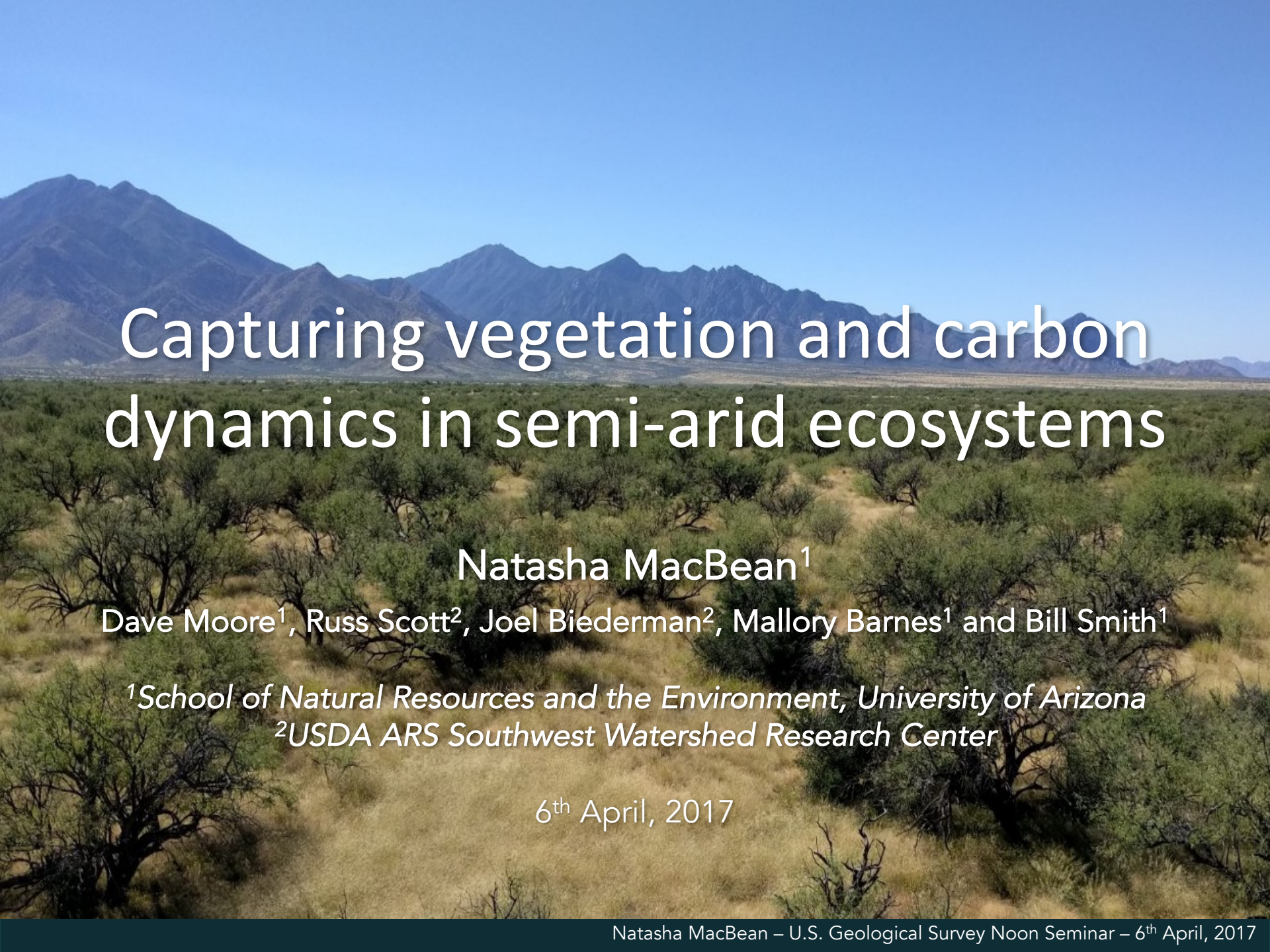


Capturing vegetation and carbon dynamics in semi-arid ecosystems

Natasha MacBean[1]

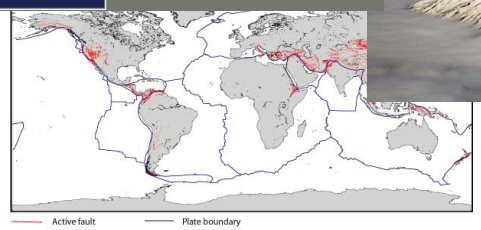
Dave Moore[1], Russ Scott[2], Joel Biederman[2], Mallory Barnes[1] and Bill Smith[1]

[1]School of Natural Resources and the Environment, University of Arizona
[2]USDA ARS Southwest Watershed Research Center

6th April, 2017

Mini biography in one slide!

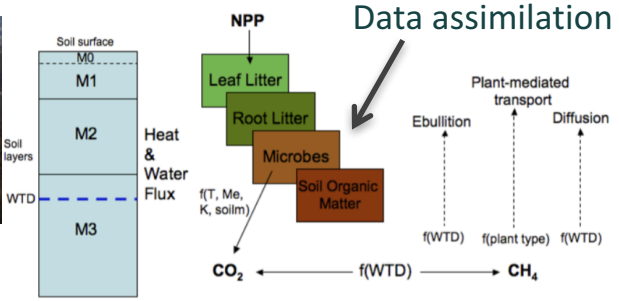
UNIVERSITY OF OXFORD
EARTHSCIENCES



UNIVERSITY of York

UCL

Data assimilation

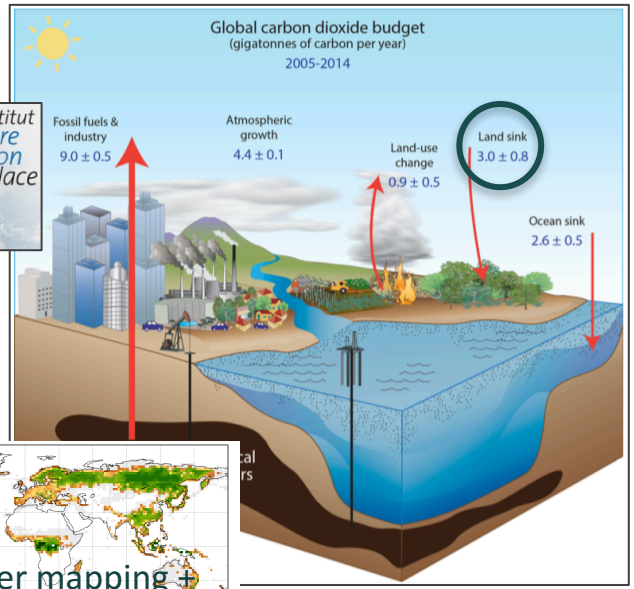


LSCE

Orchidée

Institut Pierre Simon Laplace

Sciences de l'environnement

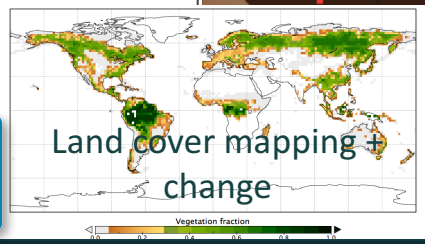


Global C cycle + data assimilation

CarboNes

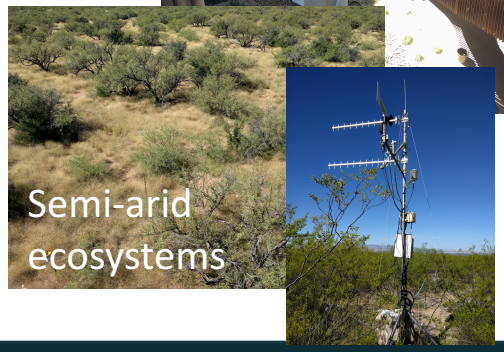
GEO CARBON

esa
European Space Agency



Land cover mapping + change

ExpeER
Ecosystem Research

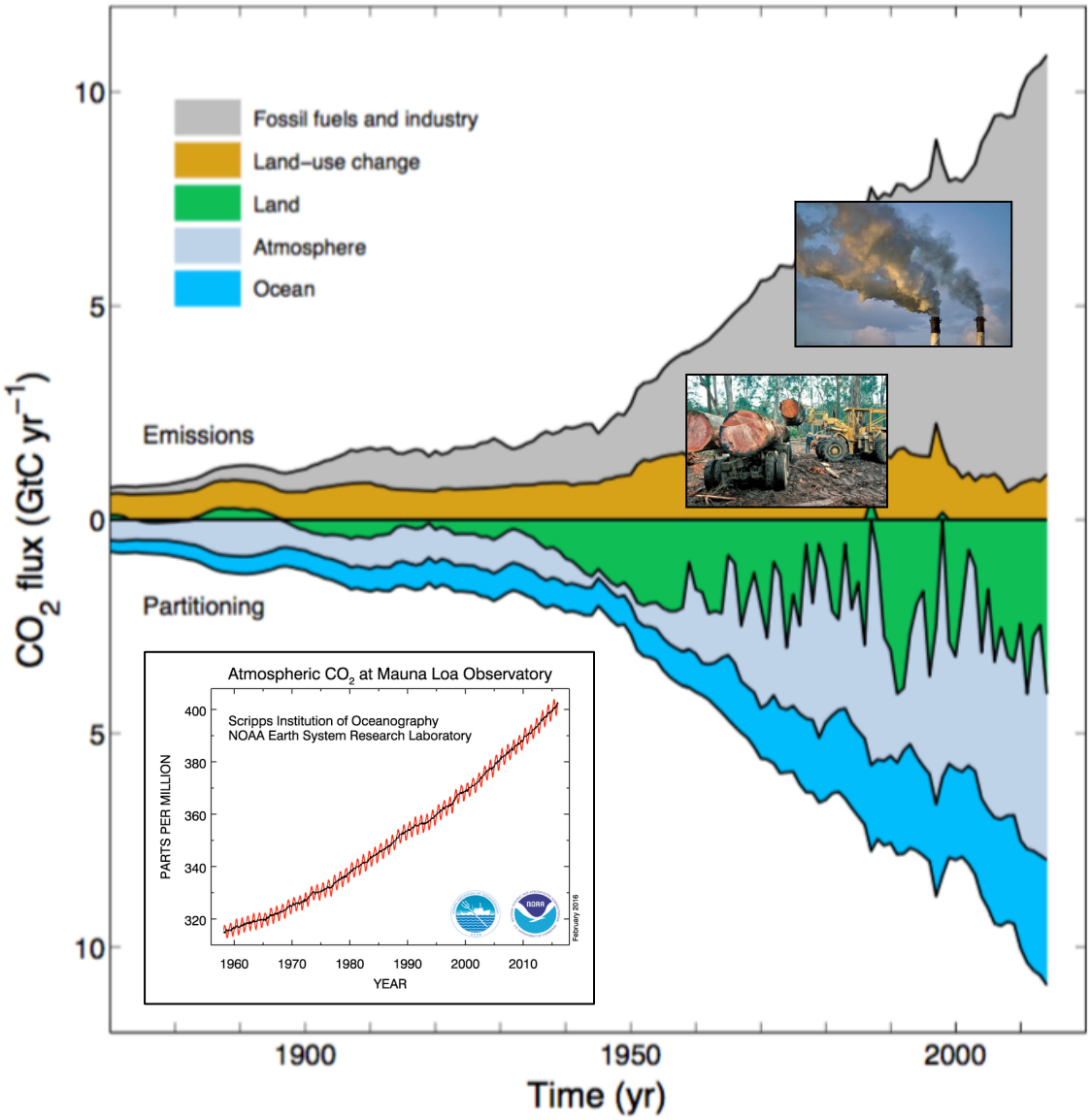


Semi-arid ecosystems

Overview of presentation

- What are the remaining uncertainties/unsolved questions in the global C budget?
- Do semi-arid regions have a dominant role in the global C budget?
- On-going work: how can we measure and model dynamics in semi-arid ecosystems? What do the data and models show?
- Future perspectives for improving our understanding of functioning in semi-arid ecosystems

