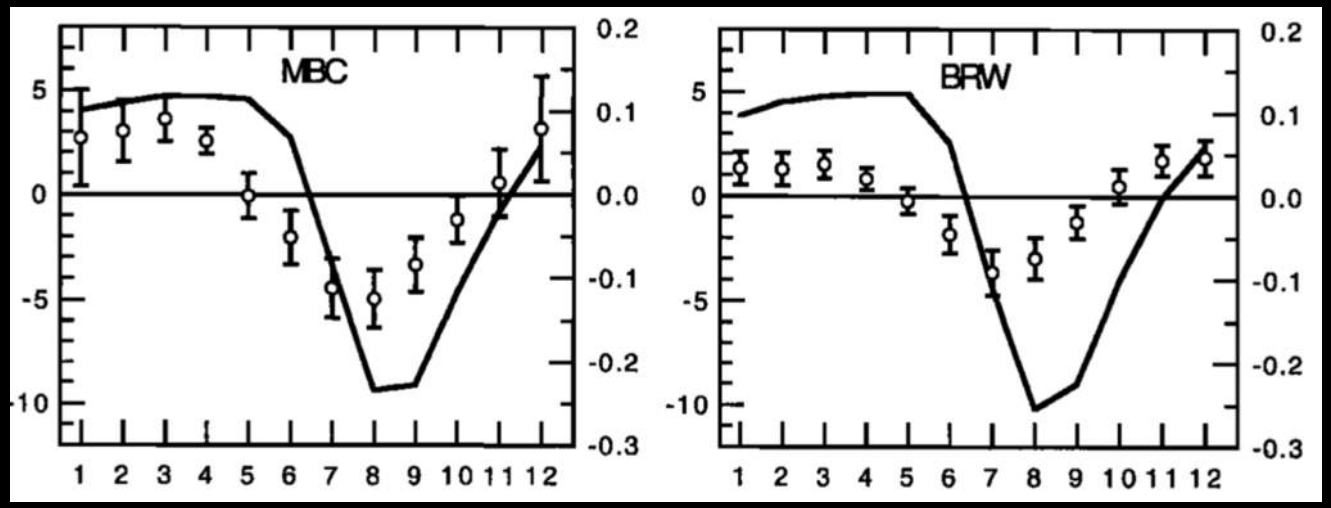
Understanding the Causes and Implications of Enhanced Seasonal CO_2 Exchange in Boreal and Arctic Ecosystems (Rogers CARBON 2016)

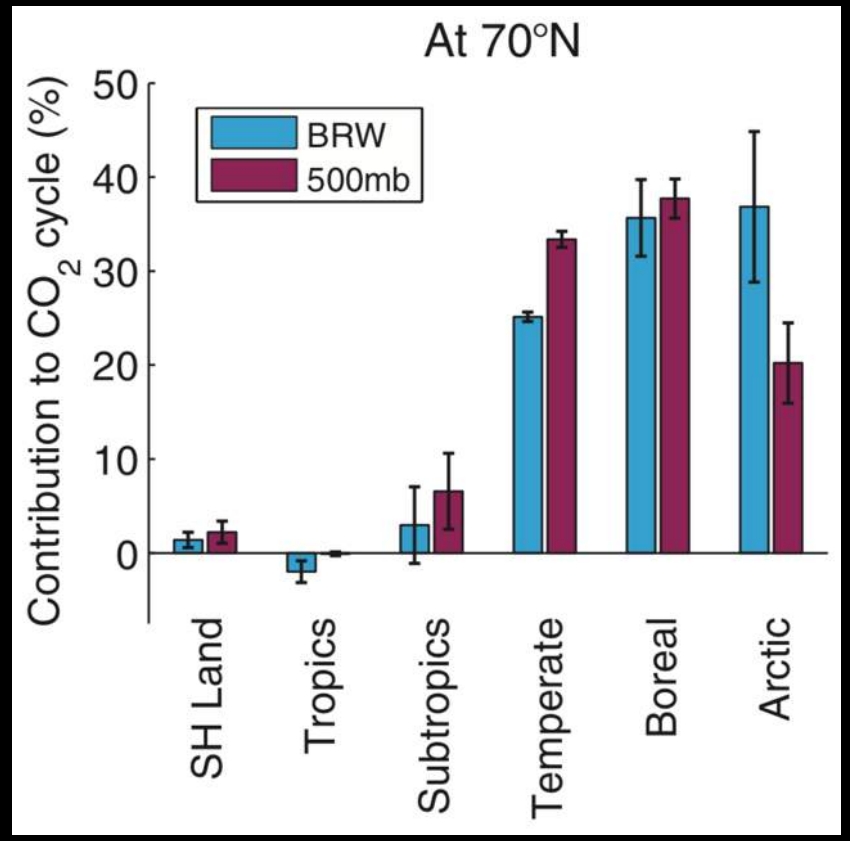
NASA Terrestrial Ecology Science Team Meeting 2019

Brendan Rogers, Leah Birch, Scott Goetz, Gretchen Keppel-Aleks, Xin Lin, Richard Massey, Sue Natali, Stefano Potter, Christopher Schwalm, Amber Soja, and Jennifer Watts

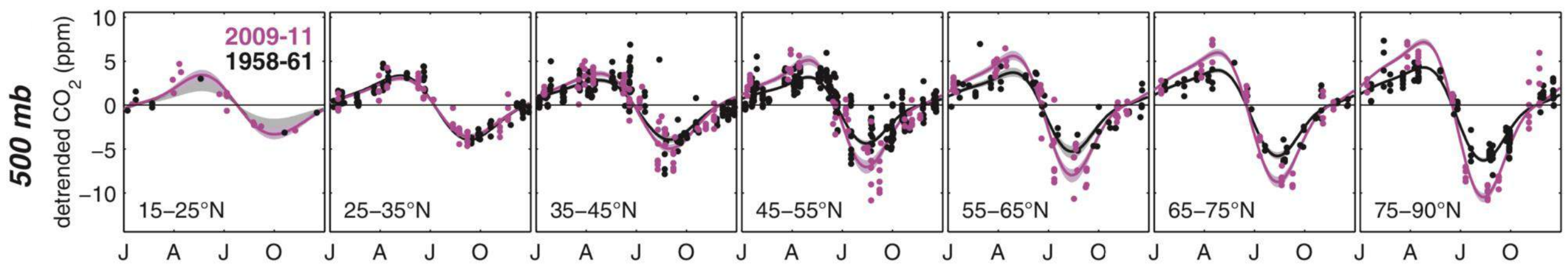
Increasing seasonal cycle amplitude (or "The hyperventilating biosphere")



Randerson et al. (1997)



Graven et al. (2013)



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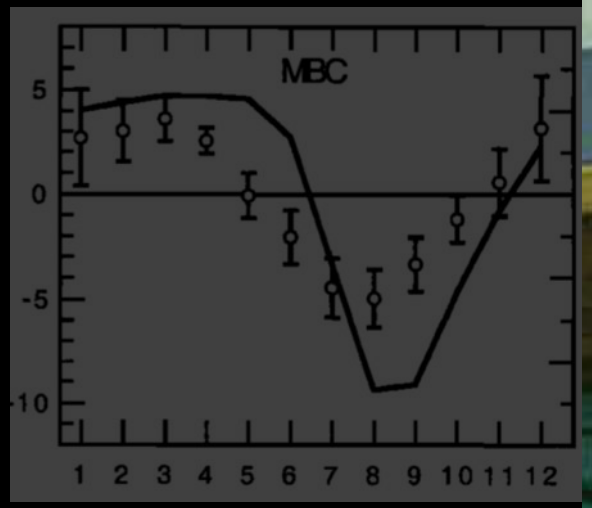

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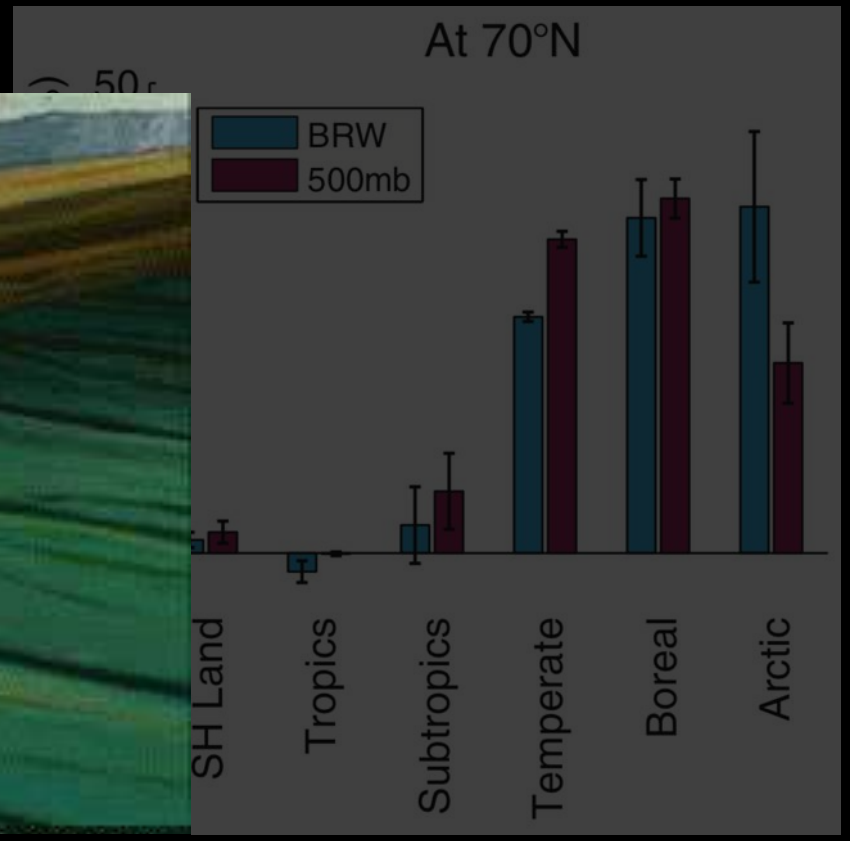

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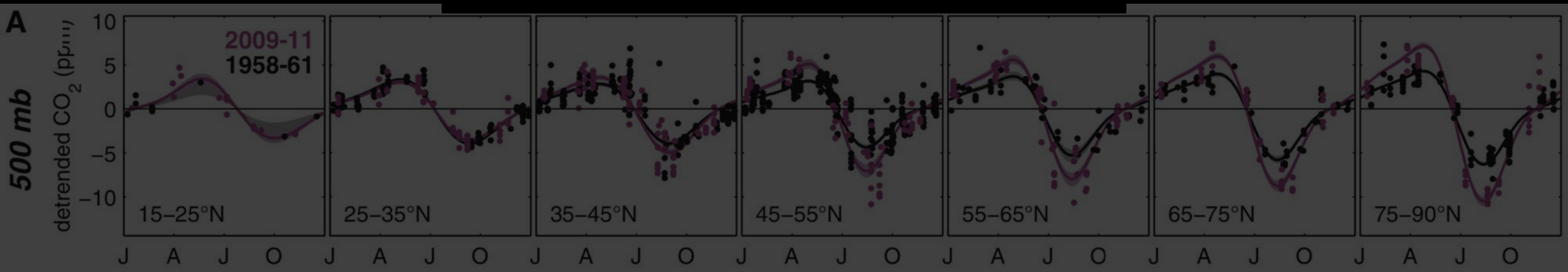
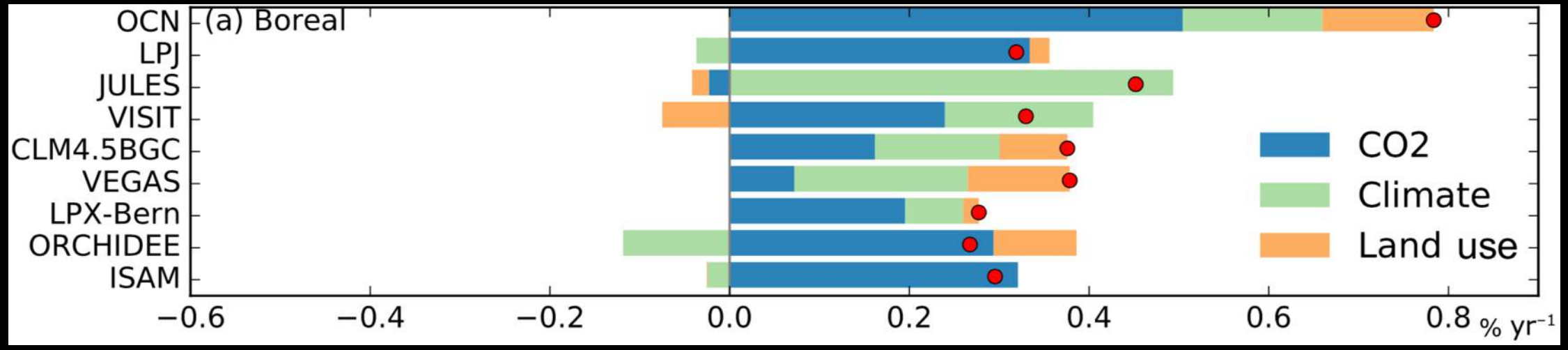


