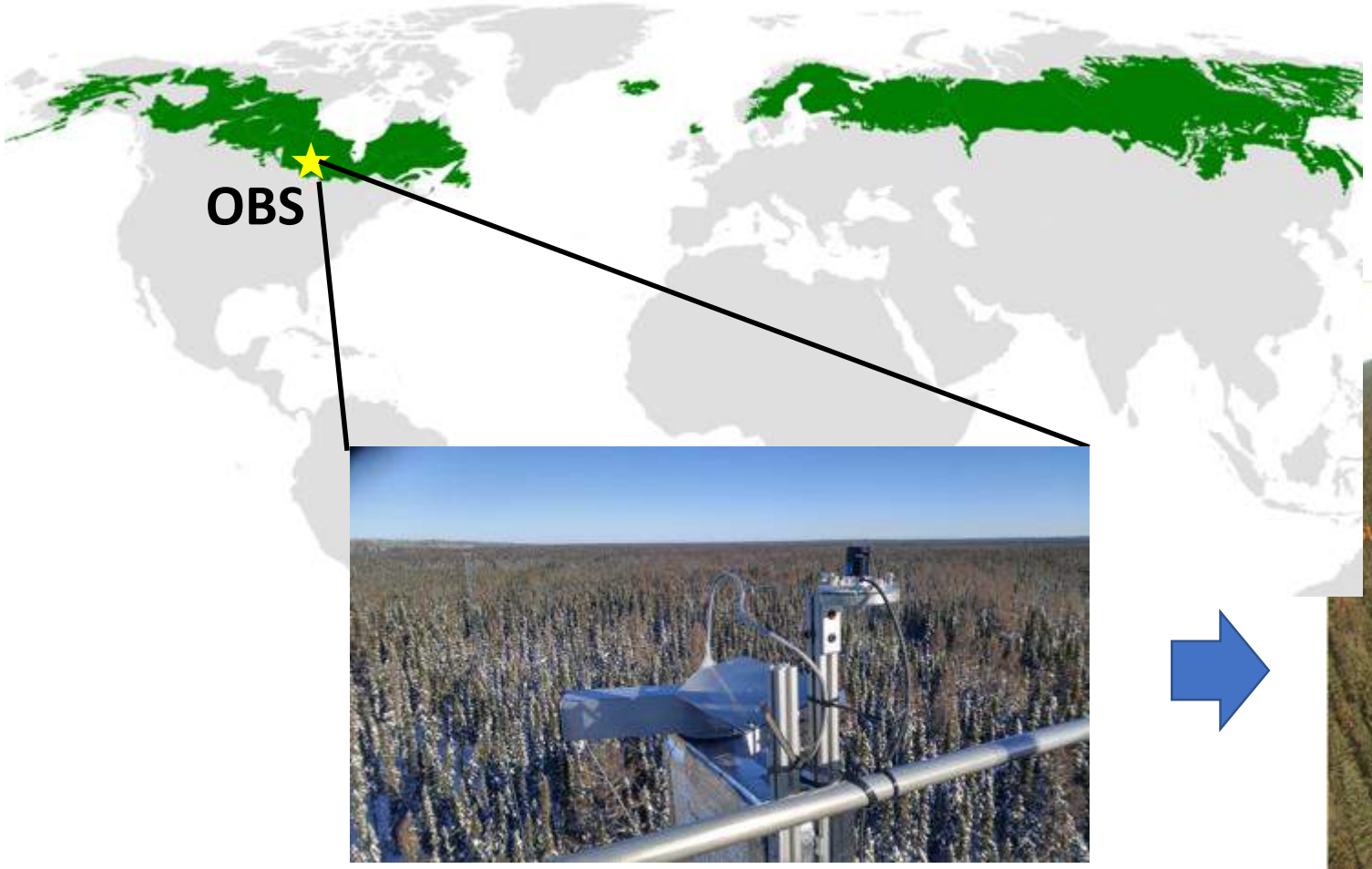


Magney et al., 2019, PNAS

Parazoo et al., 2019, JGR-Bio

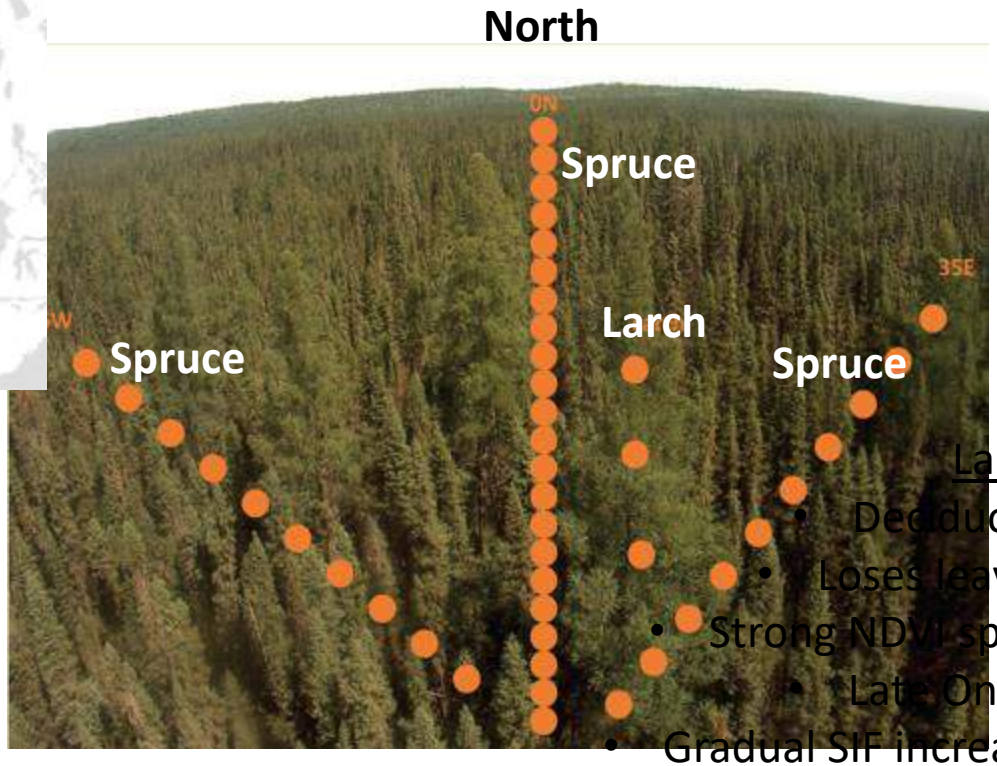


Scanning the Southern Boreal Forest for Spring Onset



Spruce: Evergreen (Retains Needles)

Larch: Deciduous (Seasonal Foliage)