Motivation: constraining uncertainty in the global carbon (C) budget



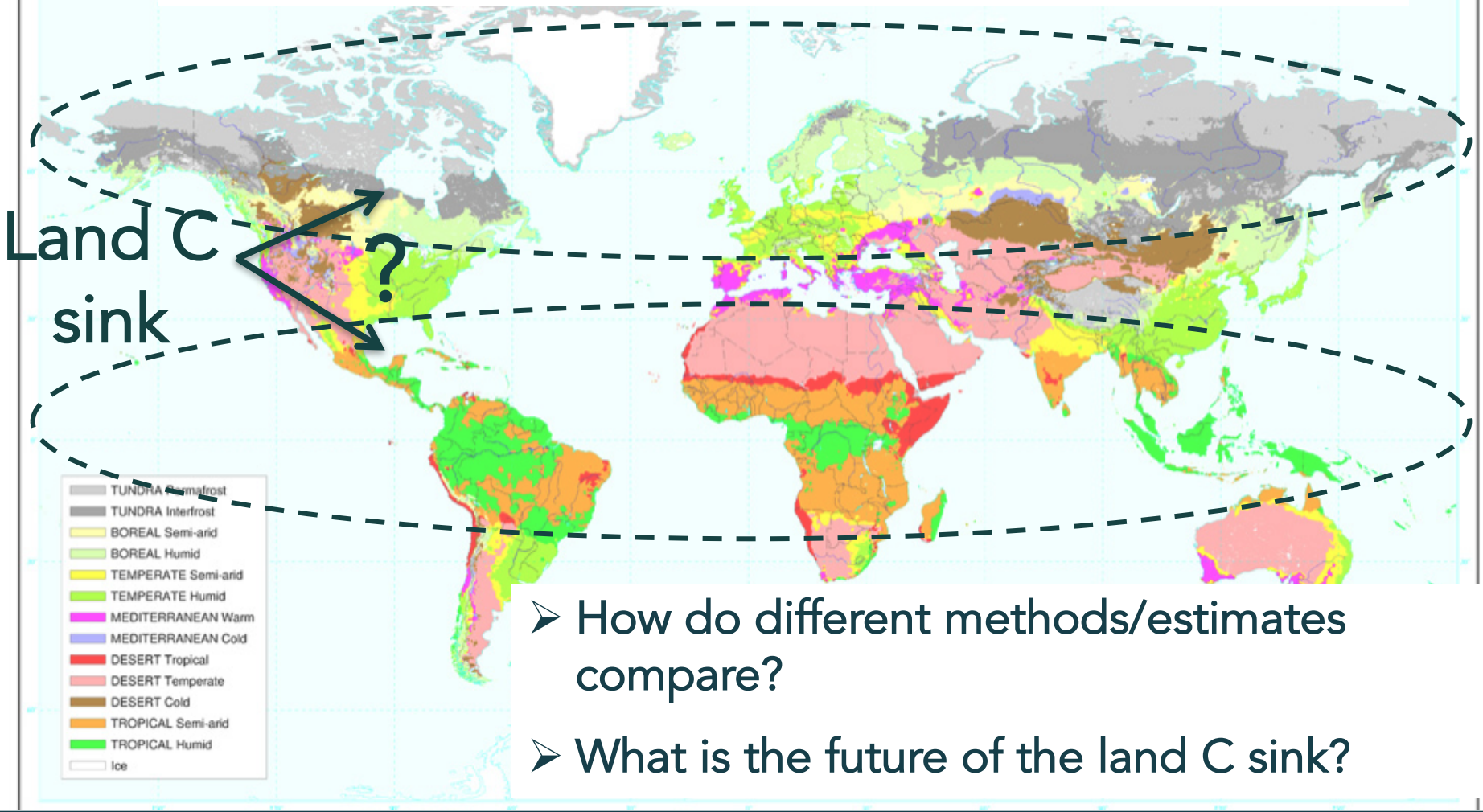
C budget 2004-2013 ($PgCyr^{-1}$)

9±0.5	Fossil fuels
0.9±0.5	LULCC (deforestation)
3±0.8	LAND (residual)
4.4±0.1	Atmosphere
2.6±0.5	Ocean

Le Quéré et al. (2015)

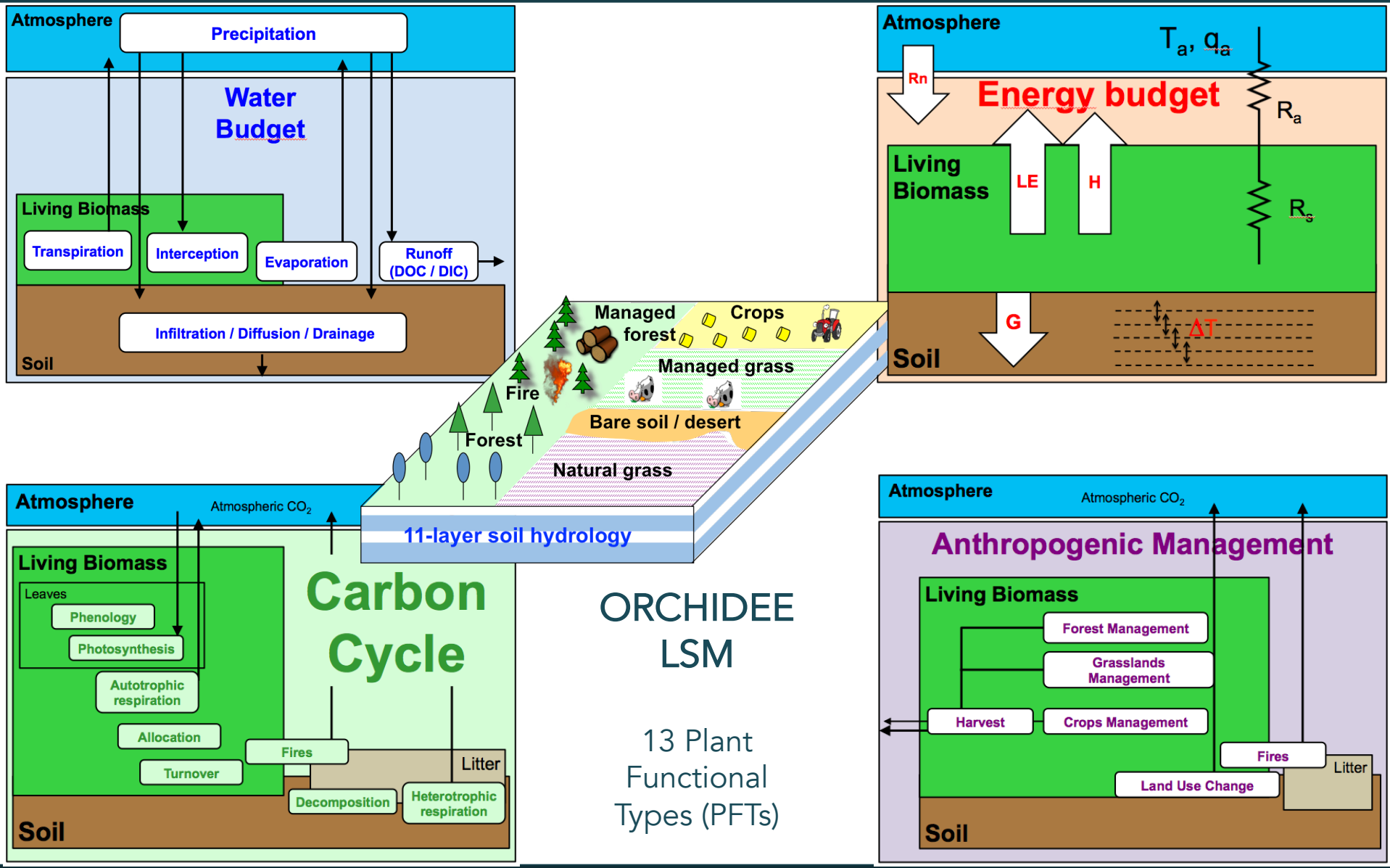
A few scientific questions…

- Which regions contribute most to the mean/trend/inter-annual variability of the global C sink?

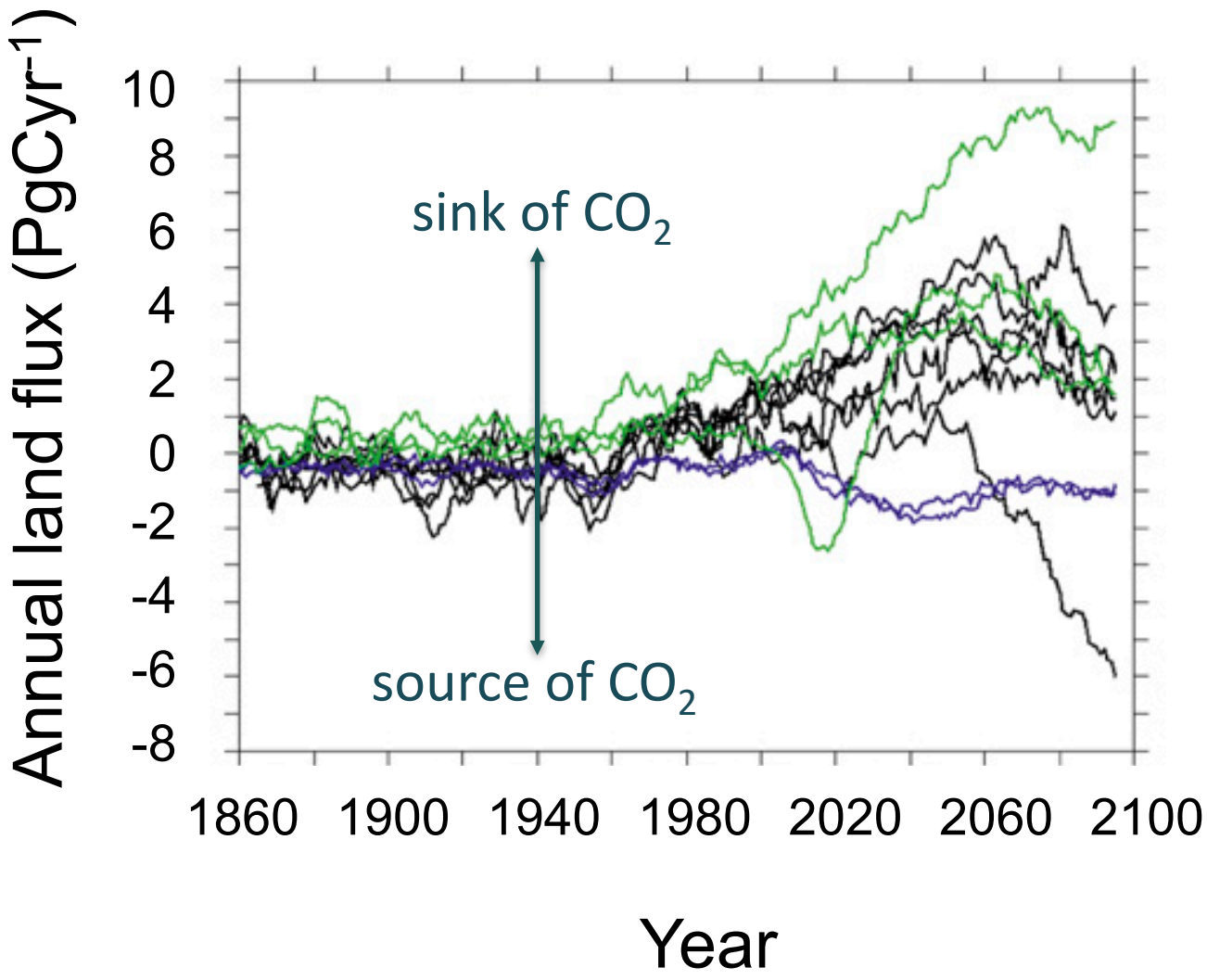


- How do different methods/estimates compare?
- What is the future of the land C sink?