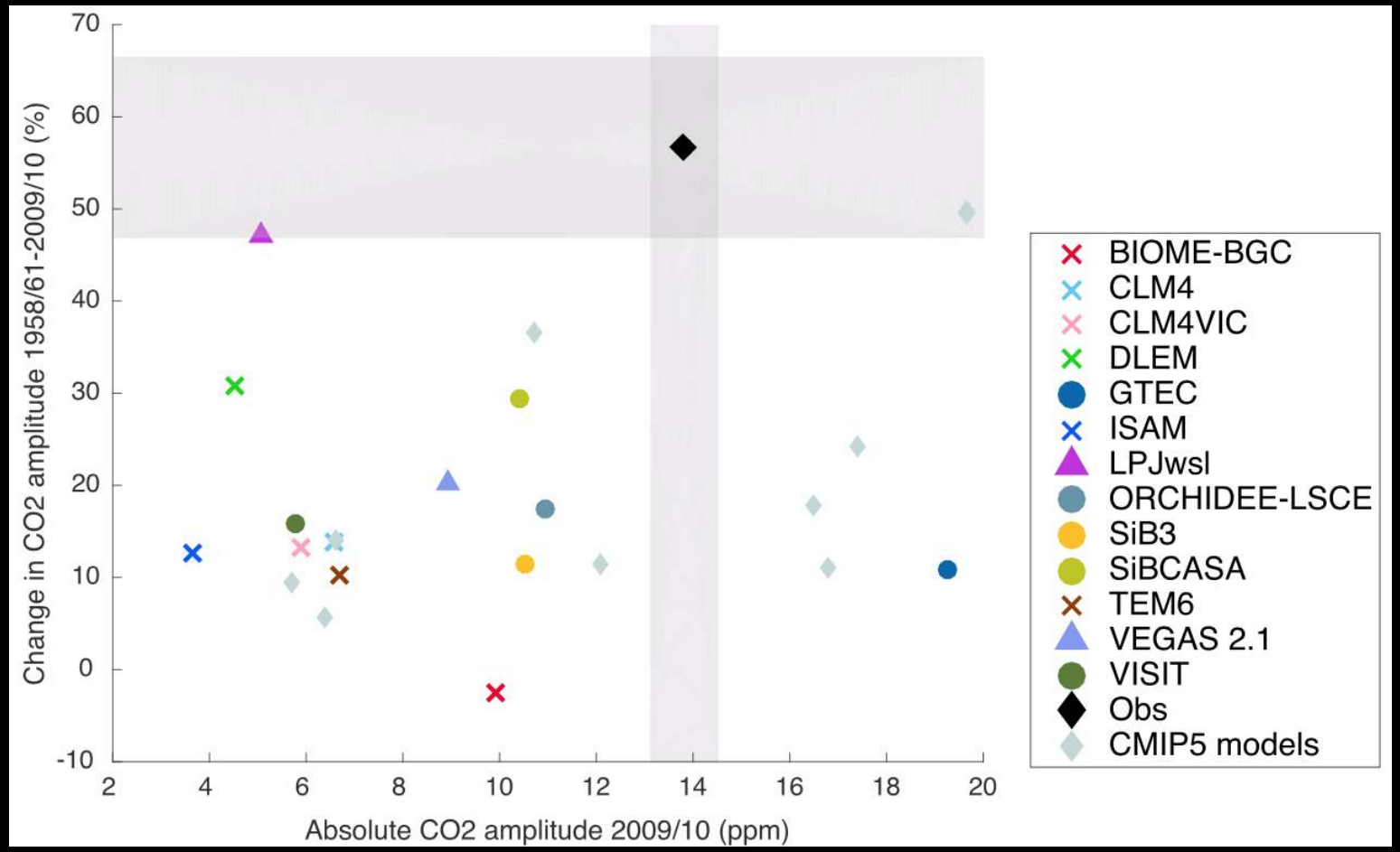
Models attribute to climate change & CO_2 fertilization



Zhao et al., 2016

Similar findings by Zhao et al. (2016), Thomas et al. (2016), Ito et al. (2017), Piao et al. (2017), and others

But model performance is…"iffy"



Thomas et al., 2016

- Cannot represent observed amplification

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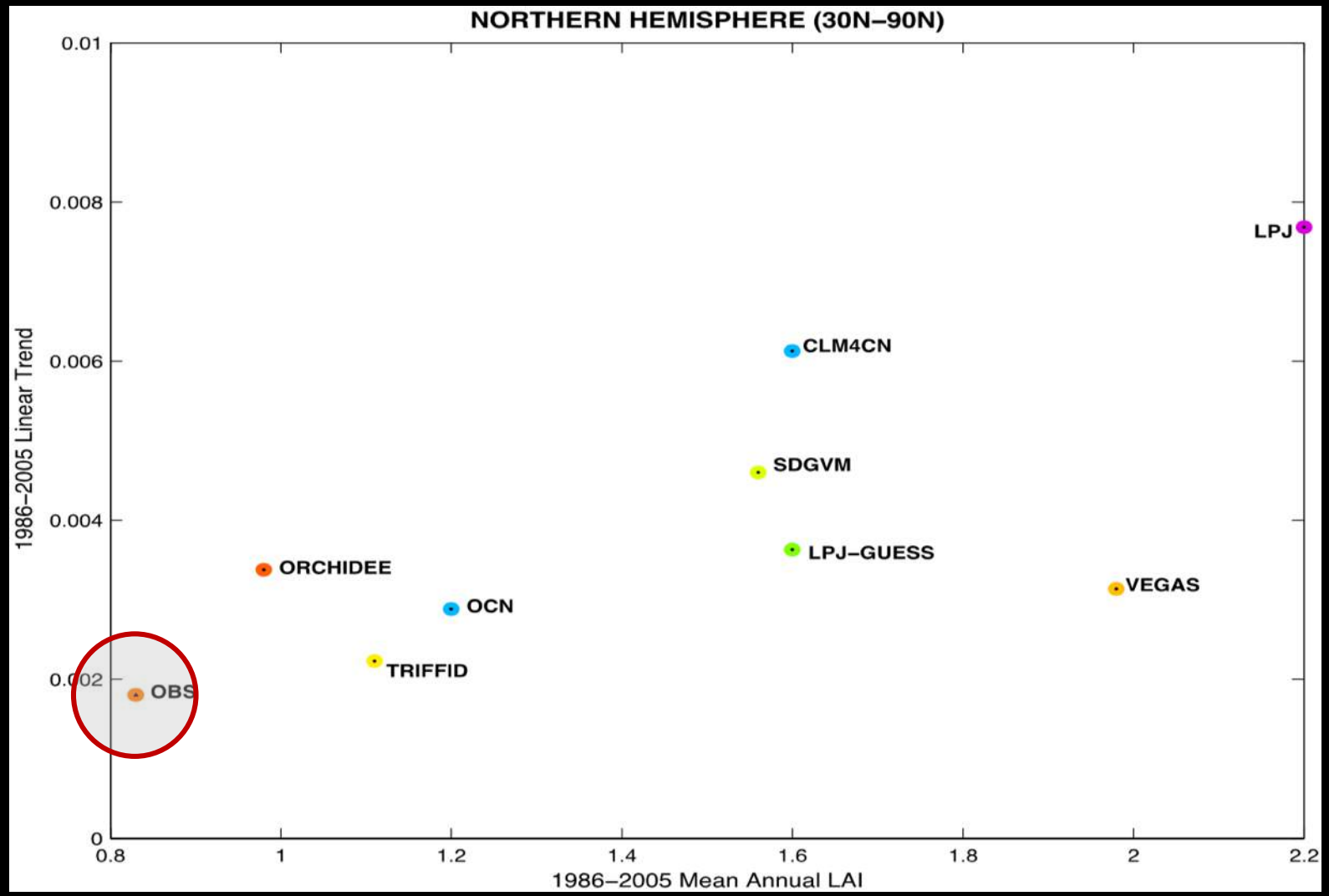

Murray-Tortoralo et al., 2013

- Cannot represent observed amplification
- Overestimate LAI and greening

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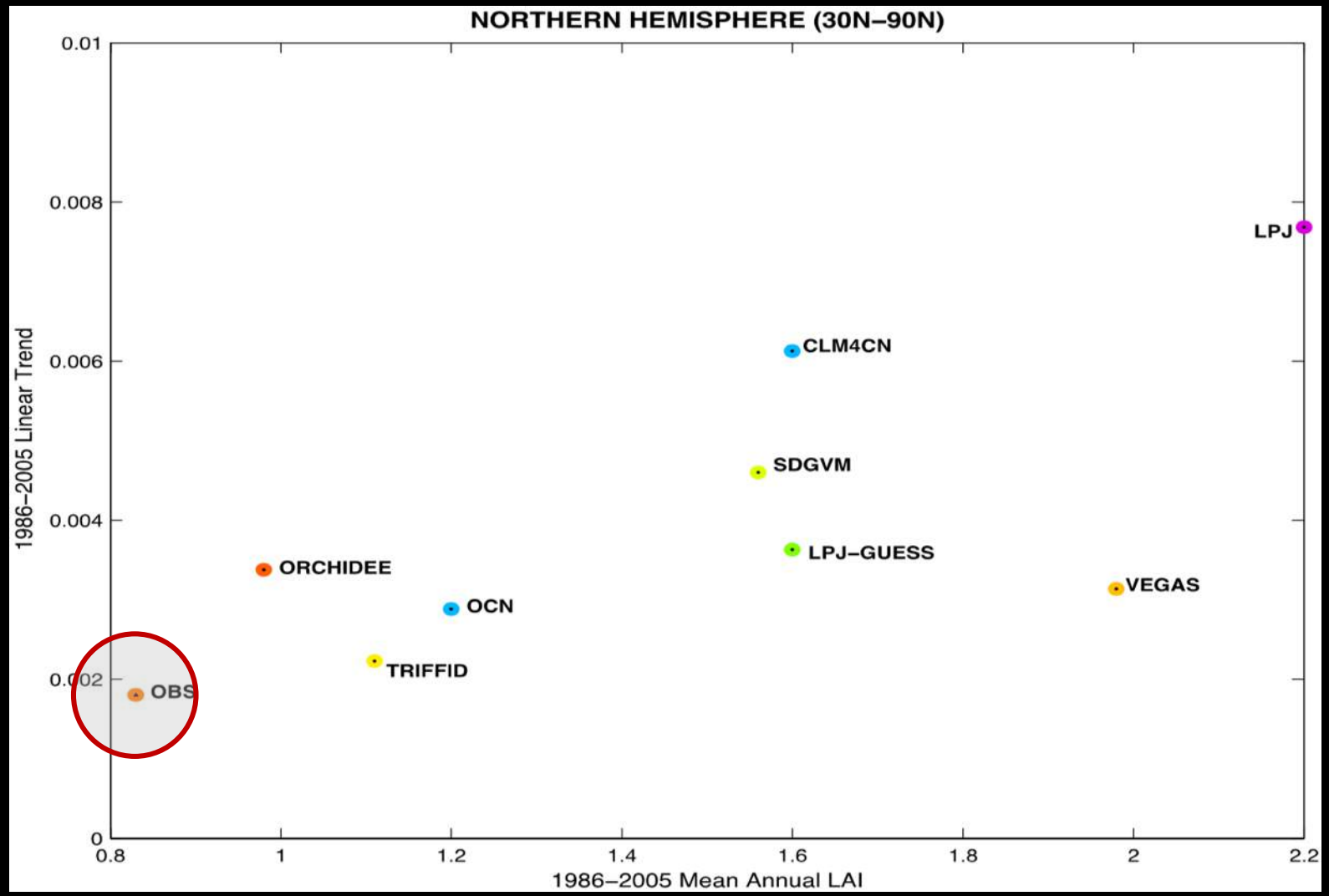