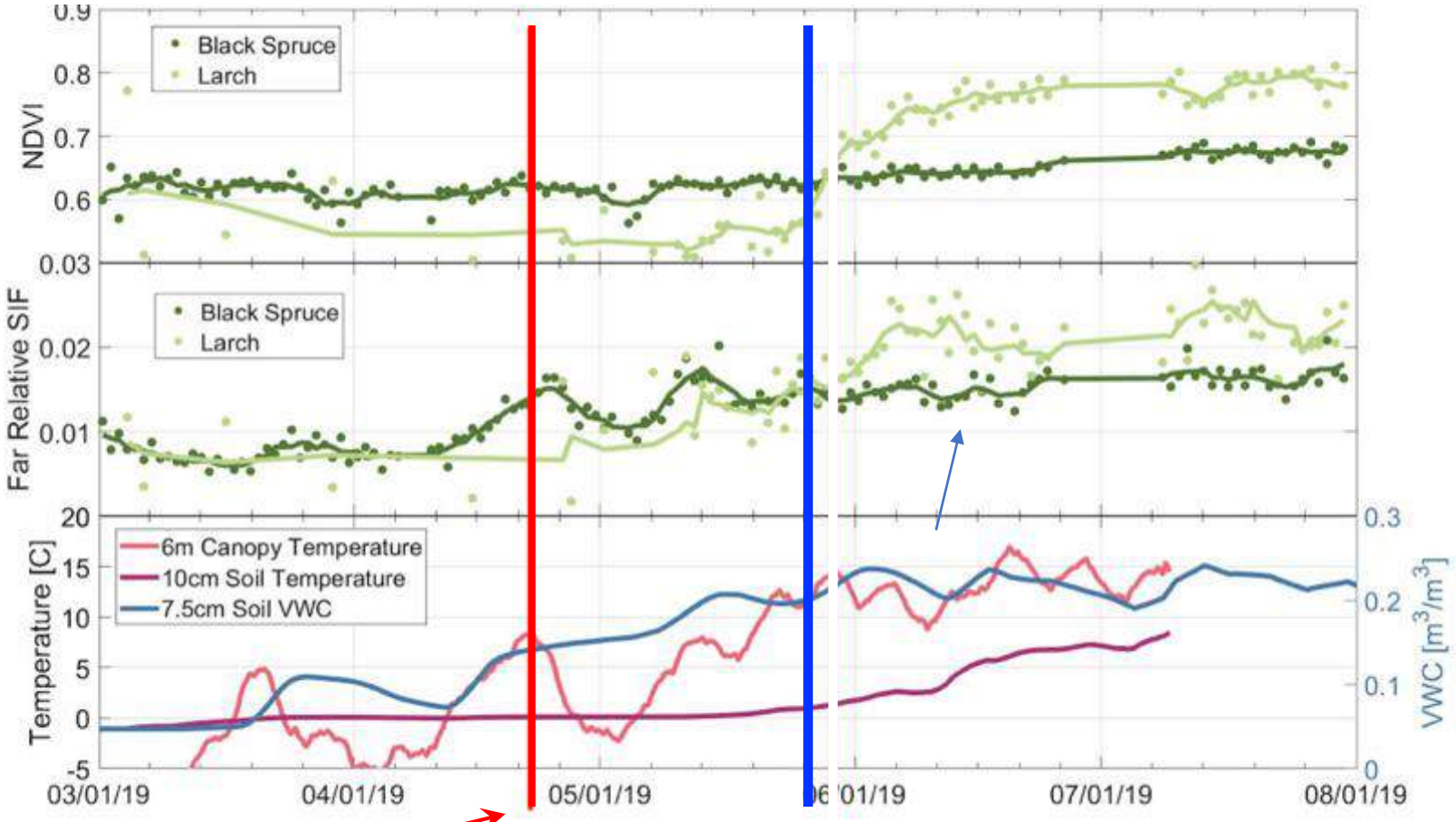


Larch
- Deciduous
- Loses leaves
- Strong NDVI spike
- Late Onset
- Gradual SIF increase with soil thaw

Zoe Pierrat: Poster 51, Tuesday 4 pm

Phenology Differences Revealed by PhotoSpec

Zoe Pierrat:
Poster 51,
Tues 4 pm

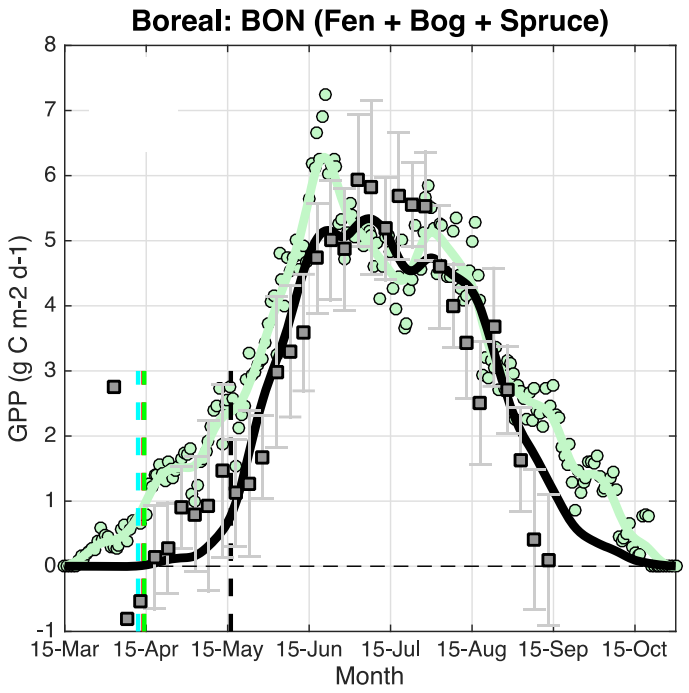


<u>Spruce</u>
- No NDVI change
- Early Onset
- SIF spike correlated to soil water and air temperature