Global terrestrial biosphere models (TBMs)

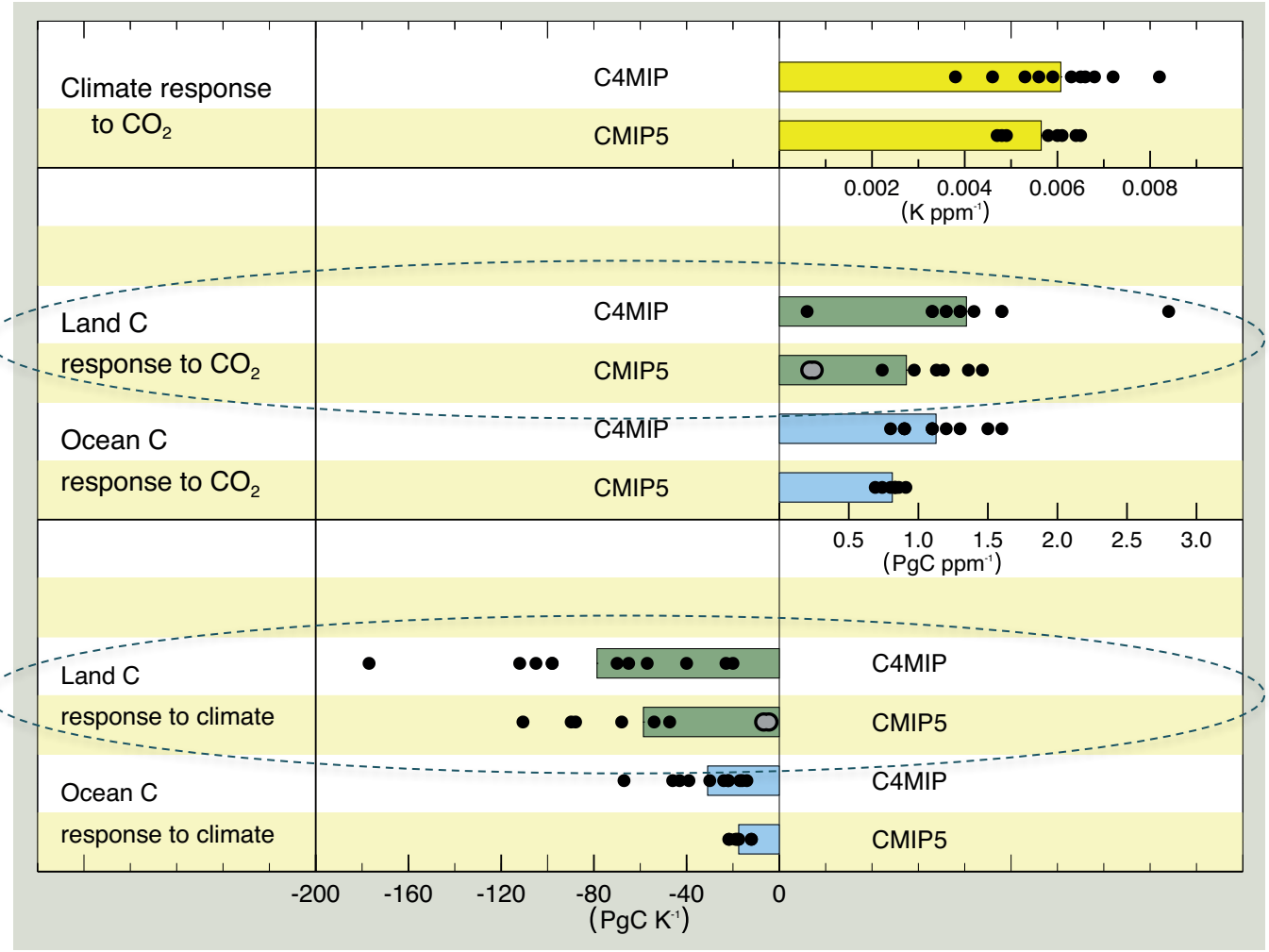


Uncertainty in the global carbon (C) budget



Friedlingstein et al. (2014)

Model uncertainty not decreased since IPCC AR4

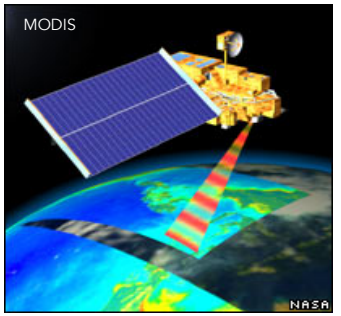


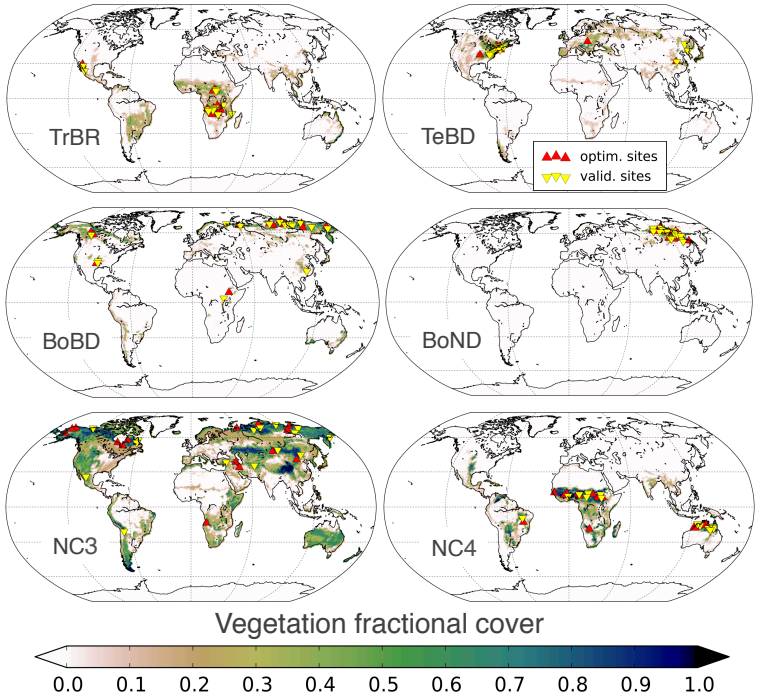
IPCC, 2013

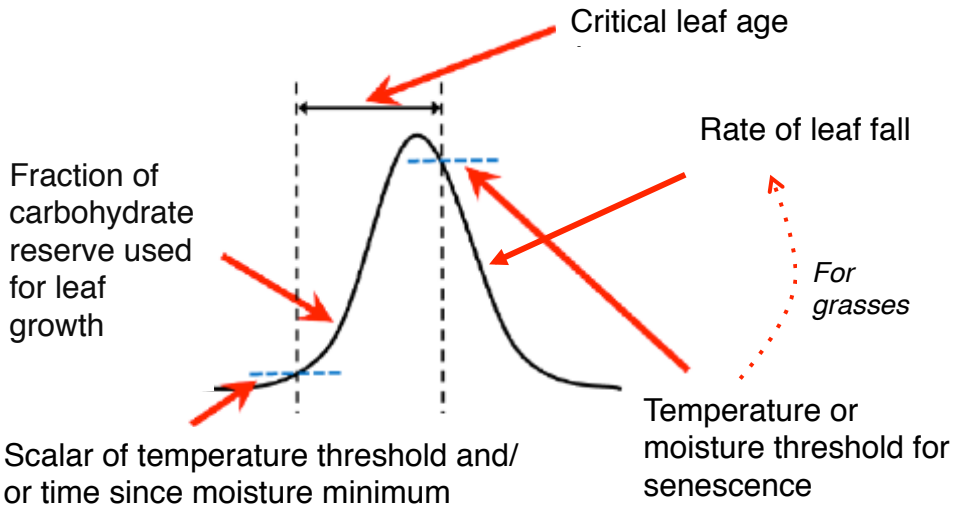
"Earth System Models indicate that there is a positive feedback between climate and the carbon cycle, but *confidence* remains *low* in the strength of this feedback, particularly for the land."

Constraining the vegetation dynamics of global TBMs

- Satellite NDVI compared to simulated fraction of absorbed photosynthetic radiation (fAPAR)
- 4 – 6 parameters per plant functional type (PFT)
- 15 random grid points per PFT

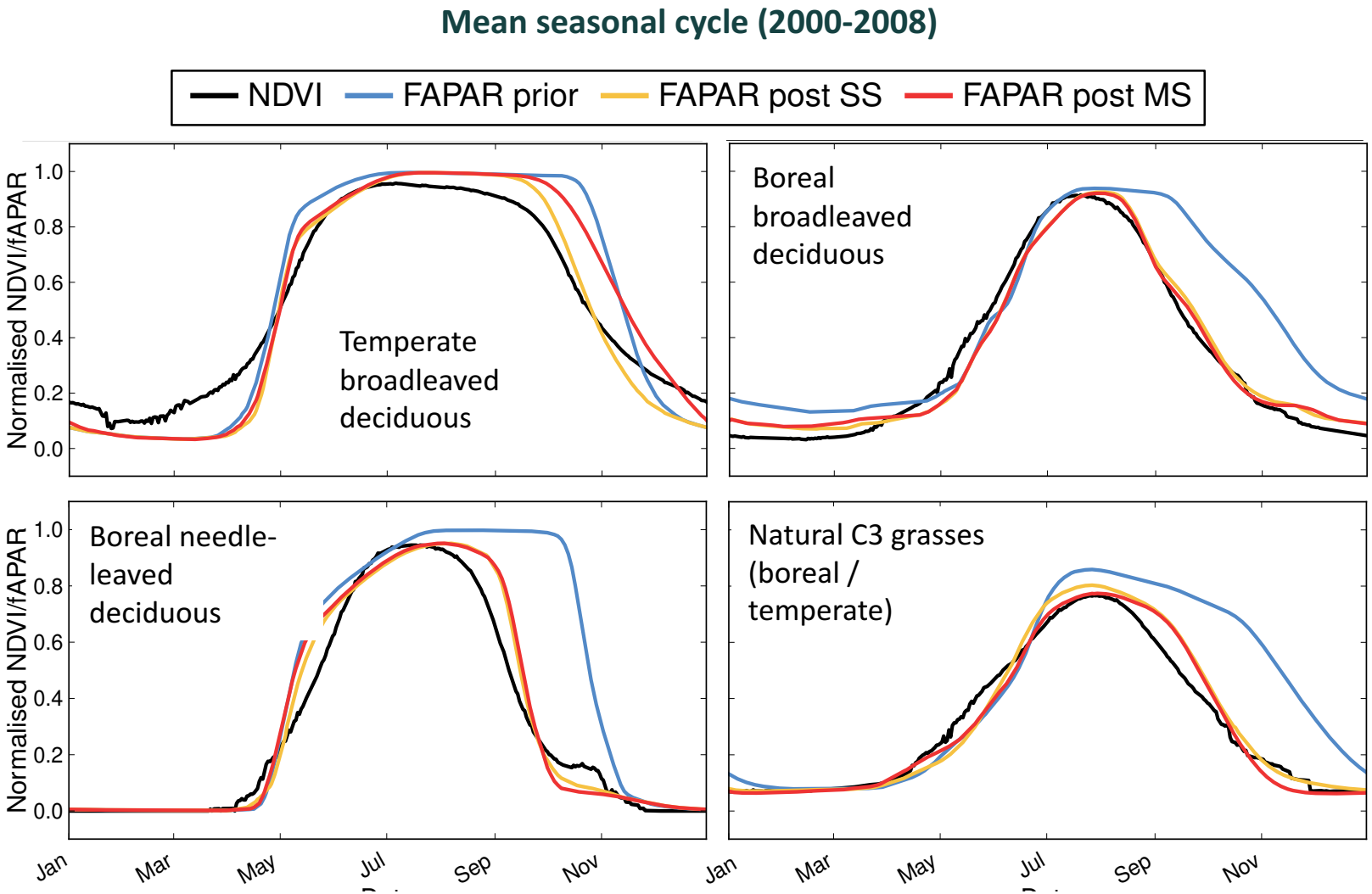






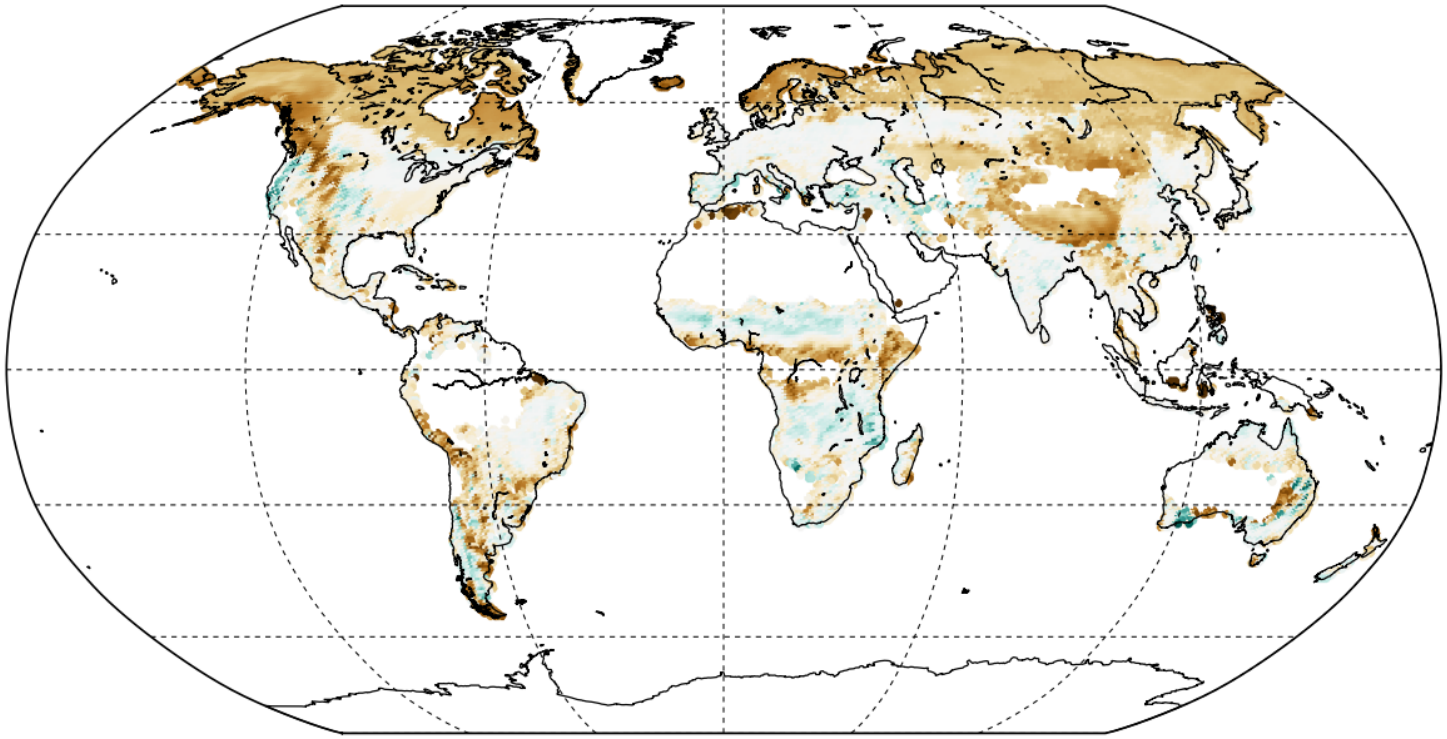
MacBean et al. (2015) Using satellite data to improve the leaf phenology of a global Terrestrial Biosphere Model, *Biogeosciences,* 12, 7185-7208