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- Misrepresent impact of warming on CO_2 uptake (e.g., Zhu et al., 2019)

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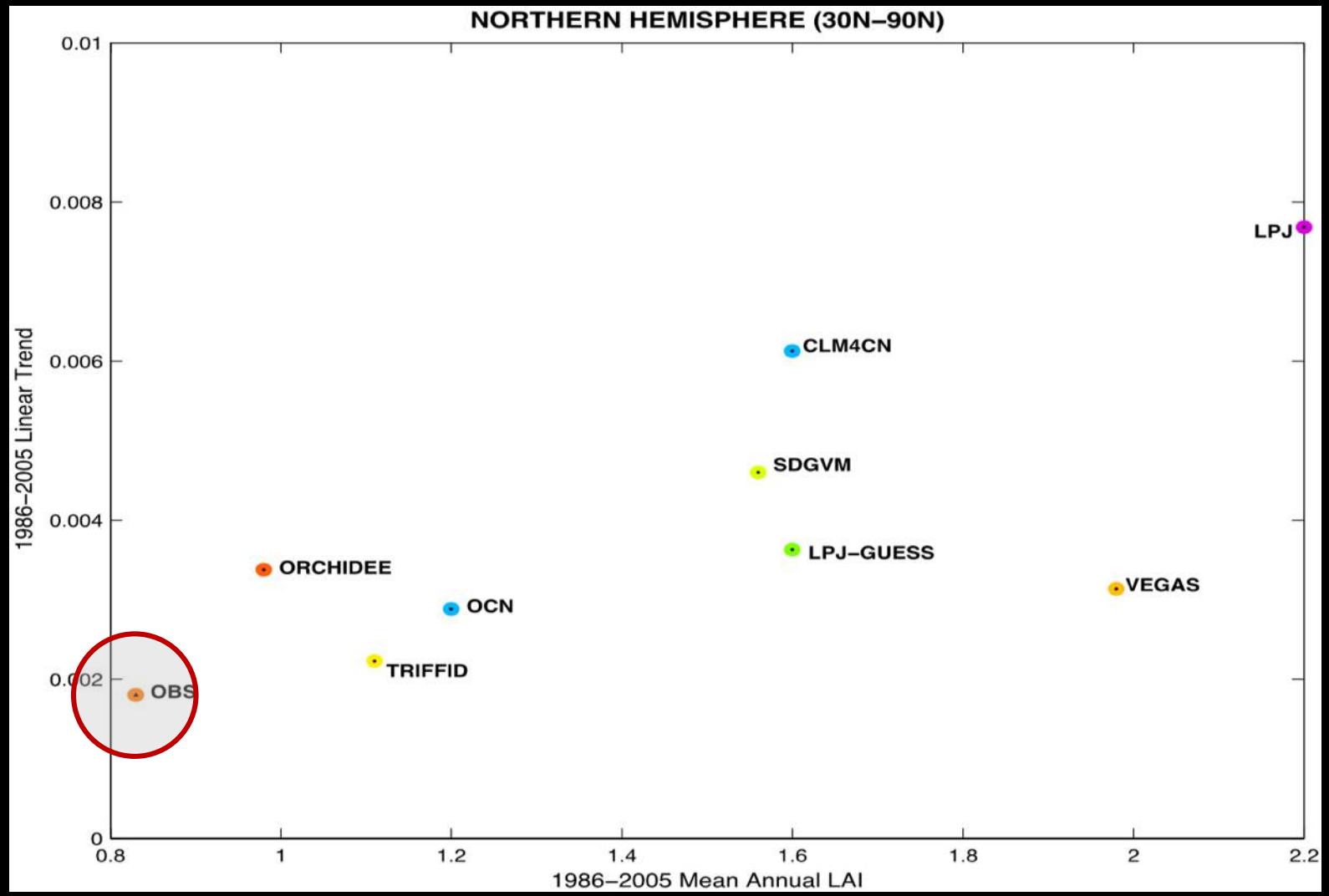
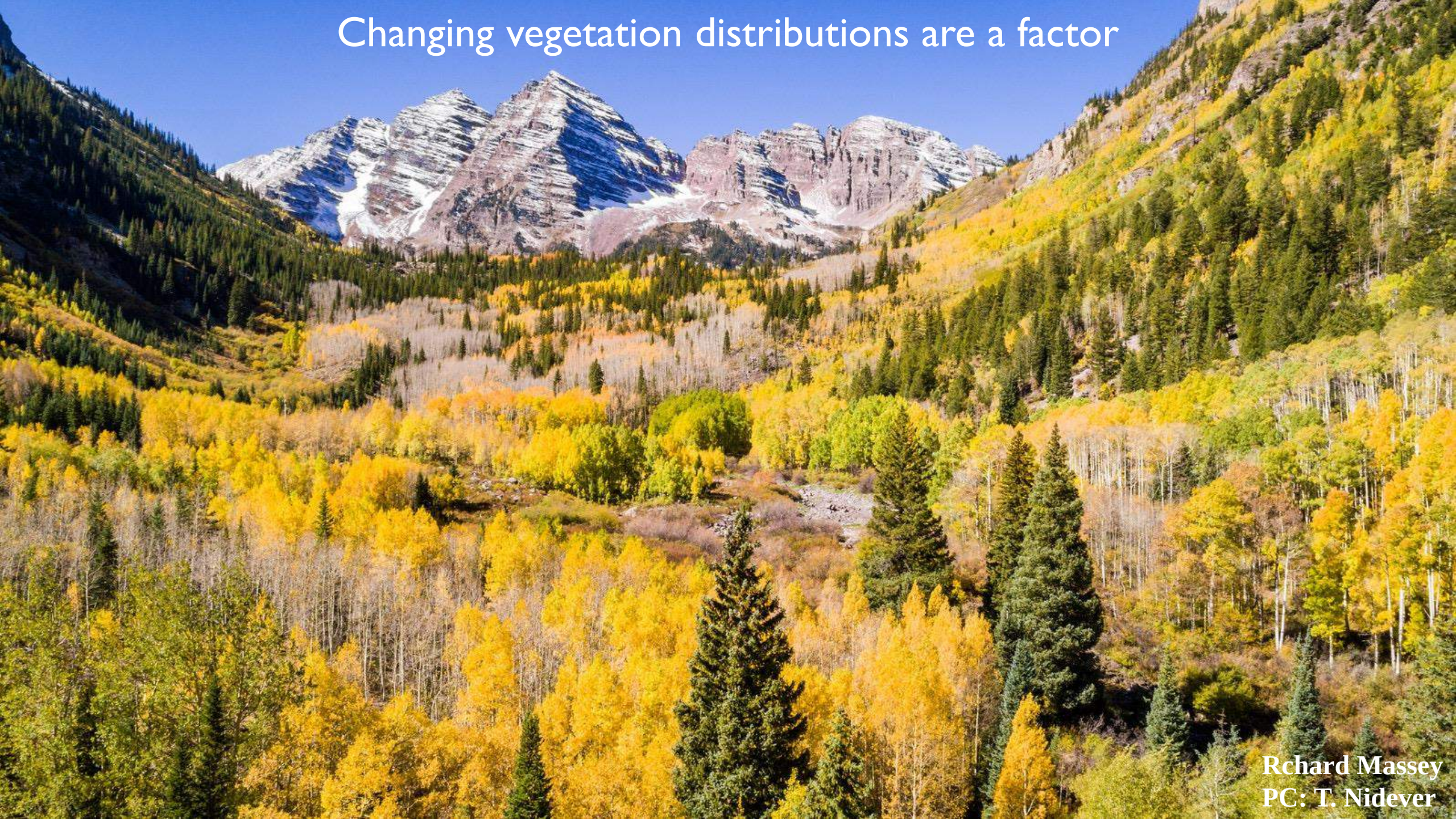


Murray-Tortoralo et al., 2013

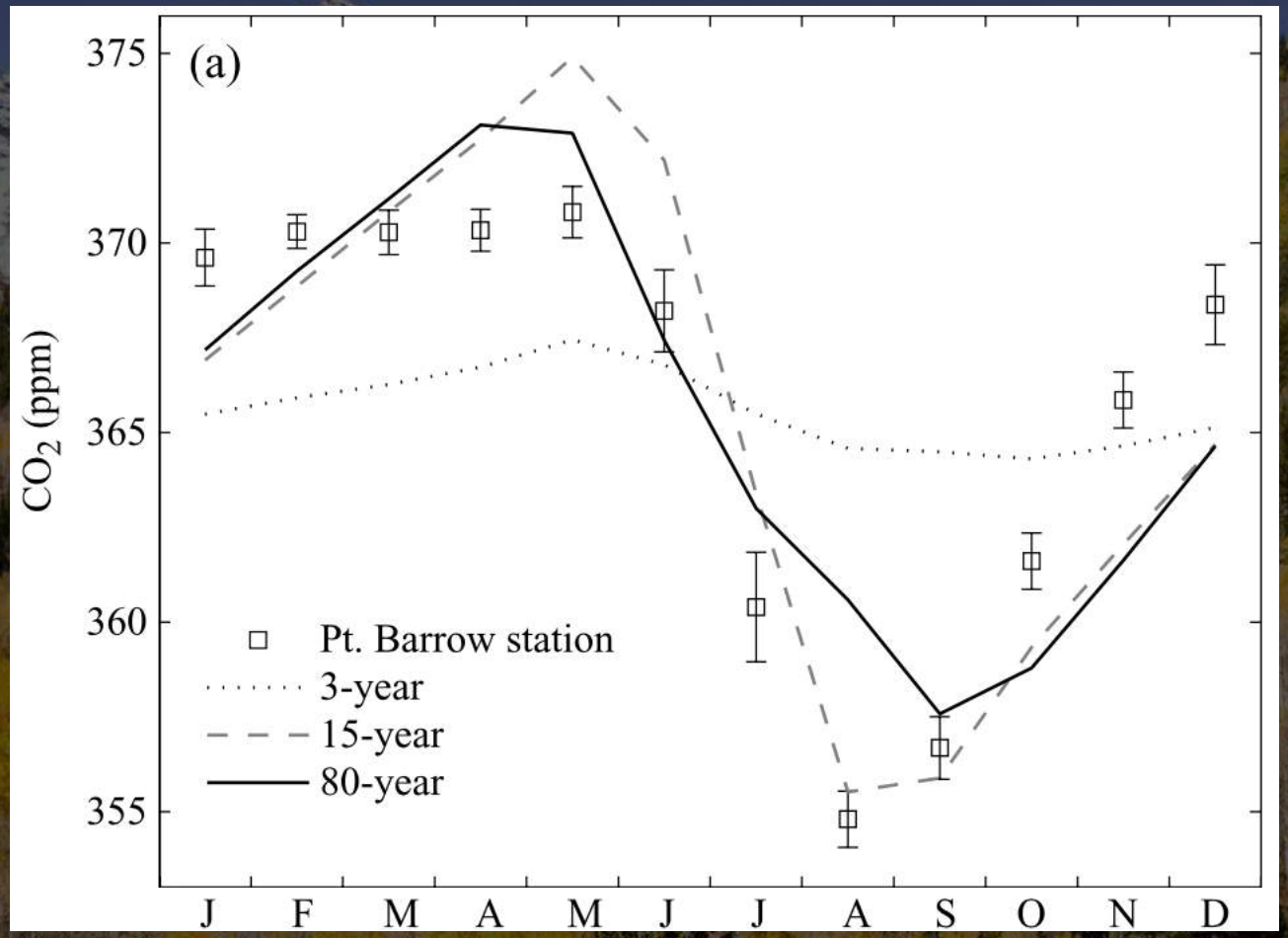
- Cannot represent observed amplification
- Overestimate LAI and greening
- Misrepresent impact of warming on CO_2 uptake (e.g., Zhu et al., 2019)
- Argued that CO_2 fertilization can only explain minor fraction (e.g., Kohlmaier et al., 1989; Randerson et al., 1997; Girardin et al., 2011)