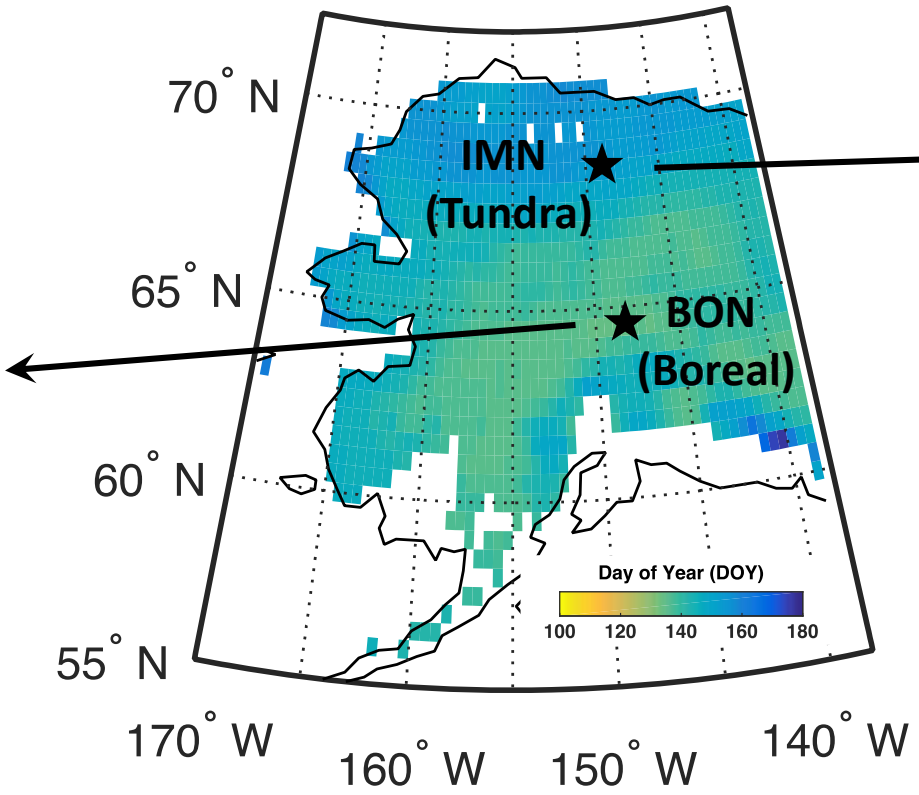
~ 1 month offset in photosynthetic onset

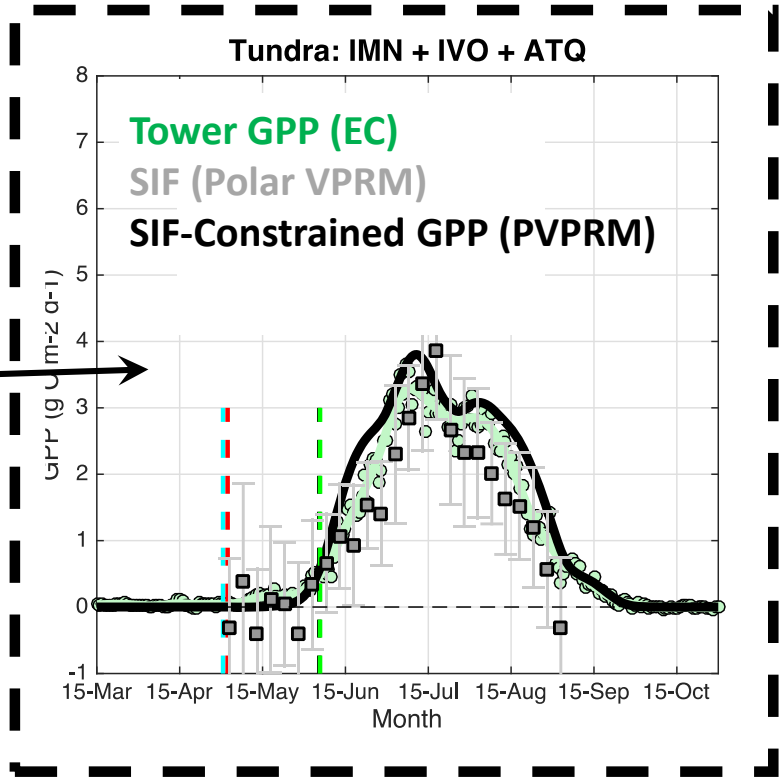
<u>Larch</u>
- Strong NDVI spike
- Late Onset
- Gradual SIF increase with soil thaw

Satellite phenology in Alaskan boreal/tundra



Spring GPP Onset
(Spaceborne SIF)