Constraining the vegetation dynamics of global TBMs



MacBean et al. (2015) Using satellite data to improve the leaf phenology of a global Terrestrial Biosphere Model, *Biogeosciences,* 12, 7185-7208

Satellite-derived "vegetation greenness" index constrains seasonal leaf dynamics in boreal/temperate regions



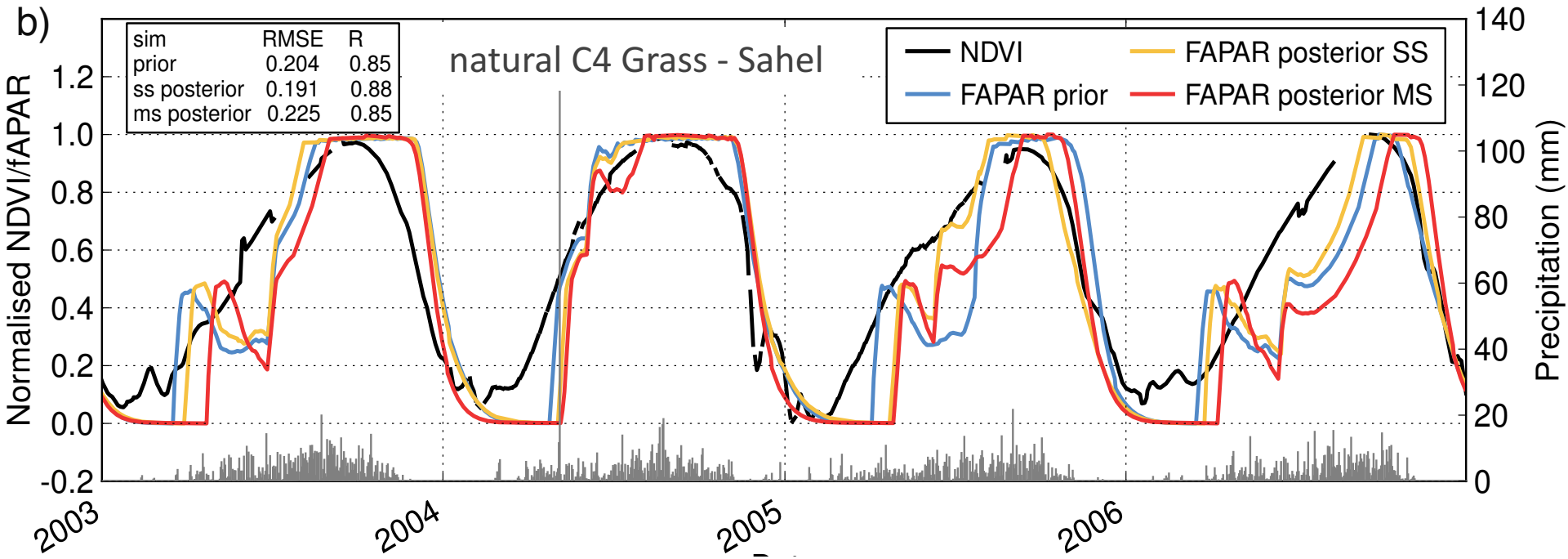
Difference in mean GSL (days) (post - prior)

−60 −45 −30 −15 0 15 30 45 60

GSL: Growing season length

MacBean et al. (2015) Using satellite data to improve the leaf phenology of a global Terrestrial Biosphere Model, *Biogeosciences,* 12, 7185-7208

Vegetation dynamics in semi-arid/dryland ecosystems

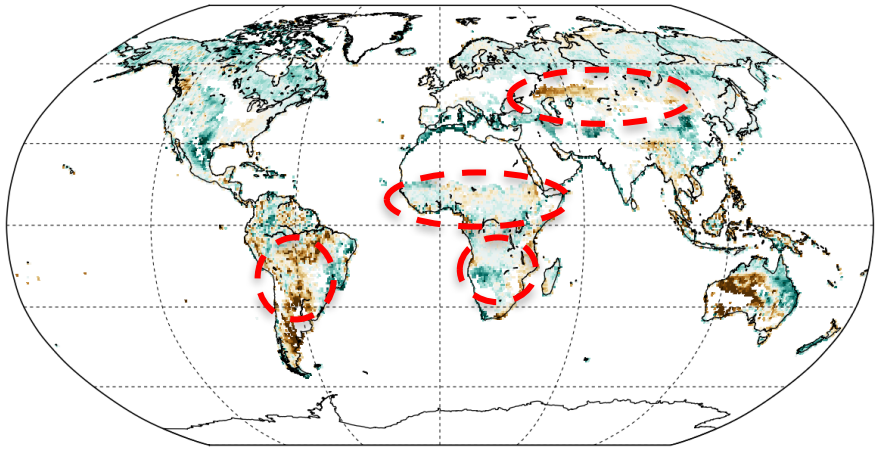


- Leaf onset/senescence controlled by moisture availability in these ecosystems (time since moisture minimum)
  - *How does moisture availability control leaf dynamics?*

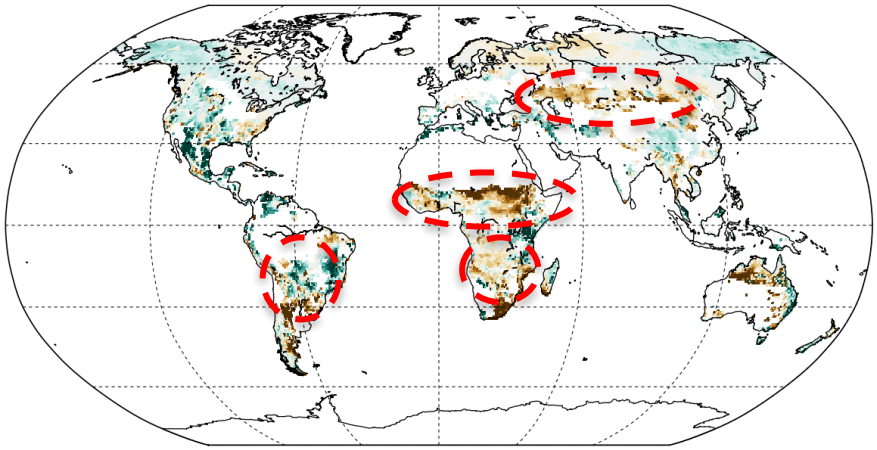
MacBean et al. (2015) Using satellite data to improve the leaf phenology of a global Terrestrial Biosphere Model, *Biogeosciences,* 12, 7185-7208

Vegetation dynamics in semi-arid/dryland ecosystems

- "Greening" or "browning" trends in model often opposite those in data in many dryland regions → even after optimization



OBS



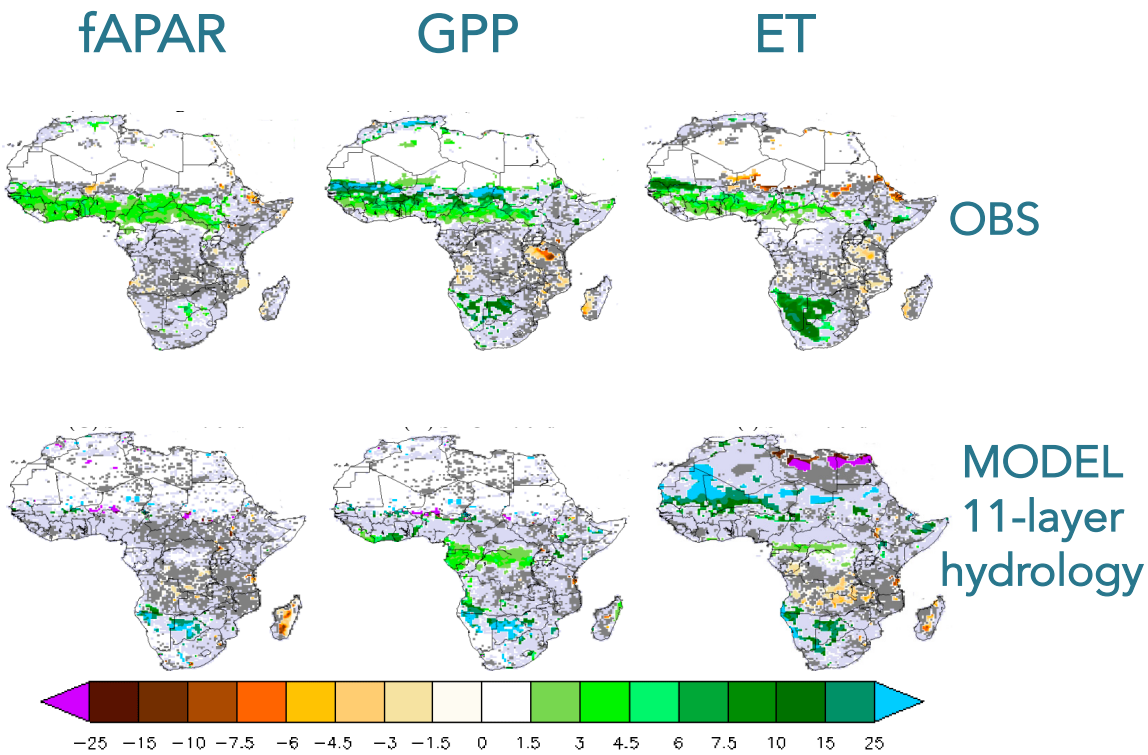
MODEL

- *What is driving the trends in vegetation productivity in these regions?*

N. MacBean et al. (2015) Using satellite data to improve the leaf phenology of a global Terrestrial Biosphere Model, *Biogeosciences,* 12, 7185-7208

Vegetation dynamics in semi-arid/dryland ecosystems

- Trends in vegetation activity (fAPAR), C uptake (GPP) and evapotranspiration (ET)



→ Model trends do not match observations

→ Even with more complex 11-layer hydrology model

→ Especially in Sahel

→ Water use efficiency (GPP/ET) likely wrong

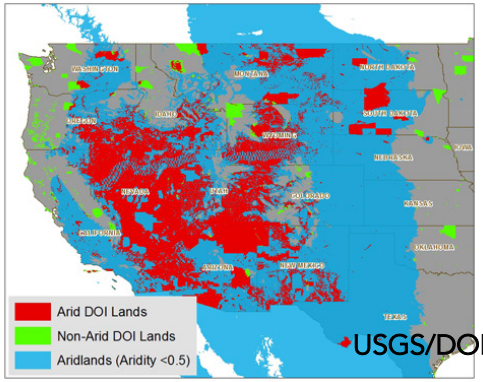
Traore et al. (2014) 1982-2010 Trends of Light Use Efficiency and Inherent Water Use Efficiency in African Vegetation, *Remote Sensing,* 6, 8923-8944

Importance of drylands in global and regional dynamics

Contribution of semi-arid ecosystems to interannual variability of the global carbon cycle

Benjamin Poulter[1,2], David Frank[3,4], Philippe Ciais[2], Ranga B. Myneni[5], Niels Andela[6], Jian Bi[5], Gregoire Broquet[2], Josep G. Canadell[7], Frederic Chevallier[2], Yi Y. Liu[8], Steven W. Running[9], Stephen Sitch[10] & Guido R. van der Werf[6]