Changing vegetation distributions are a factor



Rchard Massey
PC: T. Nidever

Changing vegetation distributions are a factor



Welp et al., 2006

Changing PFTs almost equally as important as climate change and CO_2 fertilization (Forkel et al., 2016)

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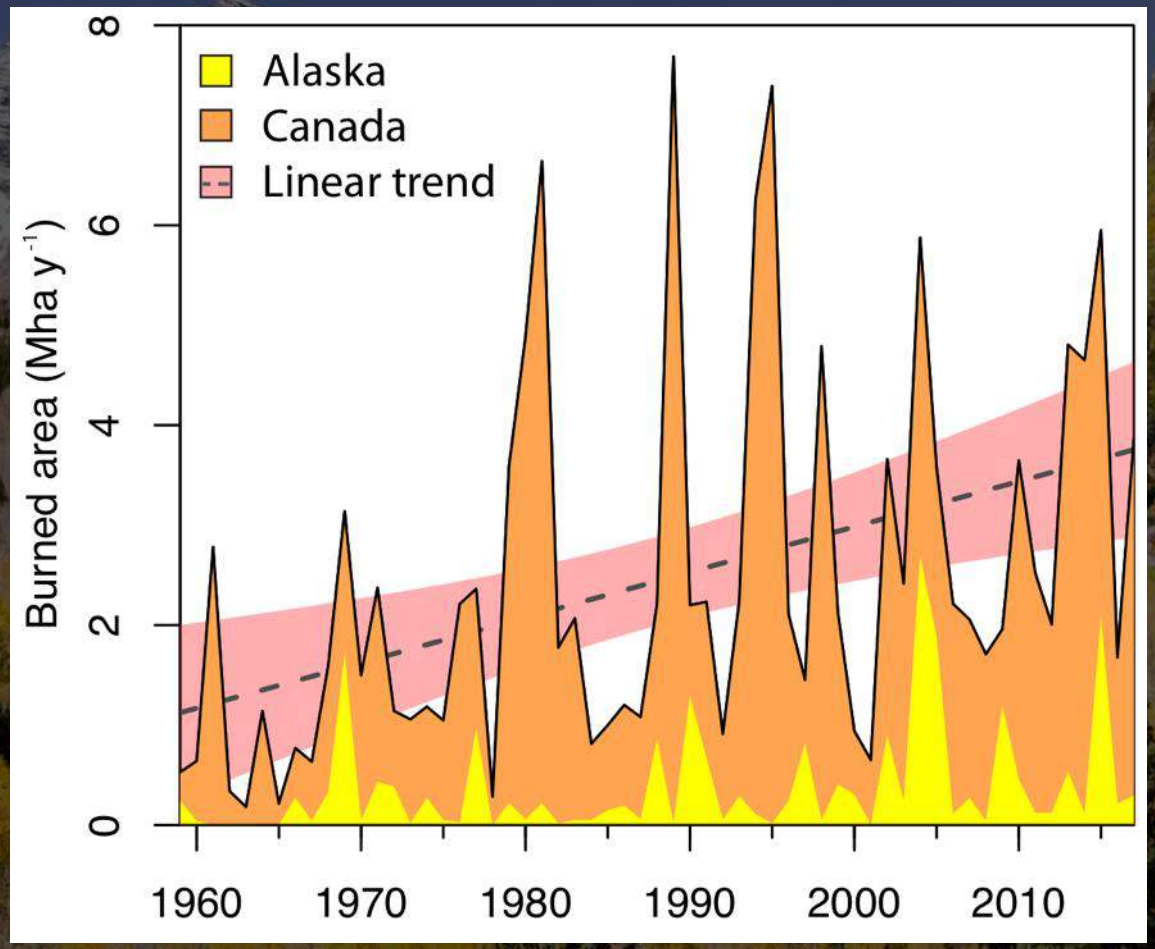
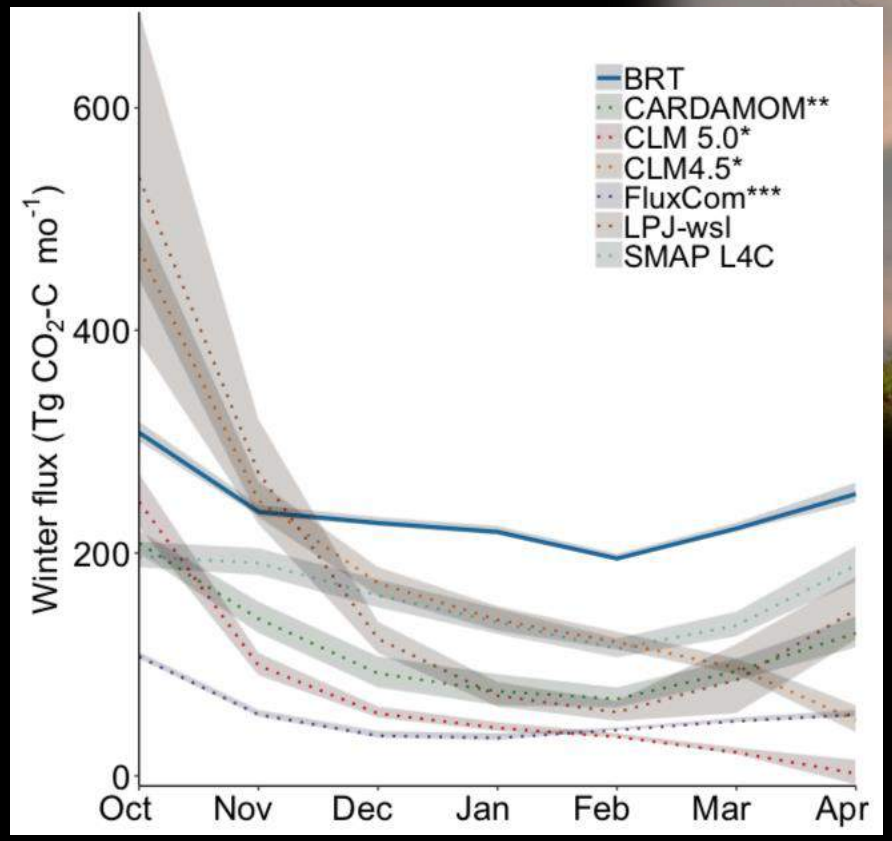


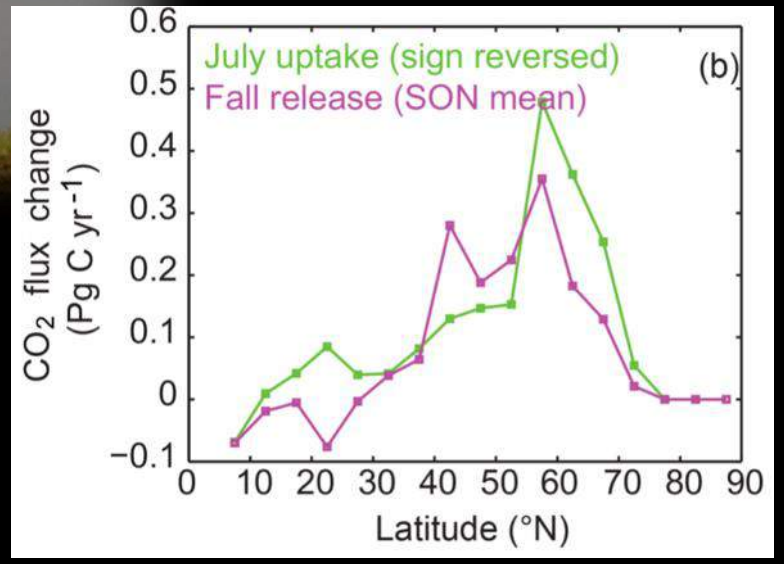
Changing PFTs almost equally as important as climate change and CO_2 fertilization (Forkel et al., 2016)

Major component of PFT changes due to wildfire

The dark horse of winter respiration

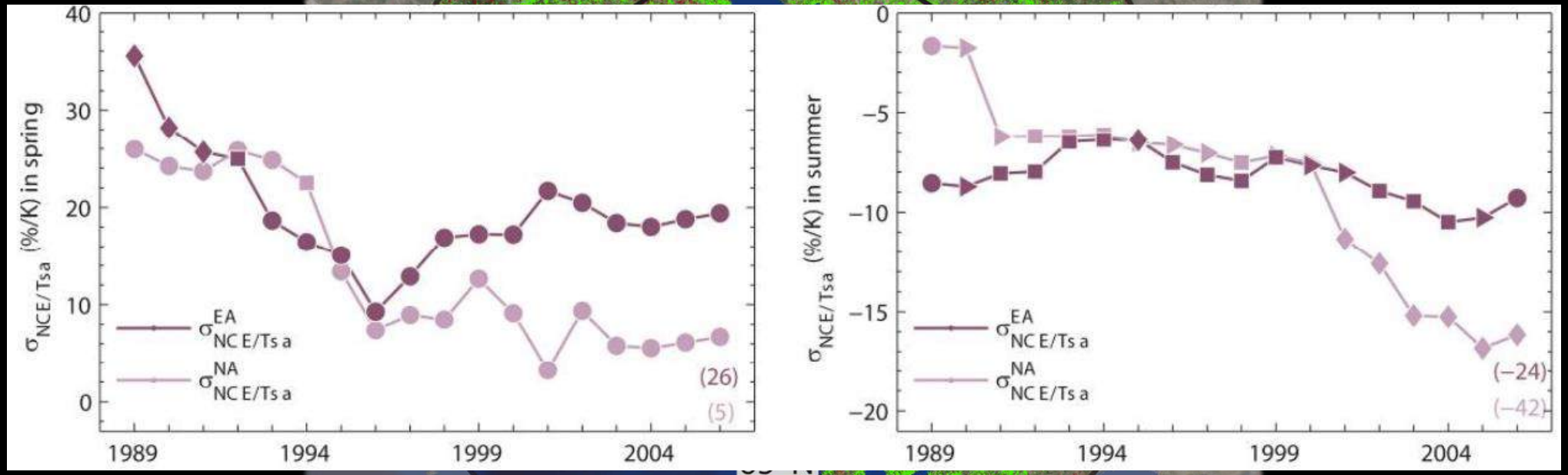


Natali et al., *in press*



Welp et al., 2016

And gosh darn it, the continents behave differently!!