Boreal Spruce

- SIF spike correlated to air temperature
- **Not** detected by spaceborne SIF (early morning bias in GOME-2)

Tundra Shrub

- Gradual SIF increase following snow melt and soil thaw
- **Detected** by spaceborne SIF

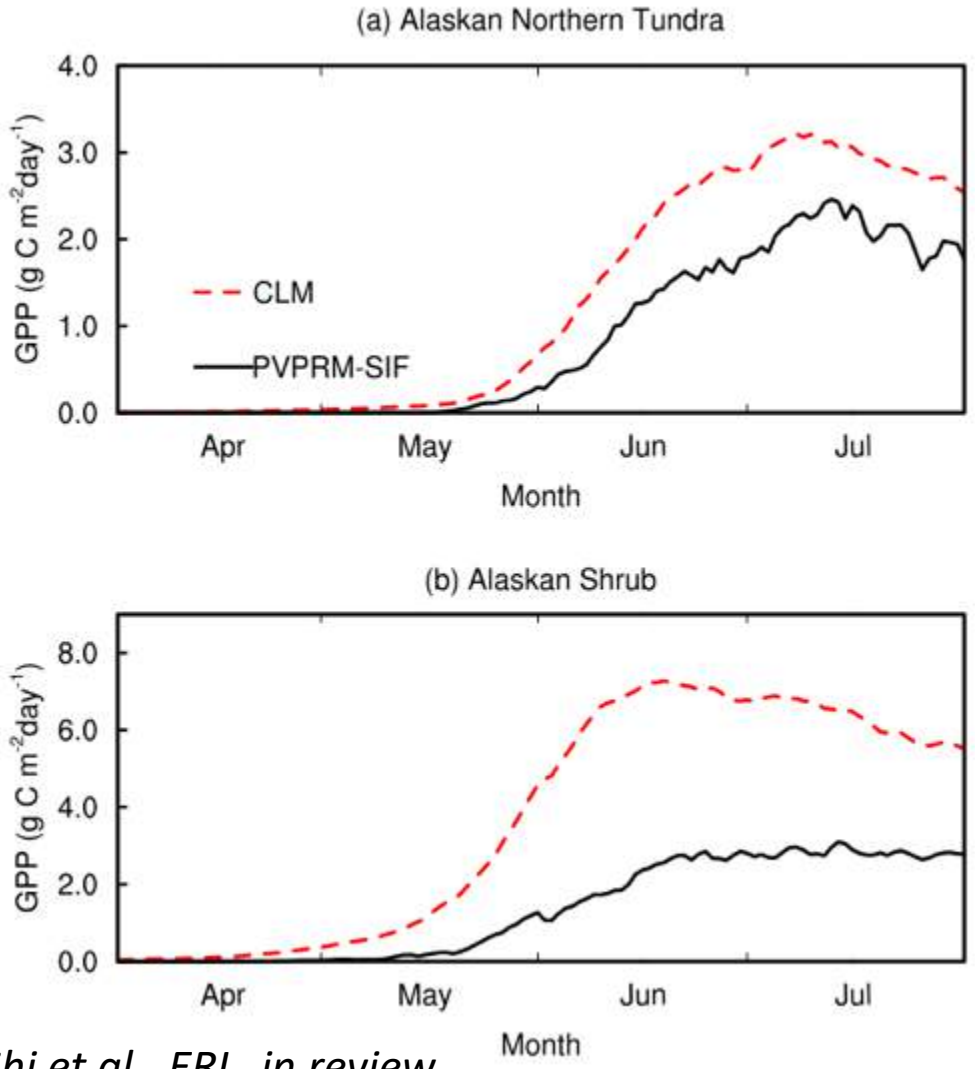
Parazoo et al., GCB, 2018

Questions

1. Why do models overestimate NHL sink?
2. **How can we use remote sensing for:**
   a) Process Attribution?
   b) Model Improvement?