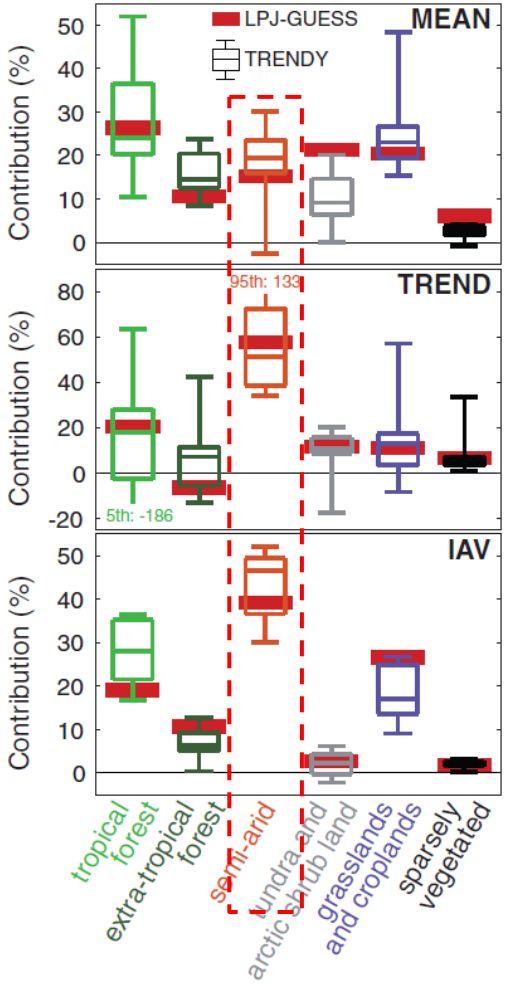
600 | NATURE | VOL 509 | 29 MAY 2014



The dominant role of semi-arid ecosystems in the trend and variability of the land CO_2 sink

Anders Ahlström,[1,2*] Michael R. Raupach,[3†] Guy Schurgers,[4] Benjamin Smith,
Almut Arneth,[5] Martin Jung,[6] Markus Reichstein,[6] Josep G. Canadell,[7] Pierre Friedl
Atul K. Jain,[9] Etsushi Kato,[10] Benjamin Poulter,[11] Stephen Sitch,[12] Benjamin D. St
Nicolas Viovy,[15] Ying Ping Wang,[16] Andy Wiltshire,[17] Sönke Zaehle,[6] Ning Zeng[18]

SCIENCE 22 MAY 2015 • VOL 348 ISSUE 6237 895



Global Change Biology (2016), doi: 10.1111/gcb.13202

Dryland vegetation response to wet episode, not inherent shift in sensitivity to rainfall, behind Australia's role in 2011 global carbon sink anomaly

VANESSA HAVERD[1], BENJAMIN SMITH[2] and CATHY TRUDINGER[3]

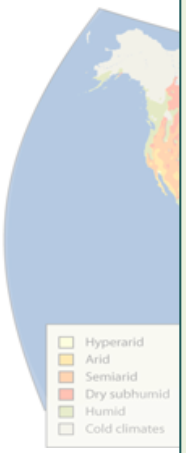
[1]*CSIRO Oceans and Atmosphere, GPO Box 3023, Canberra, ACT 2601, Australia,* [2]*Department of Physical Geography and Ecosystem Science, Lund University, 22362 Lund, Sweden,* [3]*CSIRO Oceans and Atmosphere, PMB 1, Aspendale, Vic 3195, Australia*

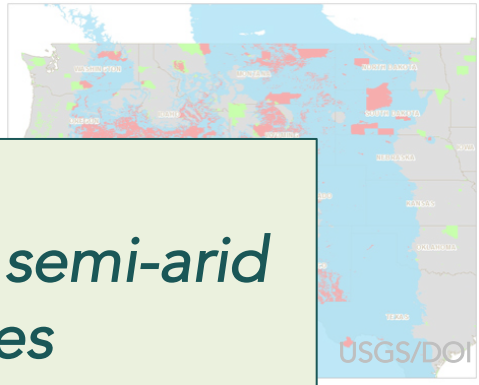
Importance of drylands in global and regional dynamics

Contribution of semi-arid ecosystems to interannual variability of the global carbon cycle

Benjamin Poulter[1,2], David
Josep G. Canadell[7], Frederi

600 | NATURE | VOL 509





-arid
d
sink

Benjamin Smith,[1]
dell,[7] Pierre Friedlingstein,[8]
,[12] Benjamin D. Stocker,[13,14]
hle,[6] Ning Zeng[18]

- *What are the drivers of change in semi-arid ecosystems on different time-scales (IAV/trend)?*
- *How can we improve the representation of these processes in the model?*
- *How do these processes interact with changing climate and CO_2?*

VANESSA HAVERD[1], BENJAMIN SMITH[2] and CATHY TRUDINGER[3]

[1]*CSIRO Oceans and Atmosphere, GPO Box 3023, Canberra, ACT 2601, Australia,* [2]*Department of Physical Geography and Ecosystem Science, Lund University, 22362 Lund, Sweden,* [3]*CSIRO Oceans and Atmosphere, PMB 1, Aspendale, Vic 3195, Australia*

Meanwhile in Tucson…

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE
10.1002/2015JG003181

Key Points:
- Effects of decadal drought on semiarid ecosystem carbon cycling are investigated

The carbon balance pivot point of southwestern U.S. semiarid ecosystems: Insights from the 21st century drought

Russell L. Scott[1], Joel A. Biederman[1], Erik P. Hamerlynck[2], and Greg A. Barron-Gafford[3,4]

Global Change Biology

Global Change Biology (2016) **22**, 1867–1879, doi: 10.1111/gcb.13222

Terrestrial carbon balance in a drier world: the effects of water availability in southwestern North America

JOEL A. BIEDERMAN[1], RUSSELL L. SCOTT[1], MICHAEL L. GOULDEN[2], RODRIGO VARGAS[3], MARCY E. LITVAK[4], THOMAS E. KOLB[5], ENRICO A. YEPEZ[6]

Global Change Biology

Explore this journal >

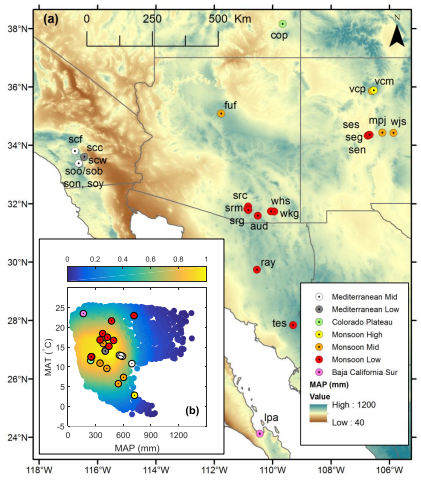
Primary Research Articles

CO_2 exchange and evapotranspiration across dryland ecosystems of southwestern North America

Joel A. Biederman ✉, Russell L. Scott, Tom W. Bell, David R. Bowling, Sabina Dore, Jaime Garatuza-Payan, Thomas E. Kolb

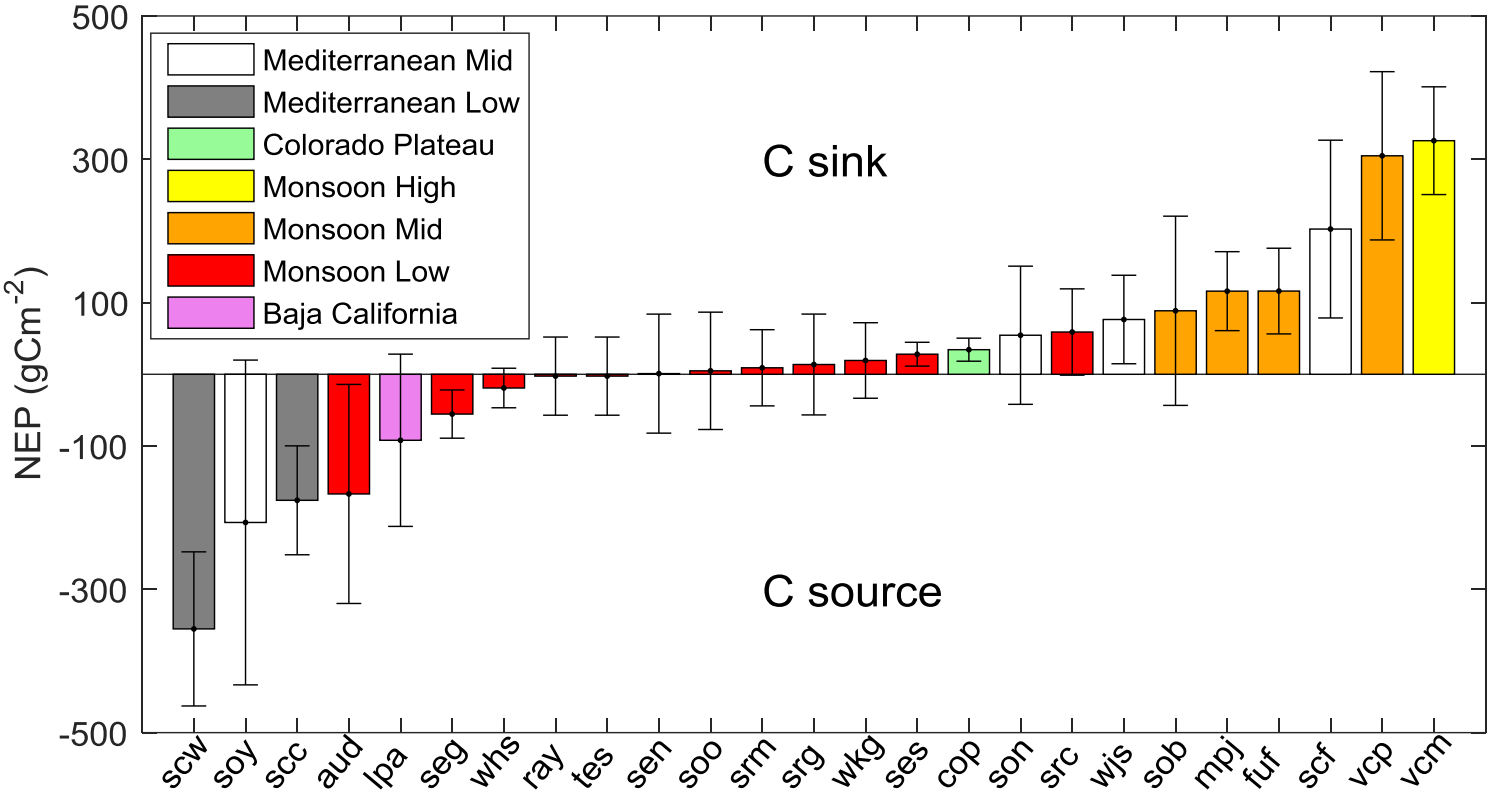
Accepted manuscript online: 13 March 2017 Full publication history