Zhu et al., 2019

Approach

New / improved data products

Better use of existing products

Improved modeling approaches

Data-driven modeling approach

Hypothesis-driven

Bottom-up and top-down approaches

Multiple co-benefits to NASA & scientific community

Approach

Summer productivity

Winter respiration

Climate

CO_2 fertilization

Vegetation distributions (fire & non-fire)

N cycling

Permafrost dynamics

Physiology

Climate

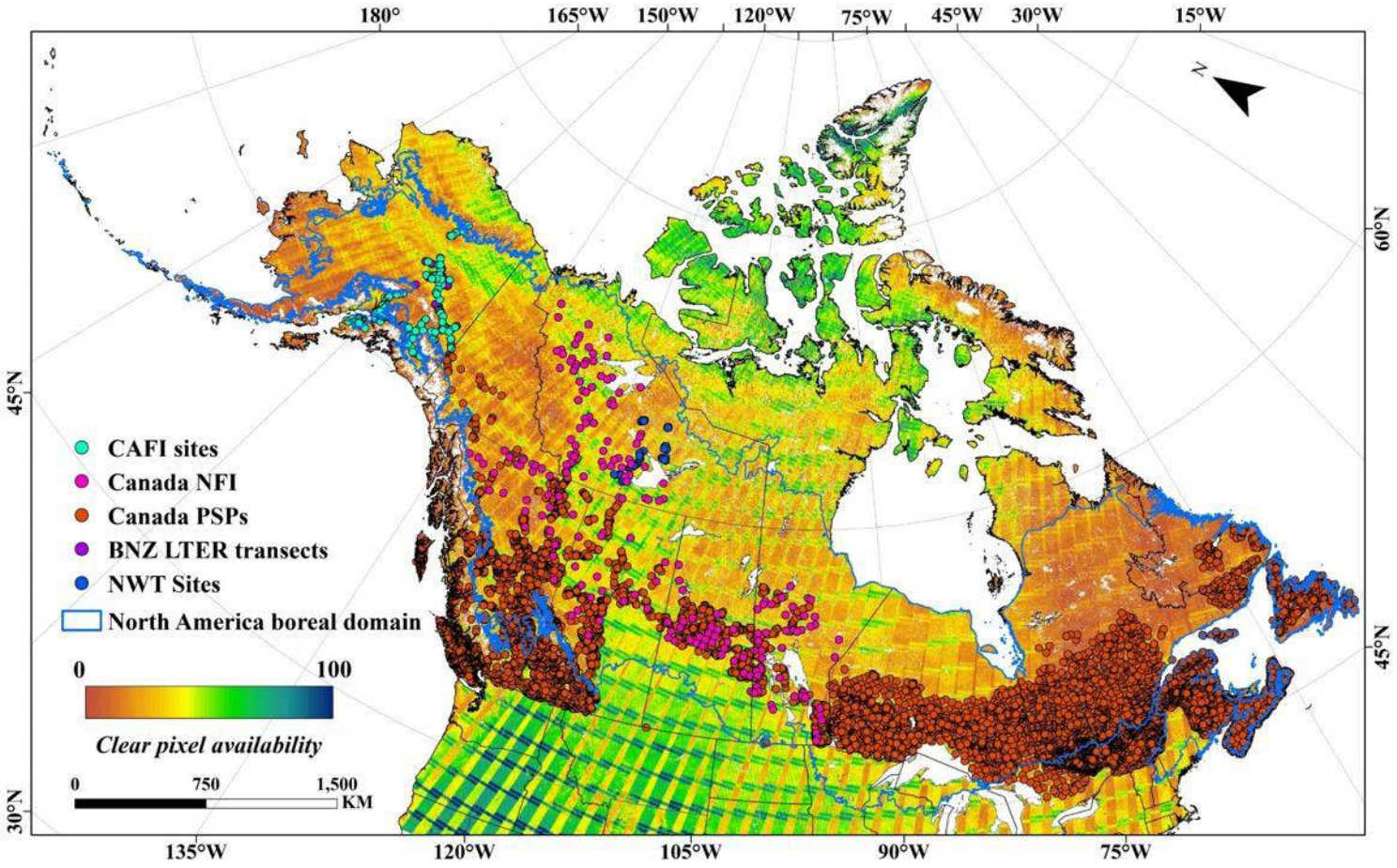
Vegetation distributions

Snow cover & depth

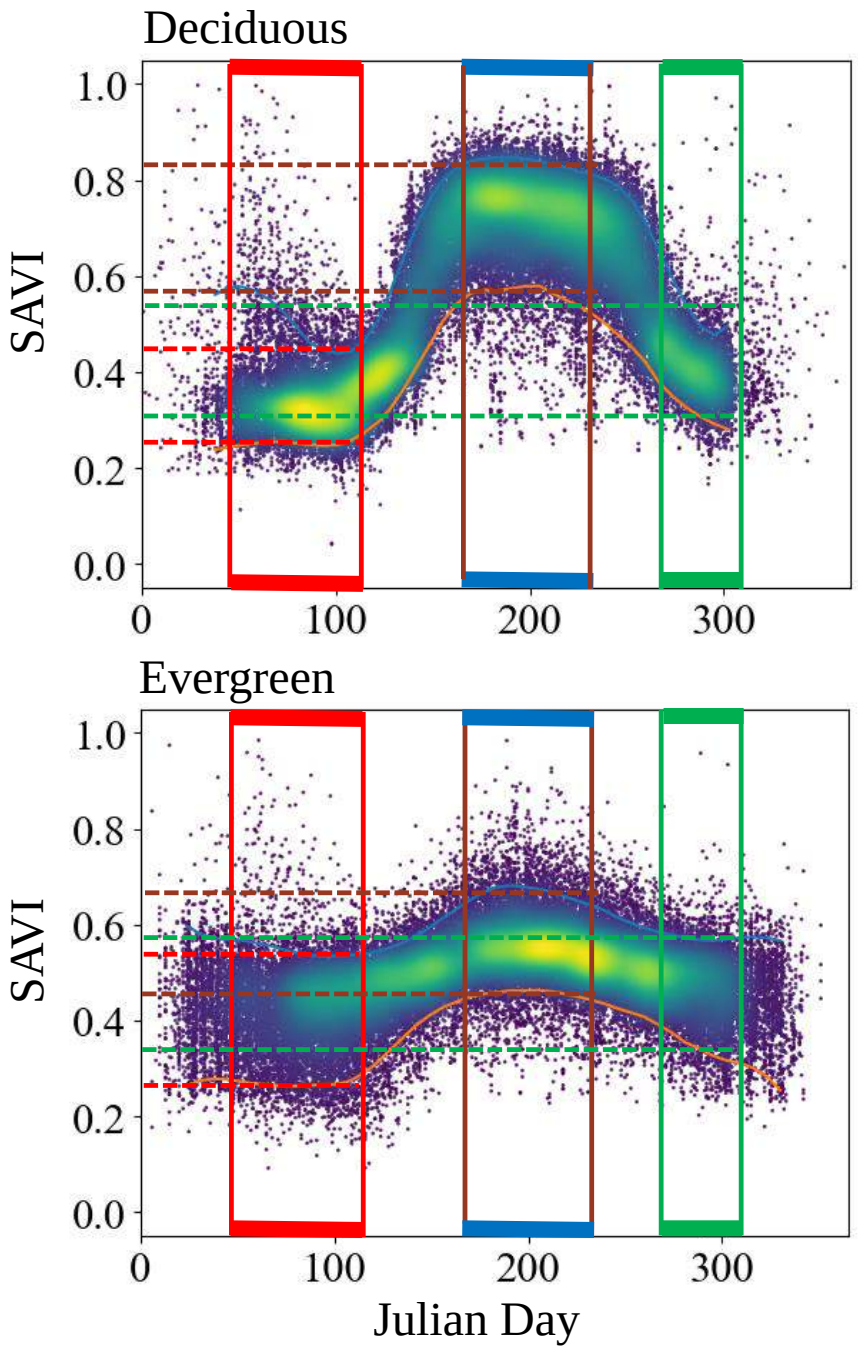
Productivity (labile substrates)

New data products

Deciduous fraction



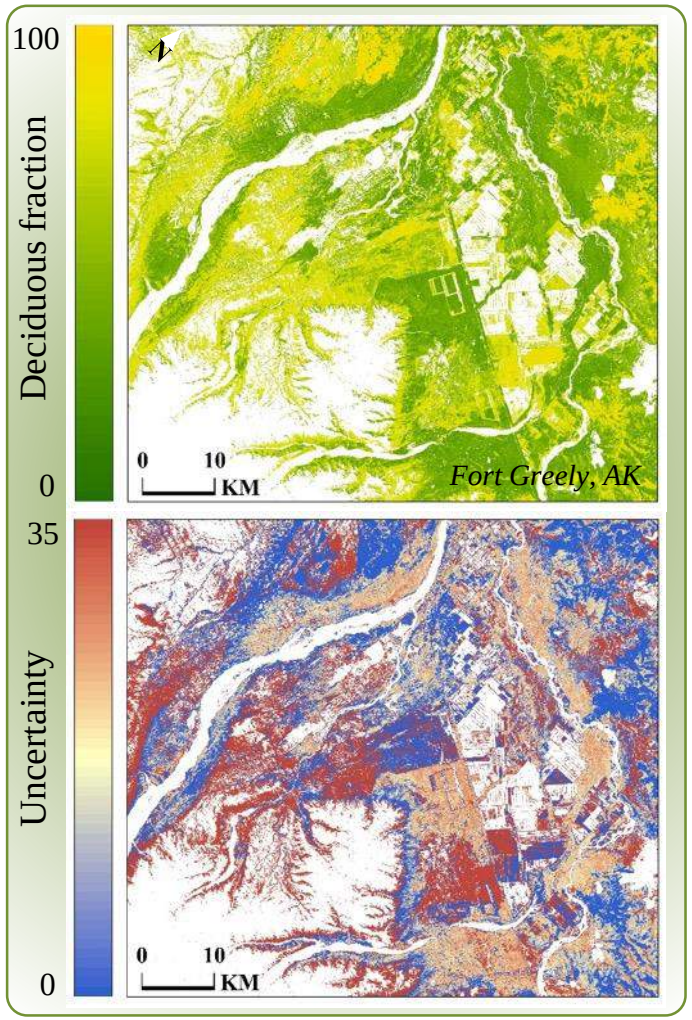
Ground samples and mid-summer clear pixel availability for Landsat 7 ETM+ and Landsat 8 OLI (2013 – 2018)