Model Benchmarking

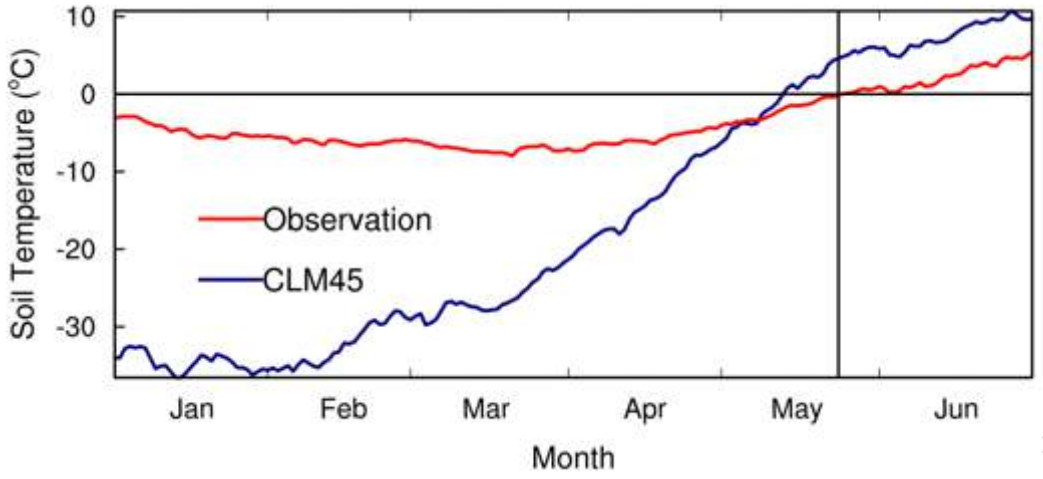
GPP Onset



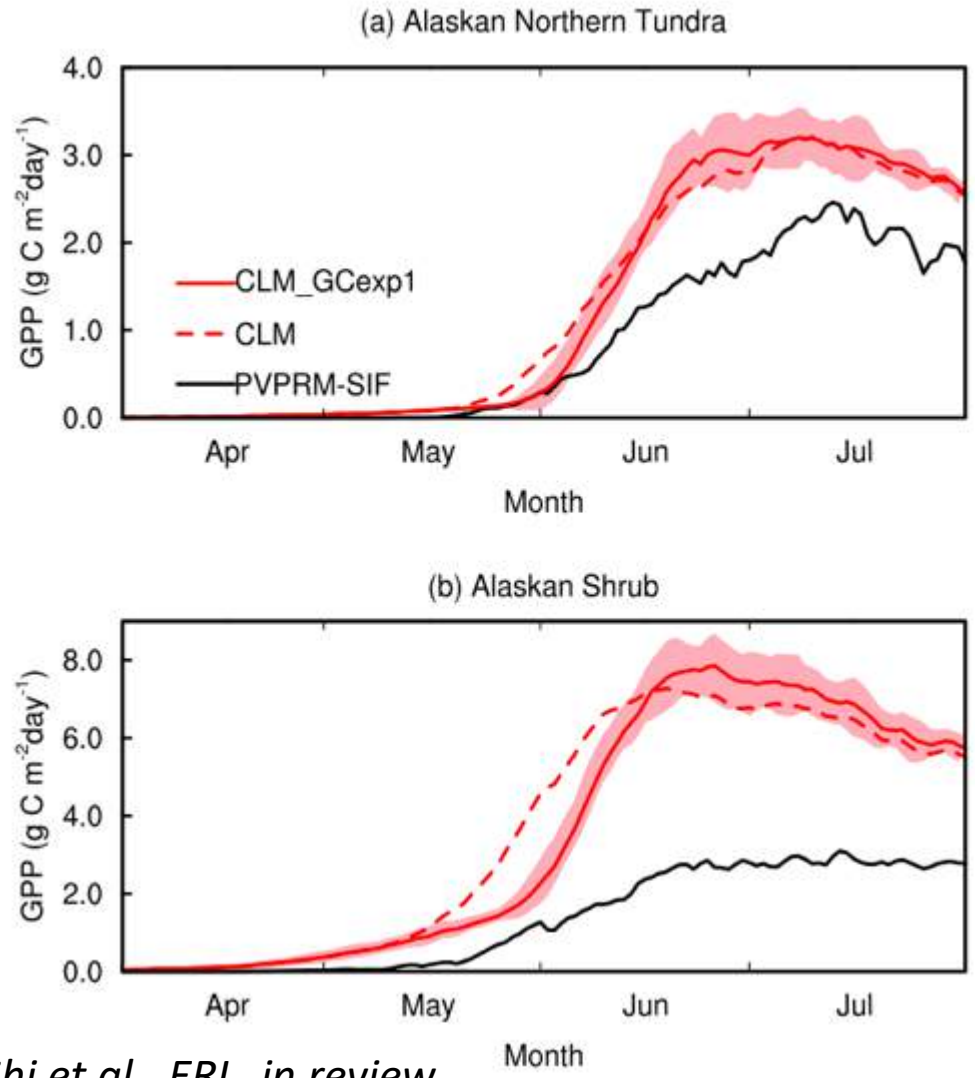
Shi et al., ERL, in review

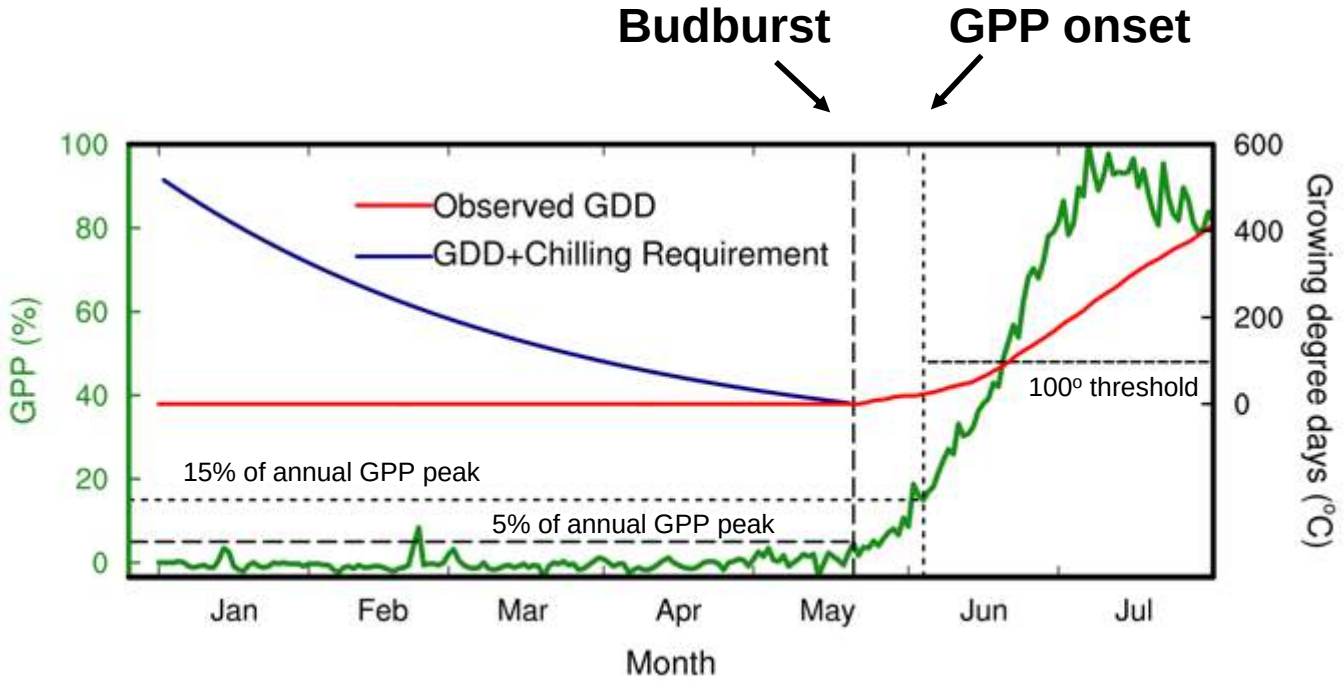
- Early GPP onset in CLM (left)
- Phenology predicted as function of soil temp, which increases too early (below)
- Soil temp is **very challenging!**

Soil Thaw (Imnavait Creek)



Modified Budburst Scheme: f(Tair)