DOI: 10.1111/gcb.13686 View/save citation



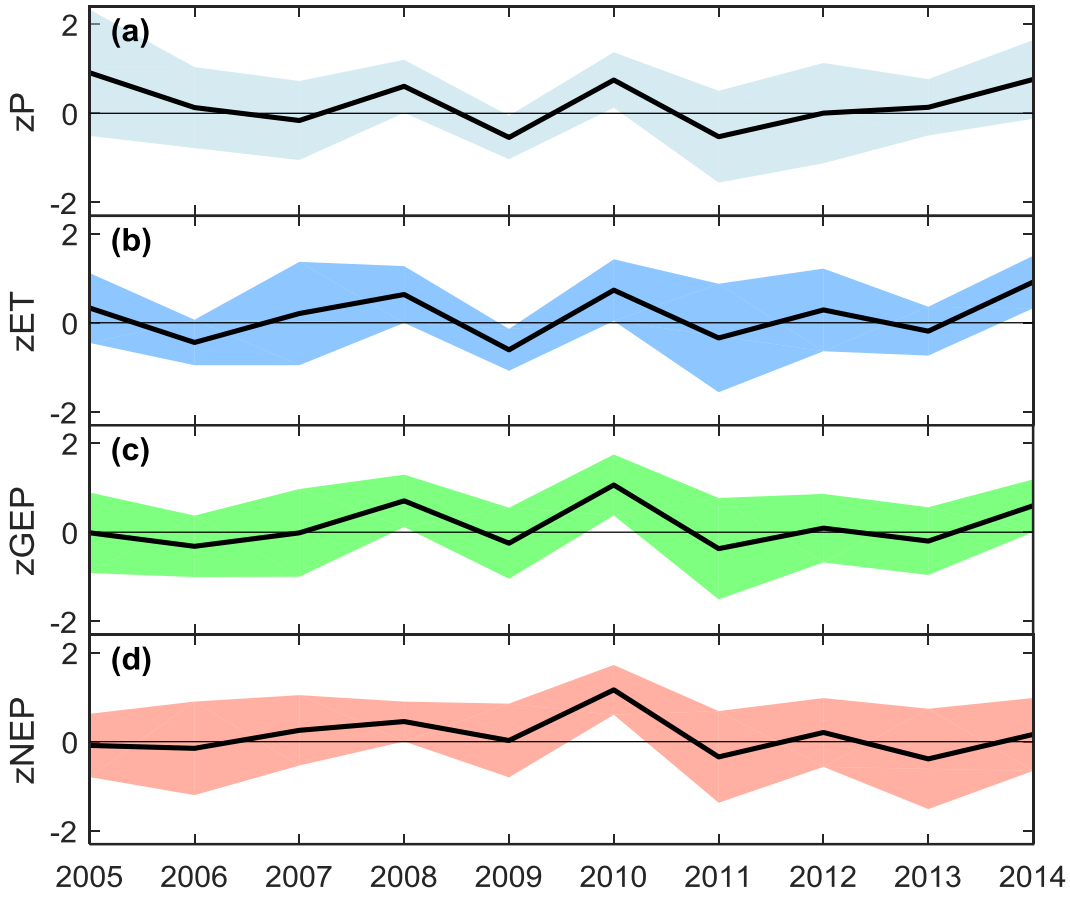
SW US C cycle dynamics

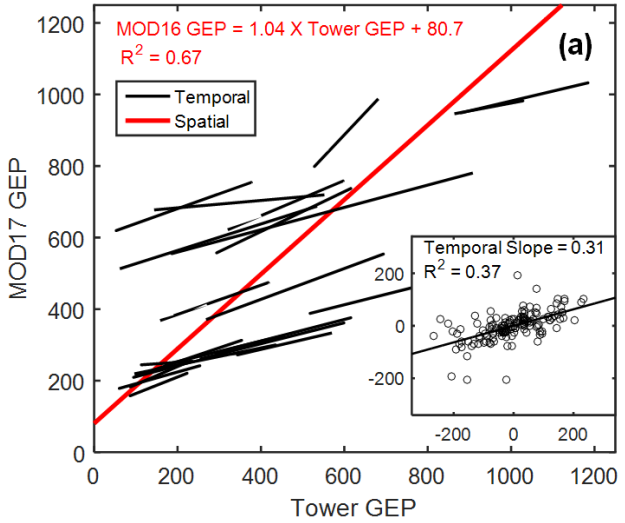
- Interannual variability of NEE, GPP and Reco larger than for mesic regions
- 50% sites switched between functioning as C sinks/sources in wet/dry years.

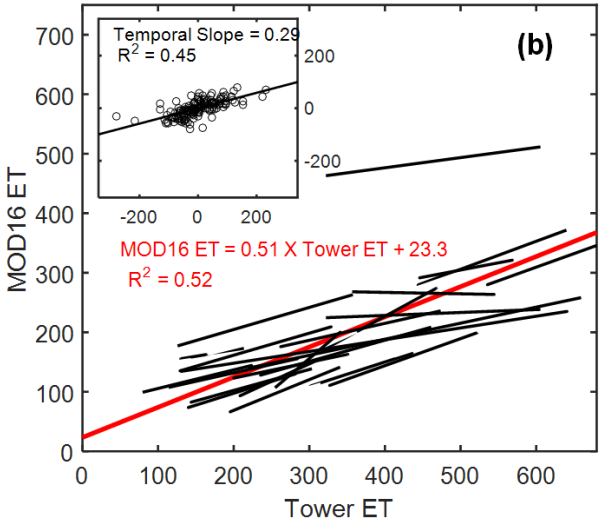


Biederman et al. (2017), GCB

SW US C cycle dynamics

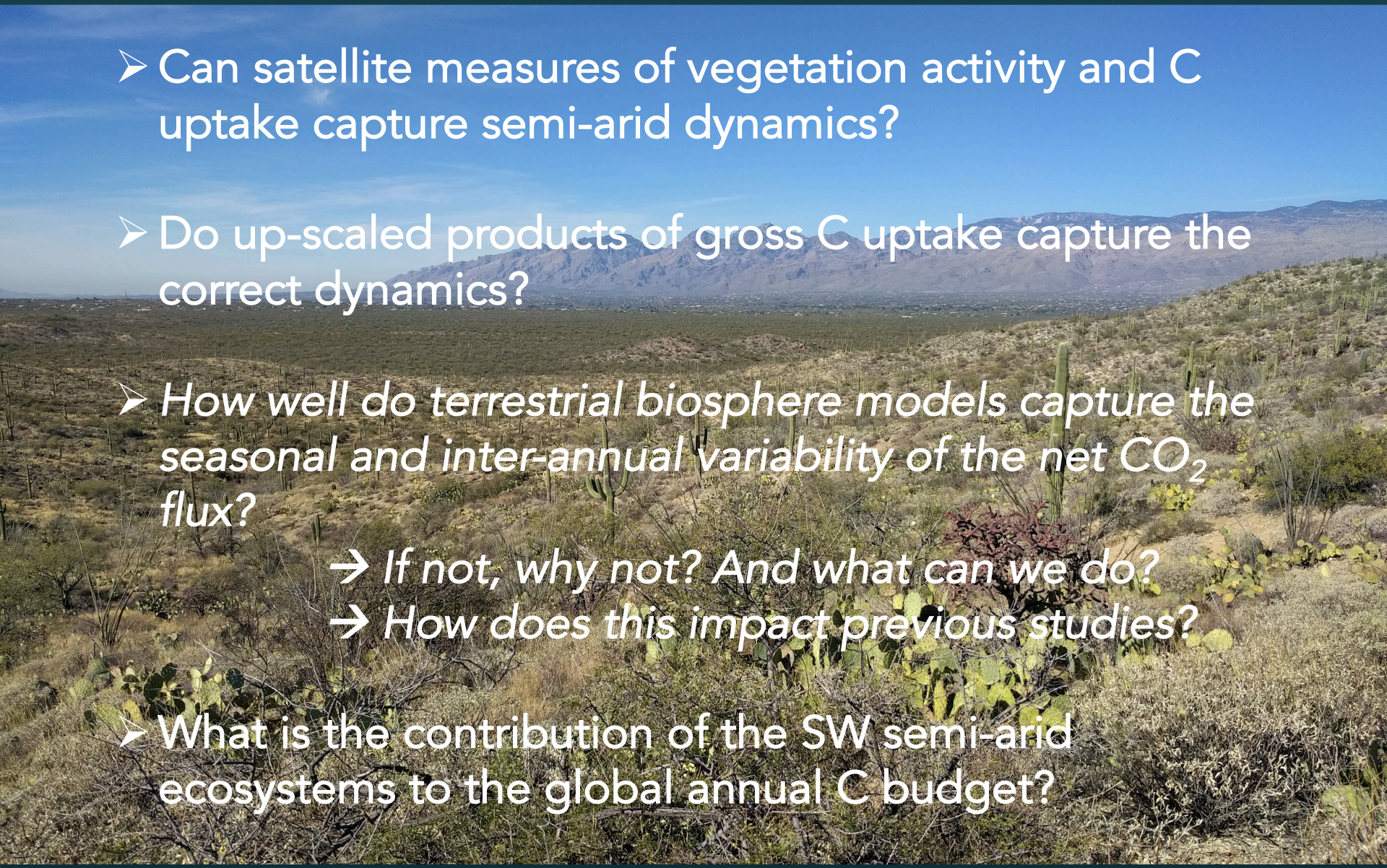






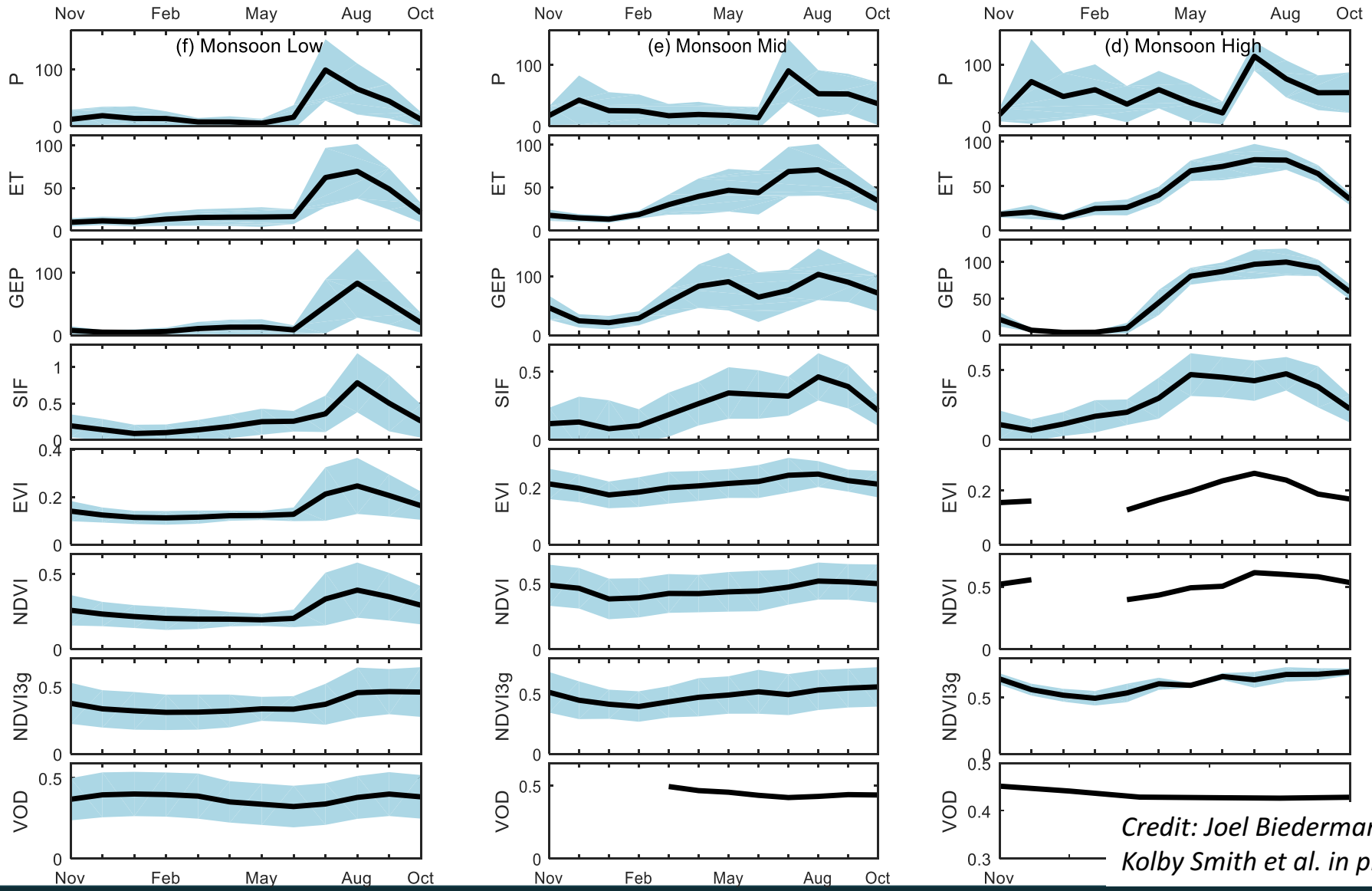
Biederman et al. (2017), GCB

Remaining questions about semi-arid ecosystems…



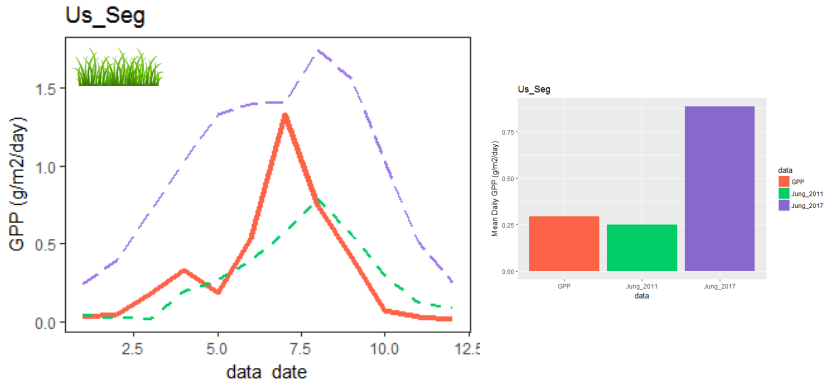
- Can satellite measures of vegetation activity and C uptake capture semi-arid dynamics?
- Do up-scaled products of gross C uptake capture the correct dynamics?
- *How well do terrestrial biosphere models capture the seasonal and inter-annual variability of the net CO_2 flux?*
  - → *If not, why not? And what can we do?*
  - → *How does this impact previous studies?*
- What is the contribution of the SW semi-arid ecosystems to the global annual C budget?