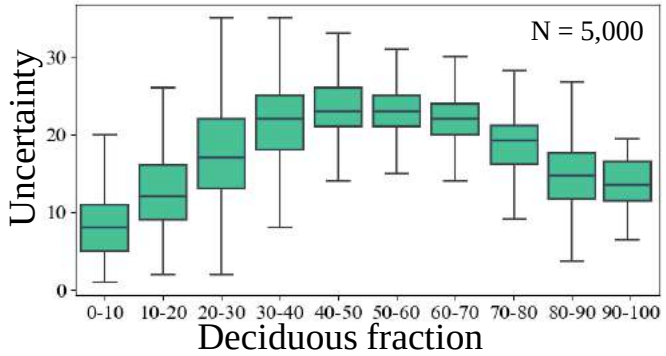


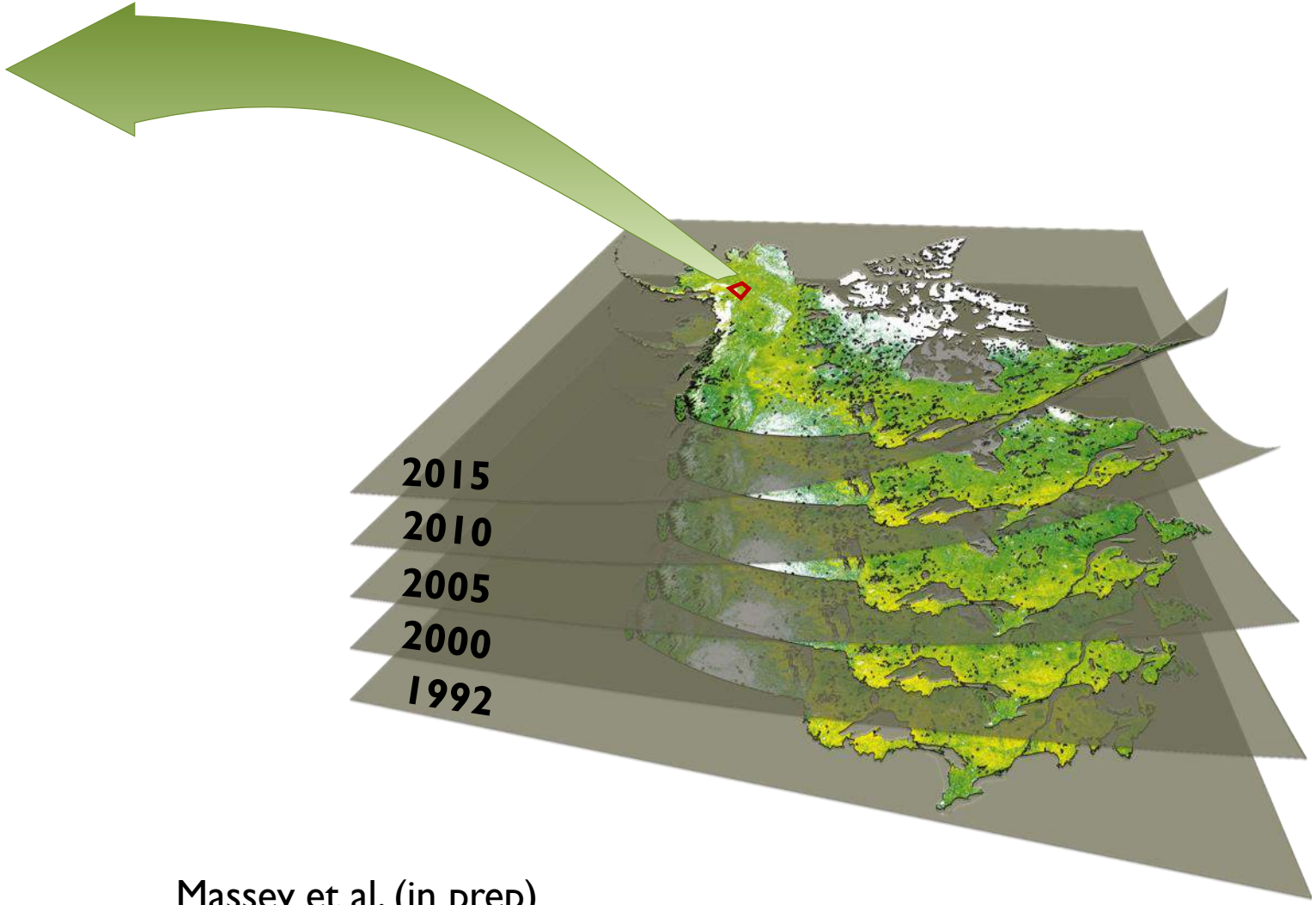
Massey et al. (in prep)

New data products

Deciduous fraction



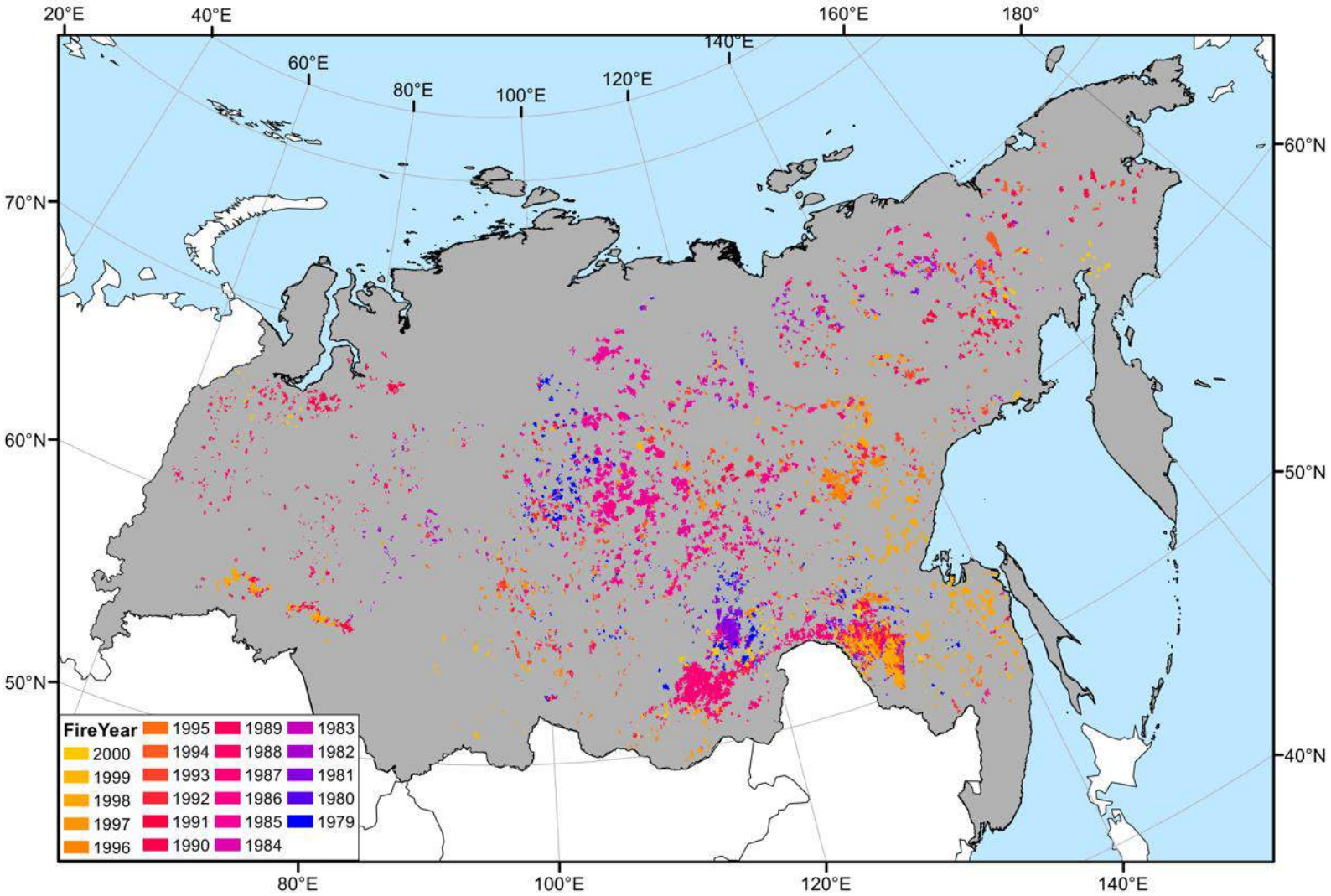


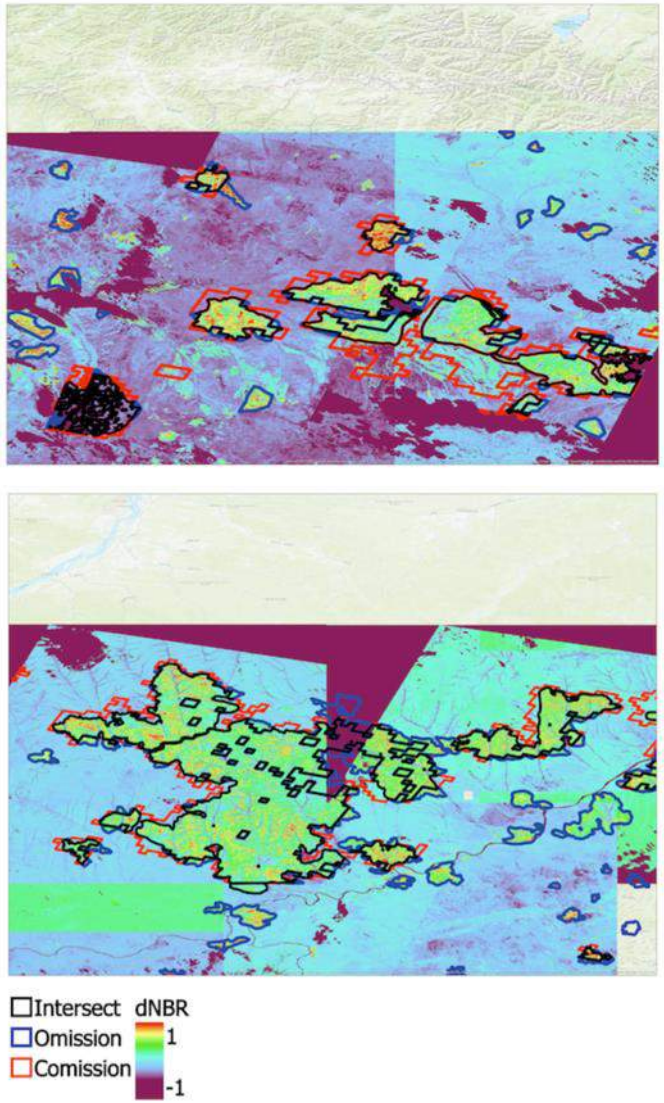


Massey et al. (in prep)

New data products

Siberian historical fire scars



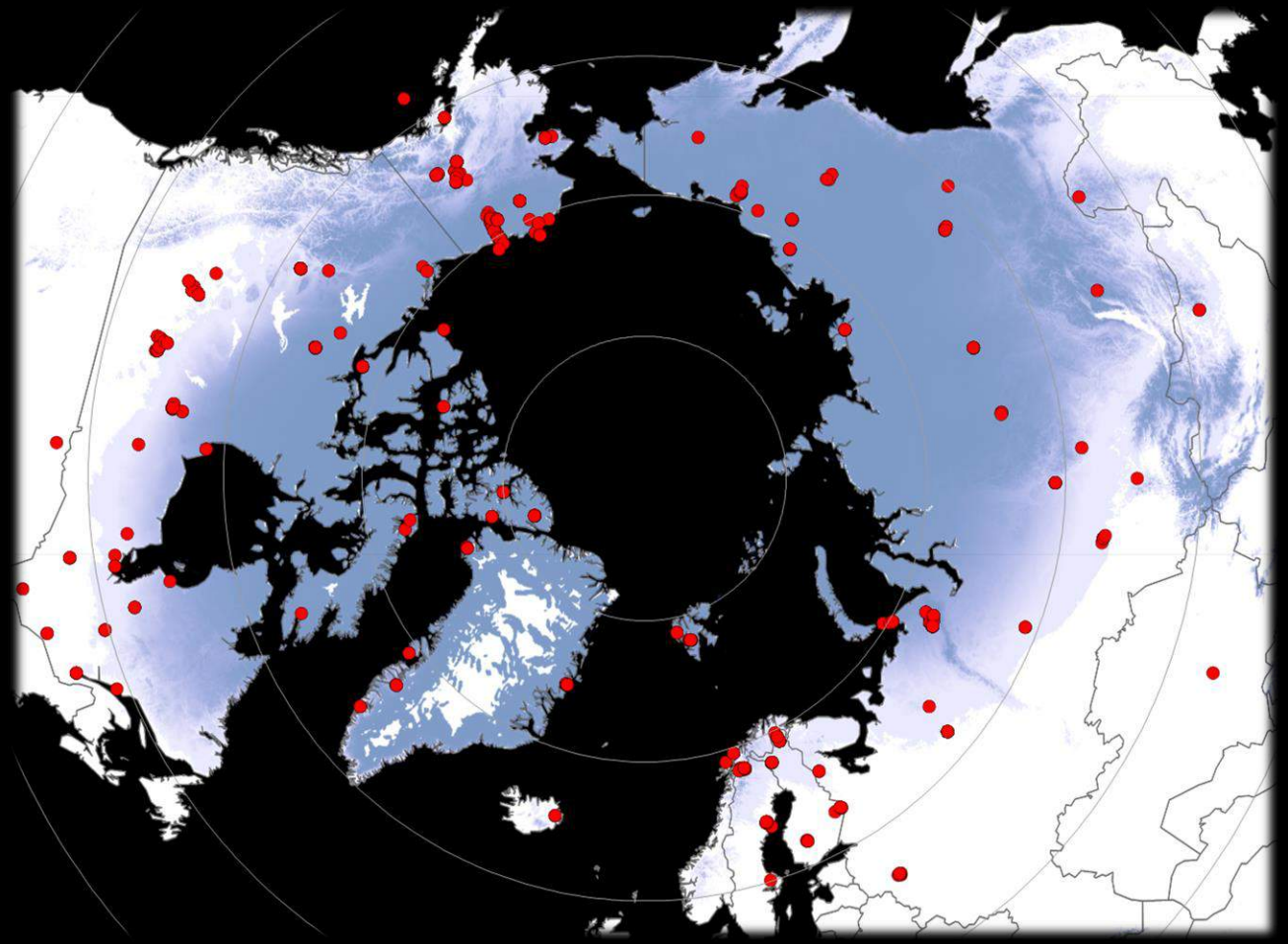


Soja et al. (in prep)