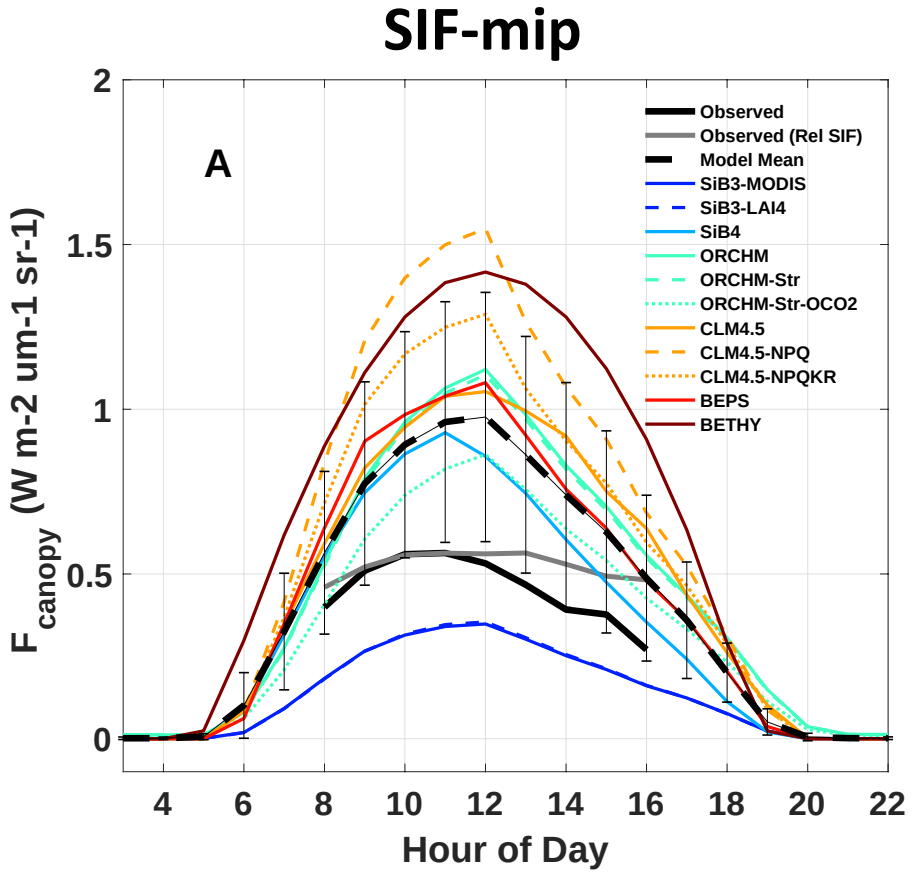


- Timing is improved
- But... offset by amplified growing season bias

Shi et al., ERL, in review

Future work

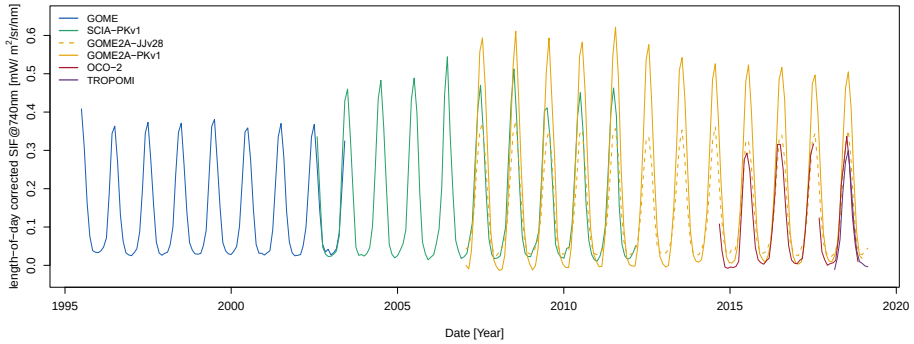
- Compare CLM thaw to observed F/T data
- Compare snow models
- More formal approach to optimize budburst scheme (against Eddy Covariance data)
- Assimilate/hardwire soil thaw and SIF (CLM-DART)
- SIF model intercomparison



MEaSUREs SIF ESDR

Improving Sensor Consistency, Duration, and Uncertainty Quantification

Information



Archiving: ORNL

http://sif2.jpl.nasa.gov/ (coming soon!)

Conclusions

- Strong negative carbon-climate feedback in Northern High Latitudes (**Carbon Sink!**)
- Models and observations agree that sink is increasing, but **models overestimate trend** in part due to **early soil warming and early start of season**
- **Good news**: More potential to lengthen growing season with warming and maintain sink
- **Bad news**: Early signs of seasonal compensation (winter warming, fall drying) as a limiting factor and increasingly important positive feedback

Acknowledgements

A portion of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. We acknowledge the Earth Science Division Interdisciplinary Science (IDS) and Making Earth Science Data Records for Use in Research Environments (MEaSUREs) programs.