Can satellite data capture semi-arid dynamics?

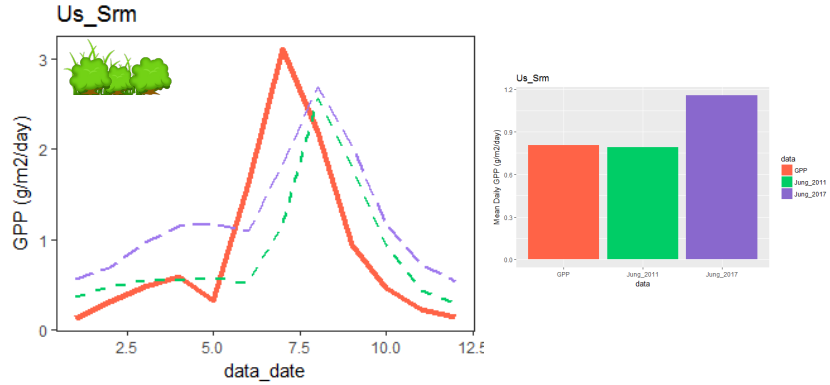


Credit: Joel Biederman
Kolby Smith et al. in prep.

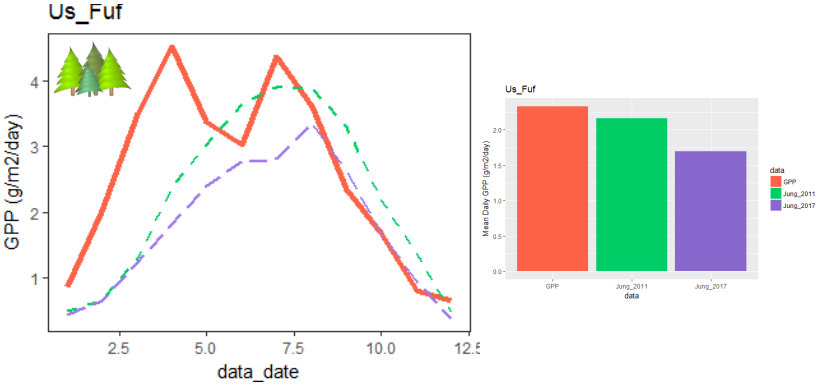
Do global up-scaled C products capture semi-arid dynamics?



Temporal Mismatch and poorly represented GPP peak:
Sevilleta Grassland – upscaled GPP peaks lag behind tower GPP peak. Peak is not as well defined. Jung 2017 dataset overestimates.



Slight temporal mismatch; GPP peak well represented:
Santa Rita Mesquite Savannah– upscaled GPP peaks lag behind tower GPP peak. Peak amplitude is well defined. Jung 2017 dataset overestimates.

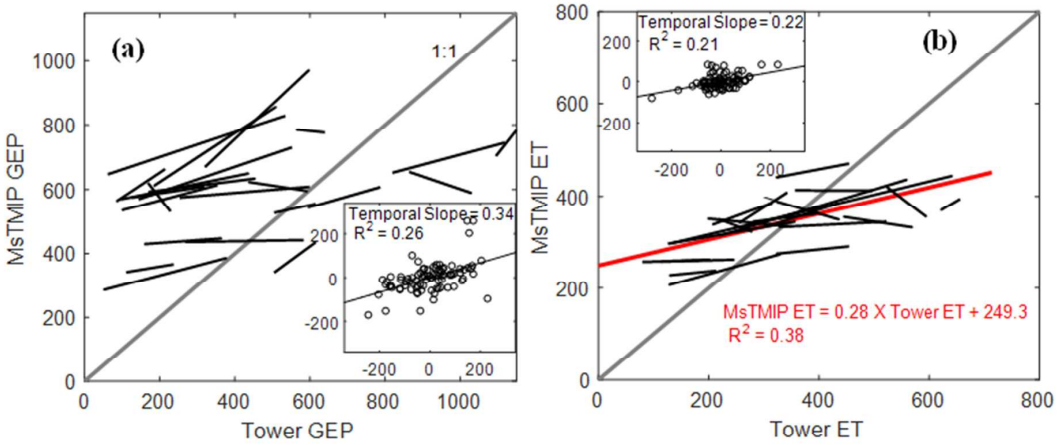


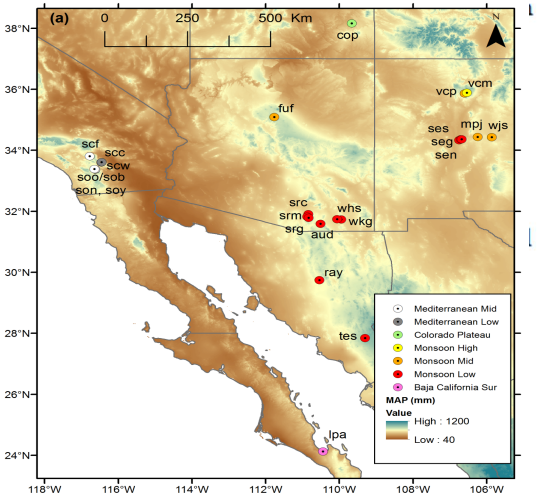
Missed spring GPP peak not captured; GPP underestimated: Flagstaff
Unmanaged forest – upscaled GPP does not capture springtime GPP peak and underestimates overall GPP

Barnes et al.: Joint NACP Ameriflux PI Meeting, March, 2017

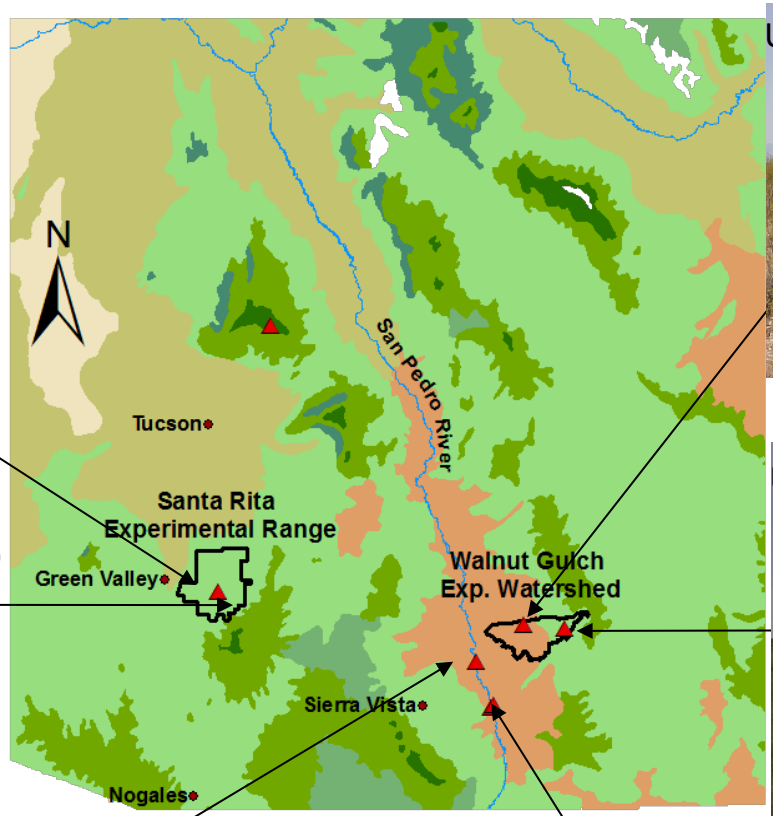
How well do models perform in SW US semi-arid ecosystems?

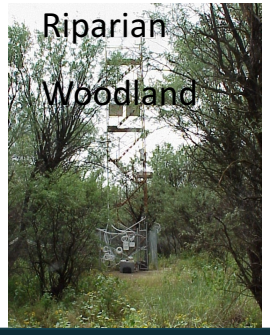
- *Extension of Biederman et al. (2017) GCB paper: "CO2 exchange and evapotranspiration across dryland ecosystems of southwestern North America"*