New data products

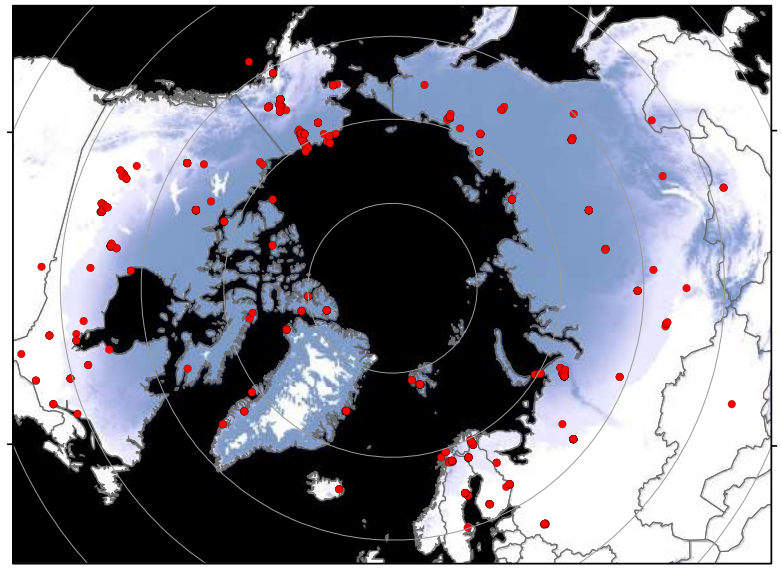
In-situ CO_2 flux synthesis

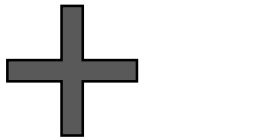
- Working with broader arctic-boreal flux community
- Two workshops in 2018
- Aggregating, standardizing, and synthesizing CO_2 flux observations from EC towers & chambers
- Previous literature, available repositories, and community contributions
- Site list and mapping tool soon to be archived

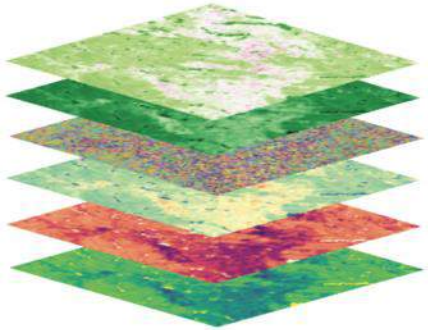


Modeling approaches

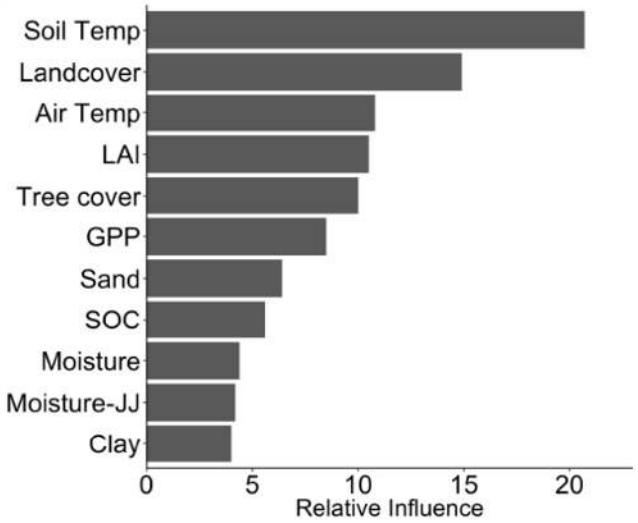
Flux upscaling

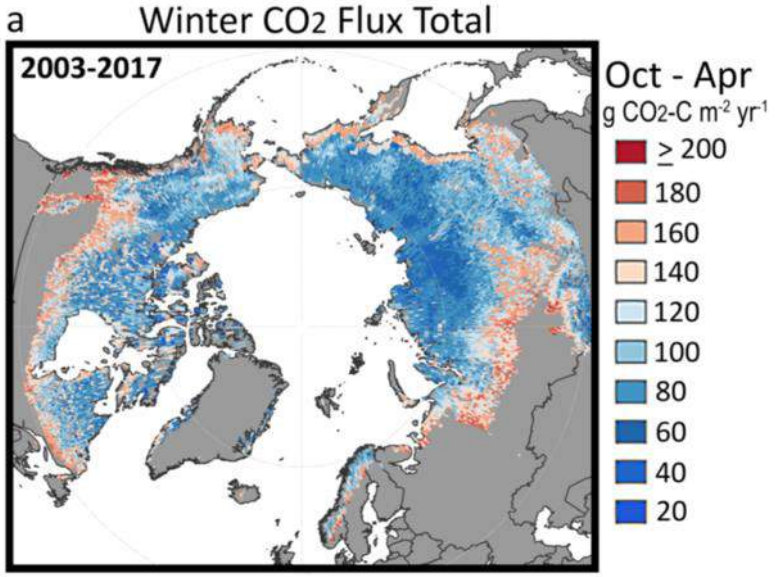






Machine learning





Natali et al. (in press)

Modeling approaches

Coupling observational products & data-driven models

Inputs

- Climate
- Vegetation type (fire & non-fire)
- Tree cover
- Snow cover

Models

- Our upscaling model
- FluxCom
- CLM-SP
- Polar VPRM

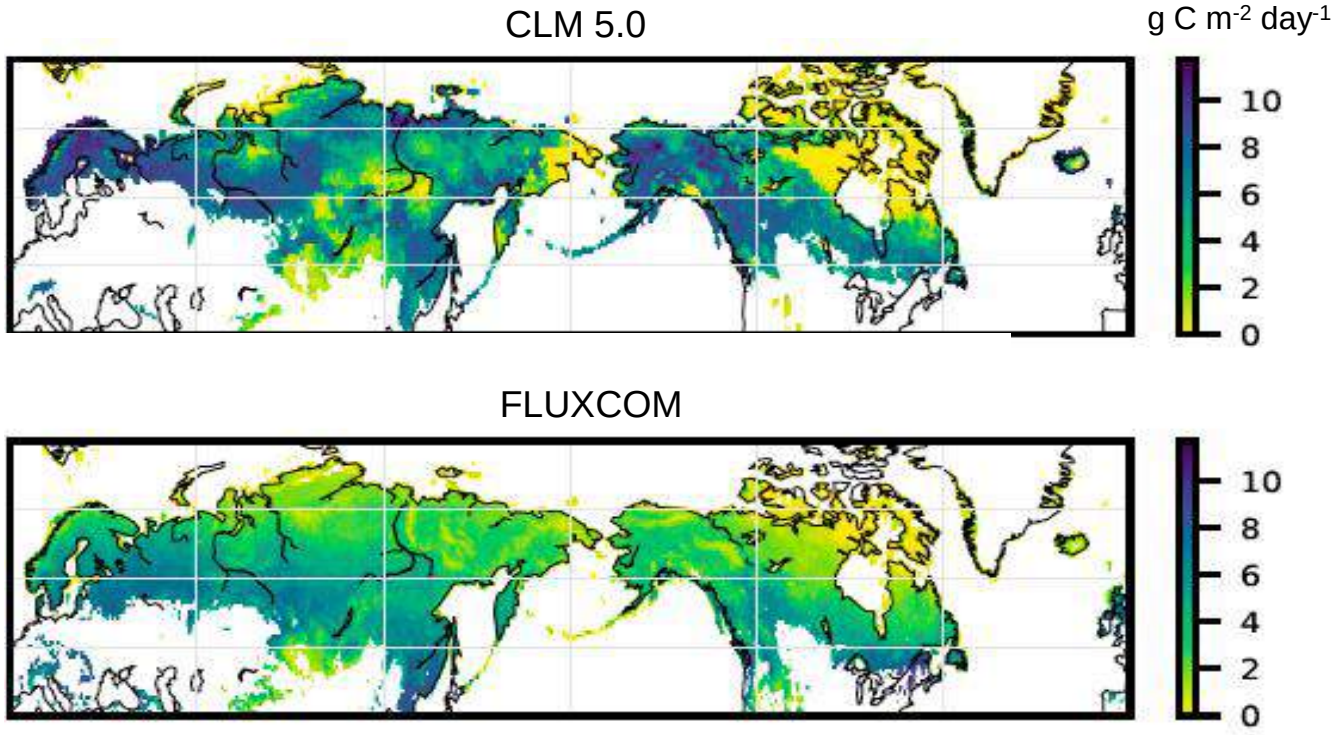
→ Individual & combined influences on seasonal CO_2 fluxes

Modeling approaches

Community Land Model

Primary issues

- Too productive in high latitudes & no latitudinal gradient (arctic shrubs and grasses much too productive).
- Large dead zones (visible with PFT-specific output).
- Phenology biases:
  - Late onset bias for shrubs and deciduous trees.
  - Early onset and peak GPP bias for needleleaf evergreen.
  - Late offset bias for All PFTs.

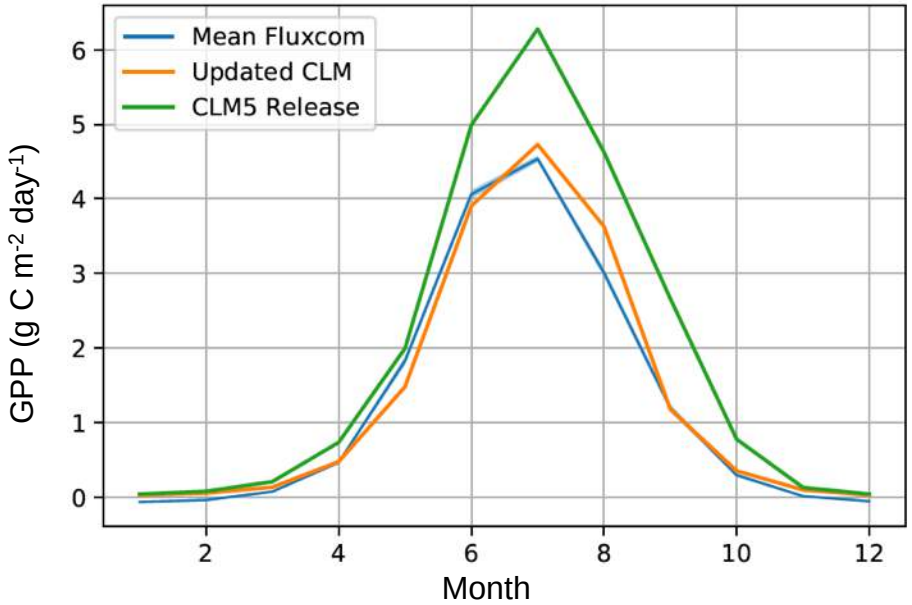


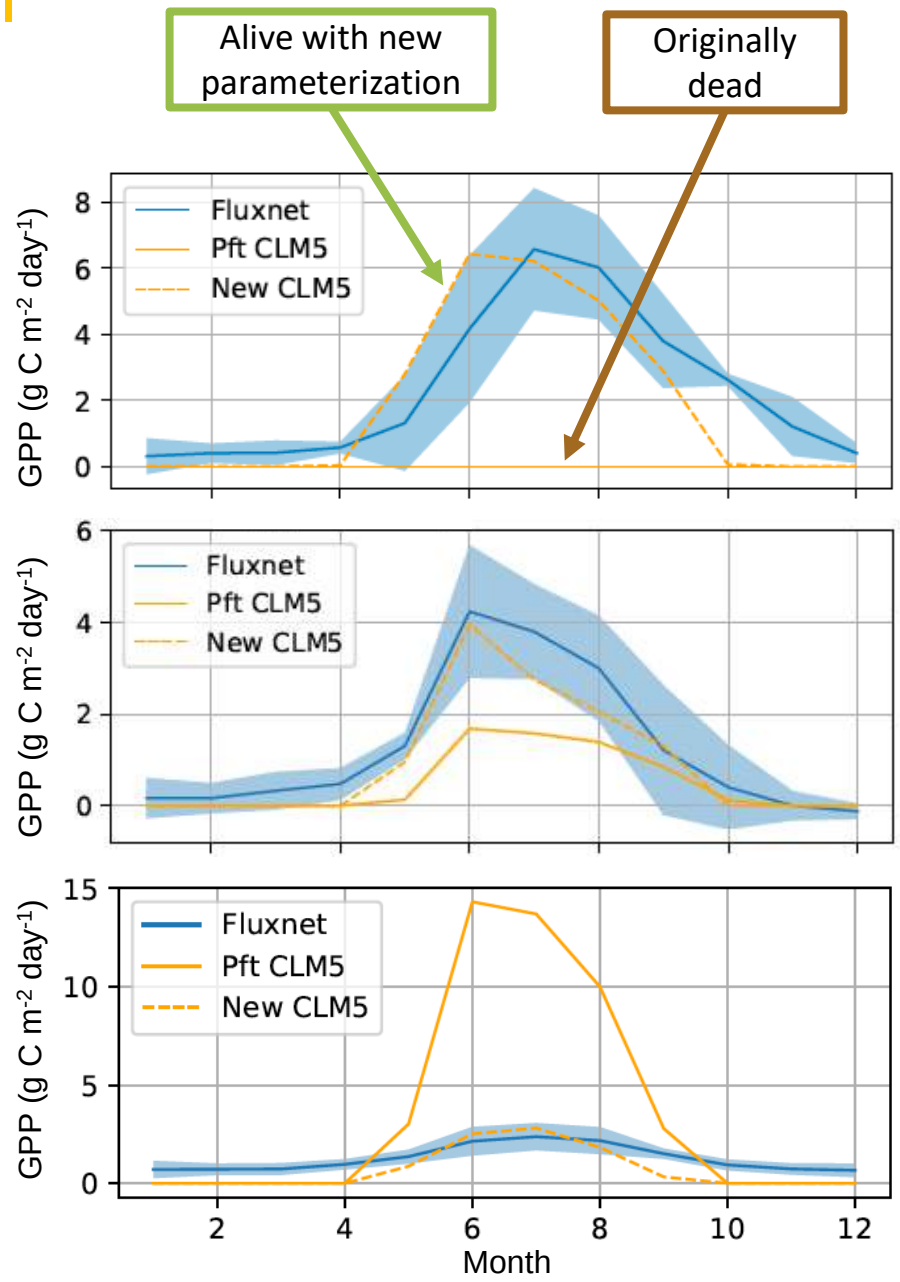
Modeling approaches

Community Land Model

<u>Model development (mechanistic approach)</u>

- Improved temperature scaling of photosynthetic parameters (V_{cmax} & J_{max}).
- Improved allocation parameters.
- Onset based on soil temperature, air temperature, and snow depth.
- Offset based on latitudinal gradient in daylight length.
- Other bug fixes.



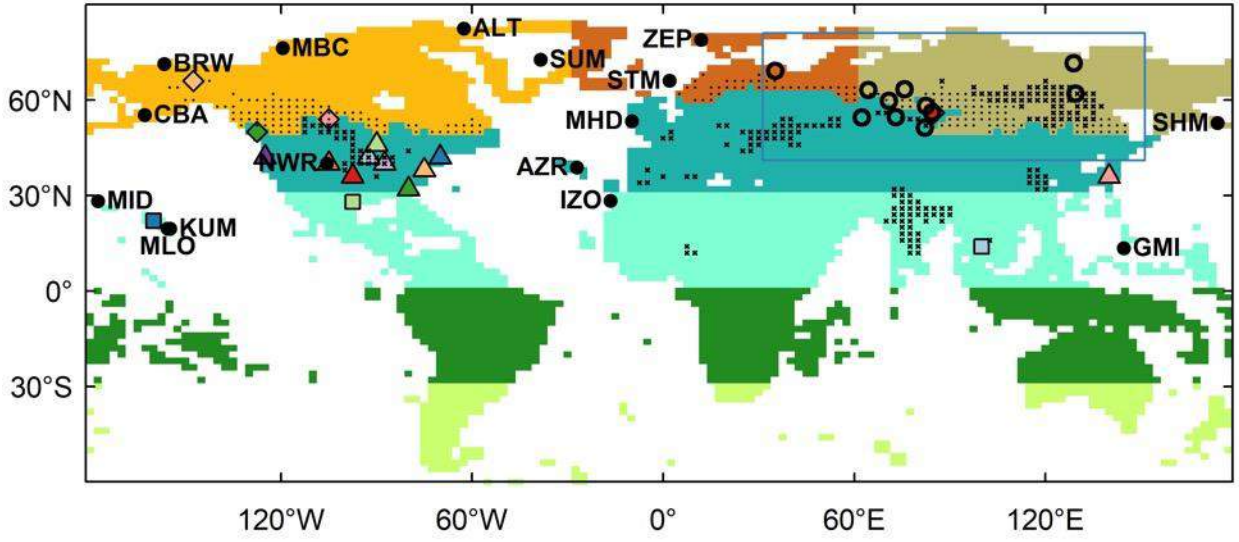


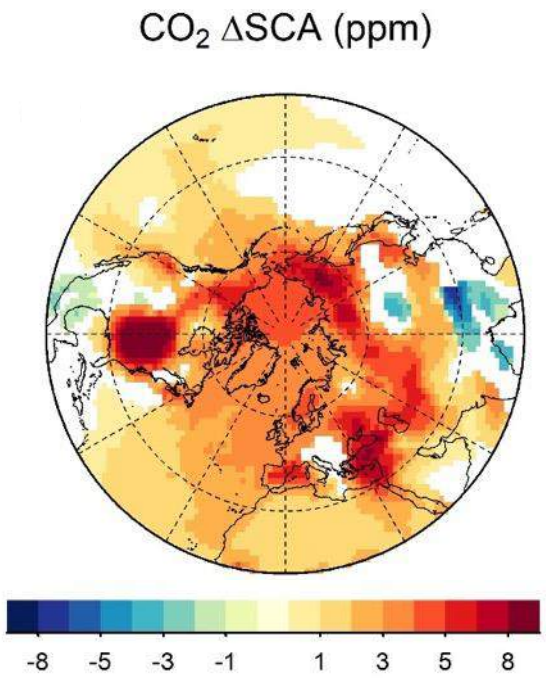
Birch et al. (in prep)

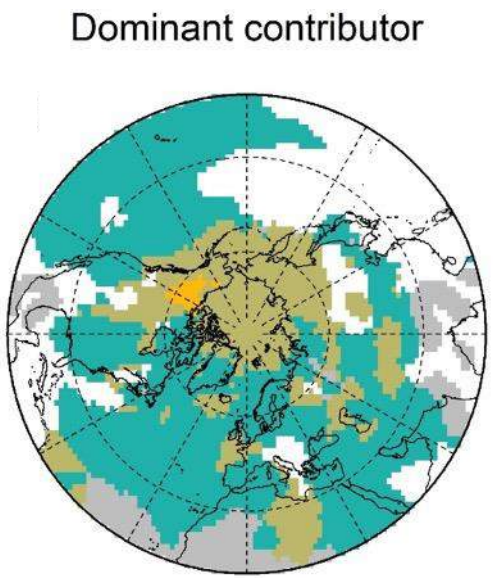
Modeling approaches

Atmospheric Transport

CAMS & CarbonTracker inversion products → GEOS-Chem atmospheric transport model







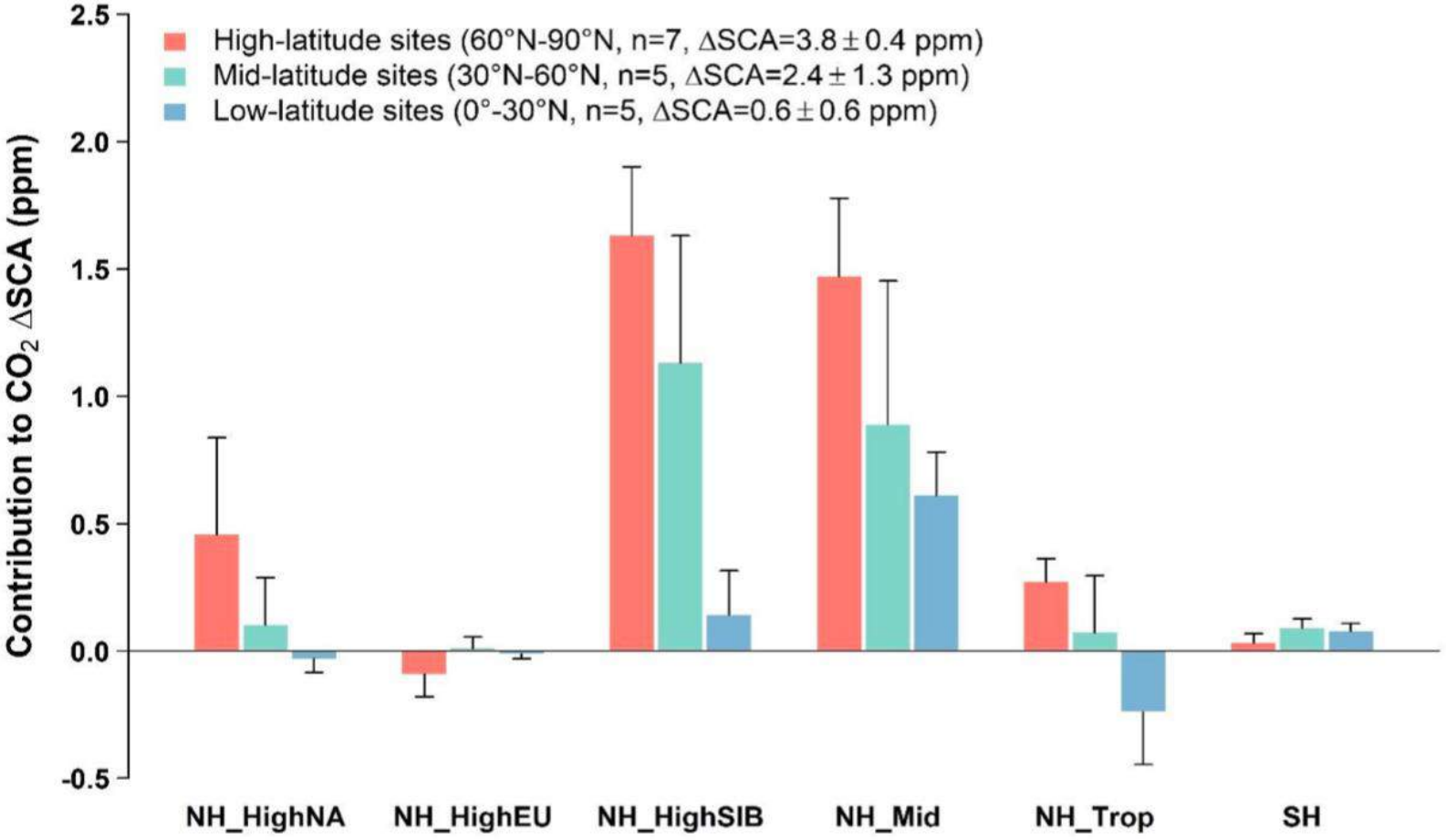
- Arctic-boreal North America
- Arctic-boreal Europe
- Siberia
- NH Mid-latitudes
- Others

Lin et al. (in review)

Modeling approaches

Atmospheric Transport

CAMS & CarbonTracker inversion products → GEOS-Chem atmospheric transport model



Lin et al. (in review)

Future directions

- Data products mostly finalized. In process of publishing & archiving
- Next year focused on conducting & analyzing model experiments
- Our focus is on the CO_2 amplitude phenomenon, but our research & data products should be useful for a variety of other NASA investigations and the scientific community