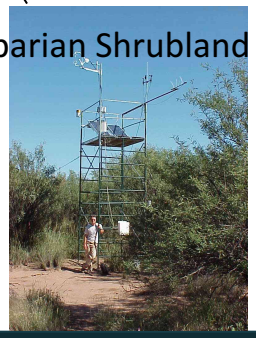




Site-level evaluation of ORCHIDEE TBM at SW semi-arid sites



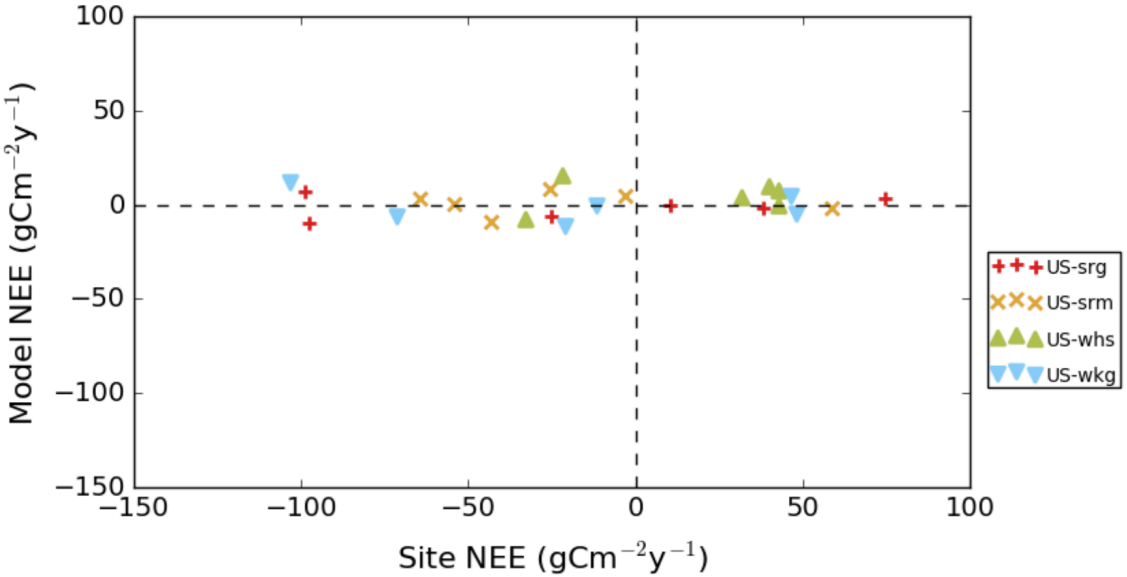


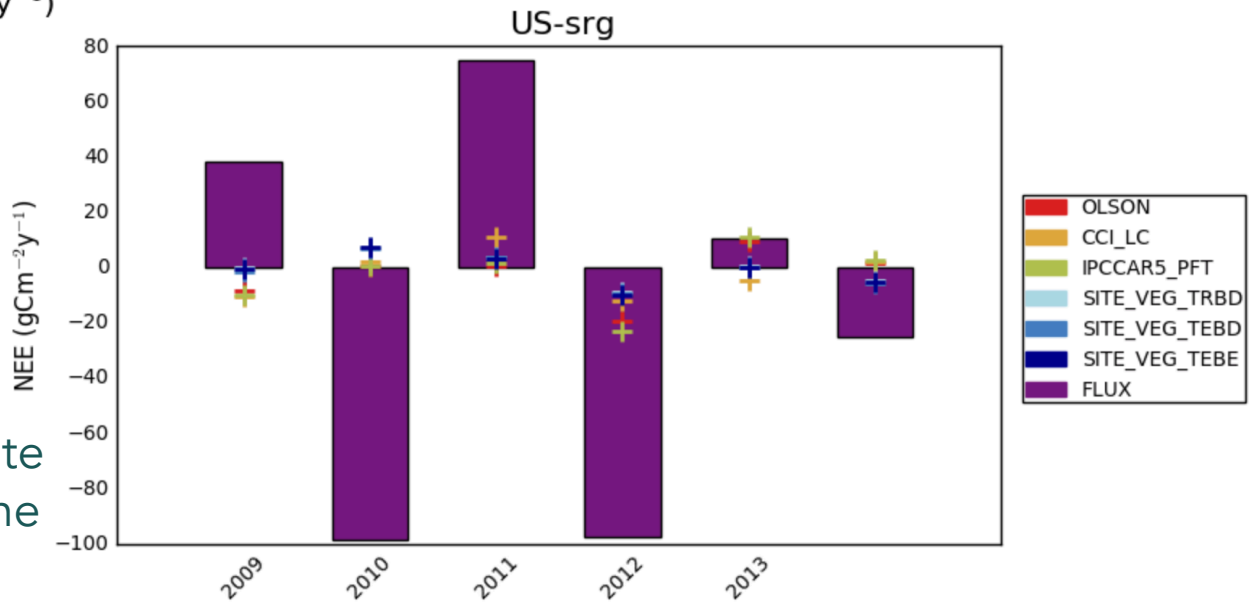


Credit: Russ Scott, USDA ARS SWRC

Ameriflux.lbl.gov

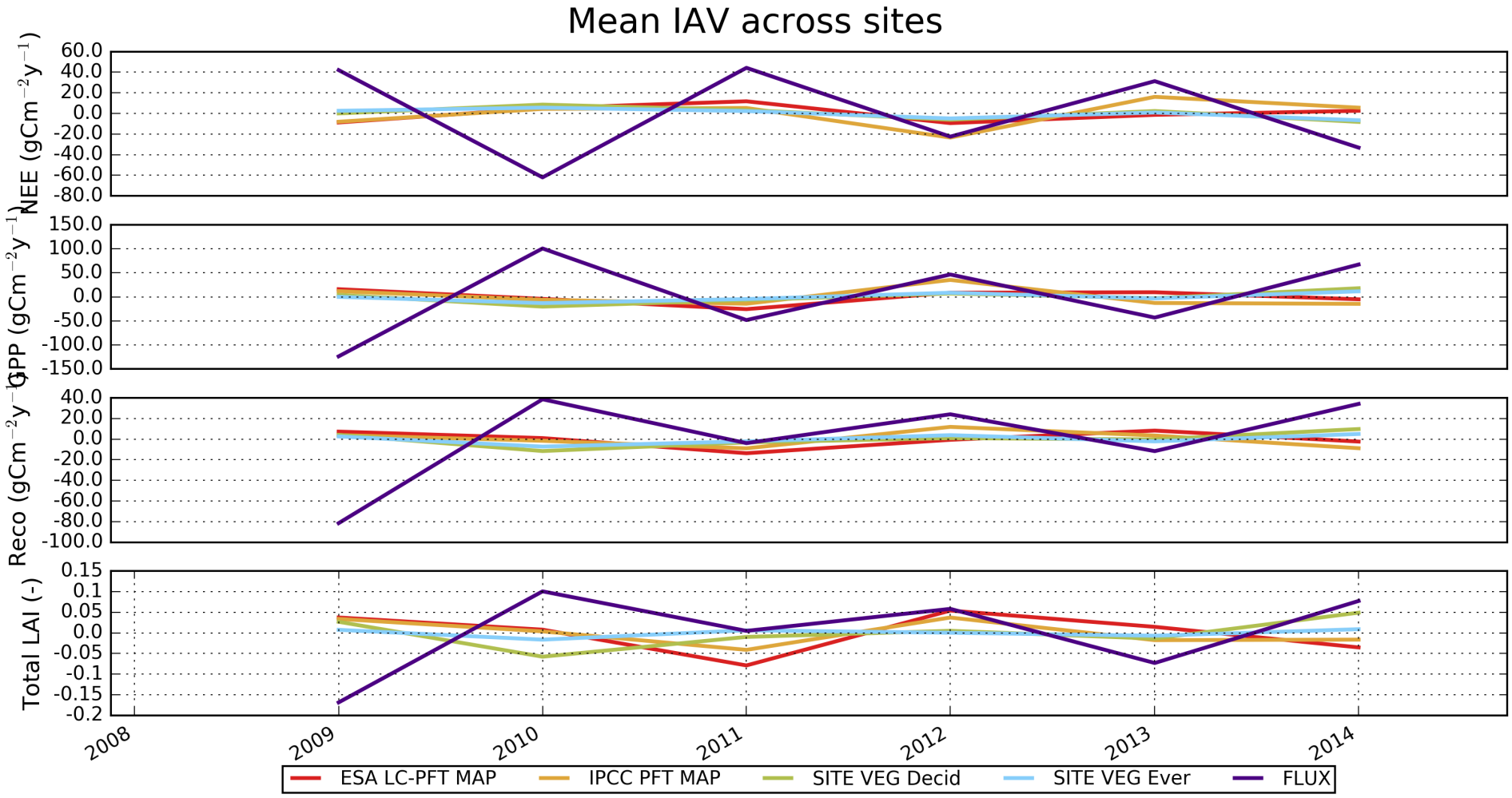
Is the ORCHIDEE TBM able to reproduce the annual net CO_2 budget for these semi-arid sites?





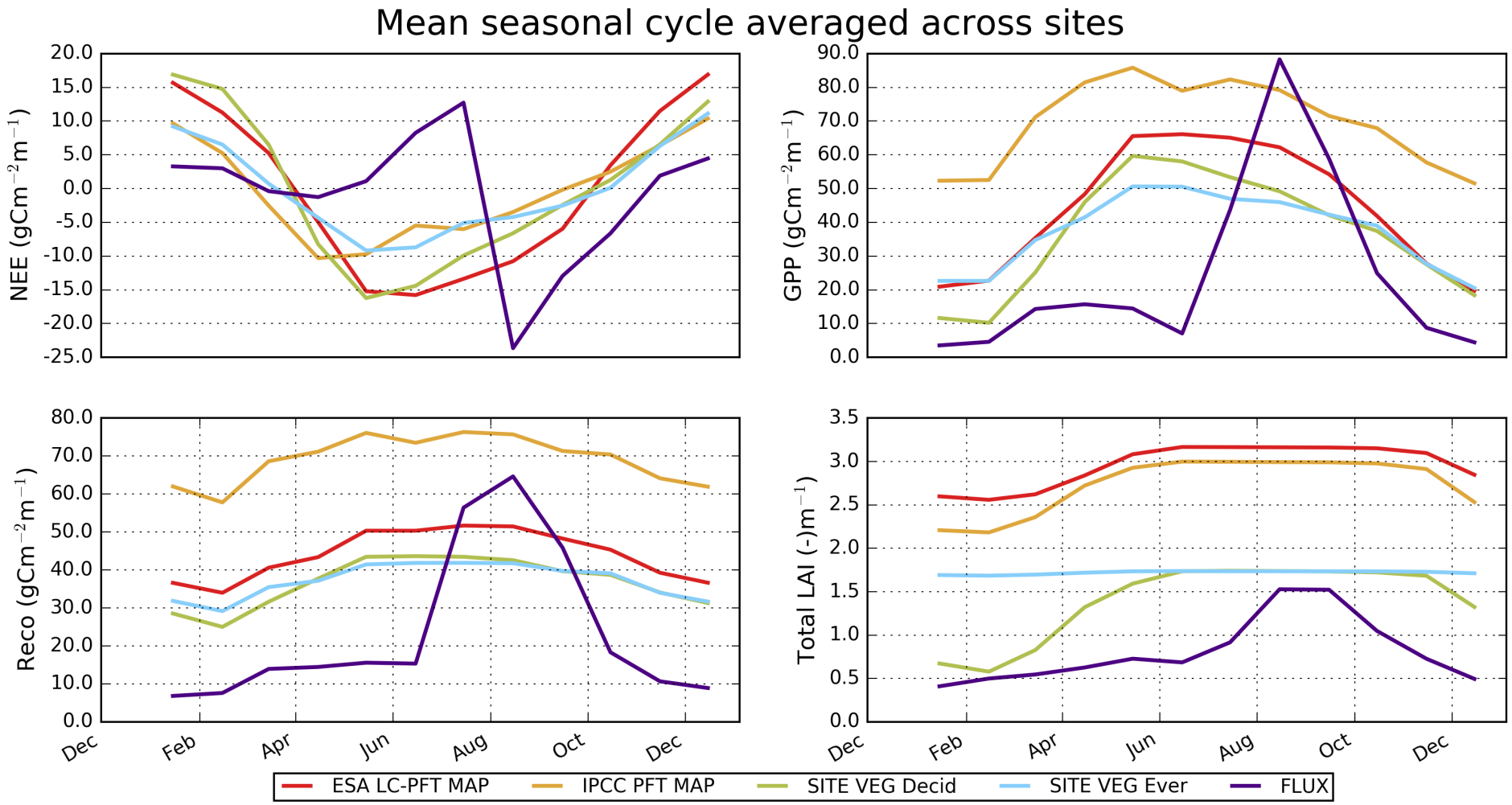
- Does uncertainty in vegetation type contribute to significant spread in the net CO_2 flux estimates?

Is the ORCHIDEE TBM able to reproduce sign and magnitude of the inter-annual variability?



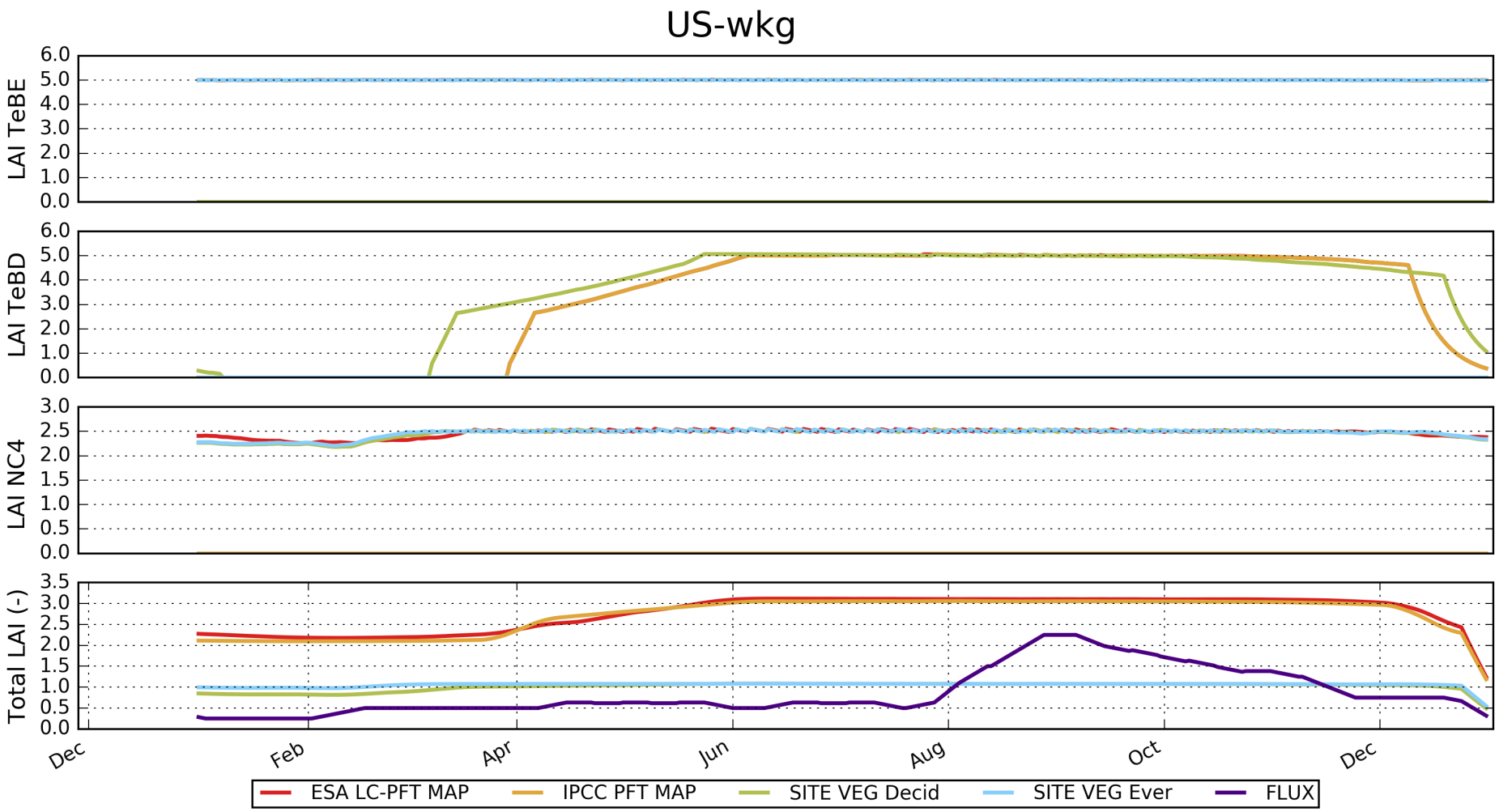
- *Could semi-arid ecosystems in the SW US play an even bigger role in the IAV of the global C budget than originally thought?*

Does ORCHIDEE capture the mean seasonal cycle?

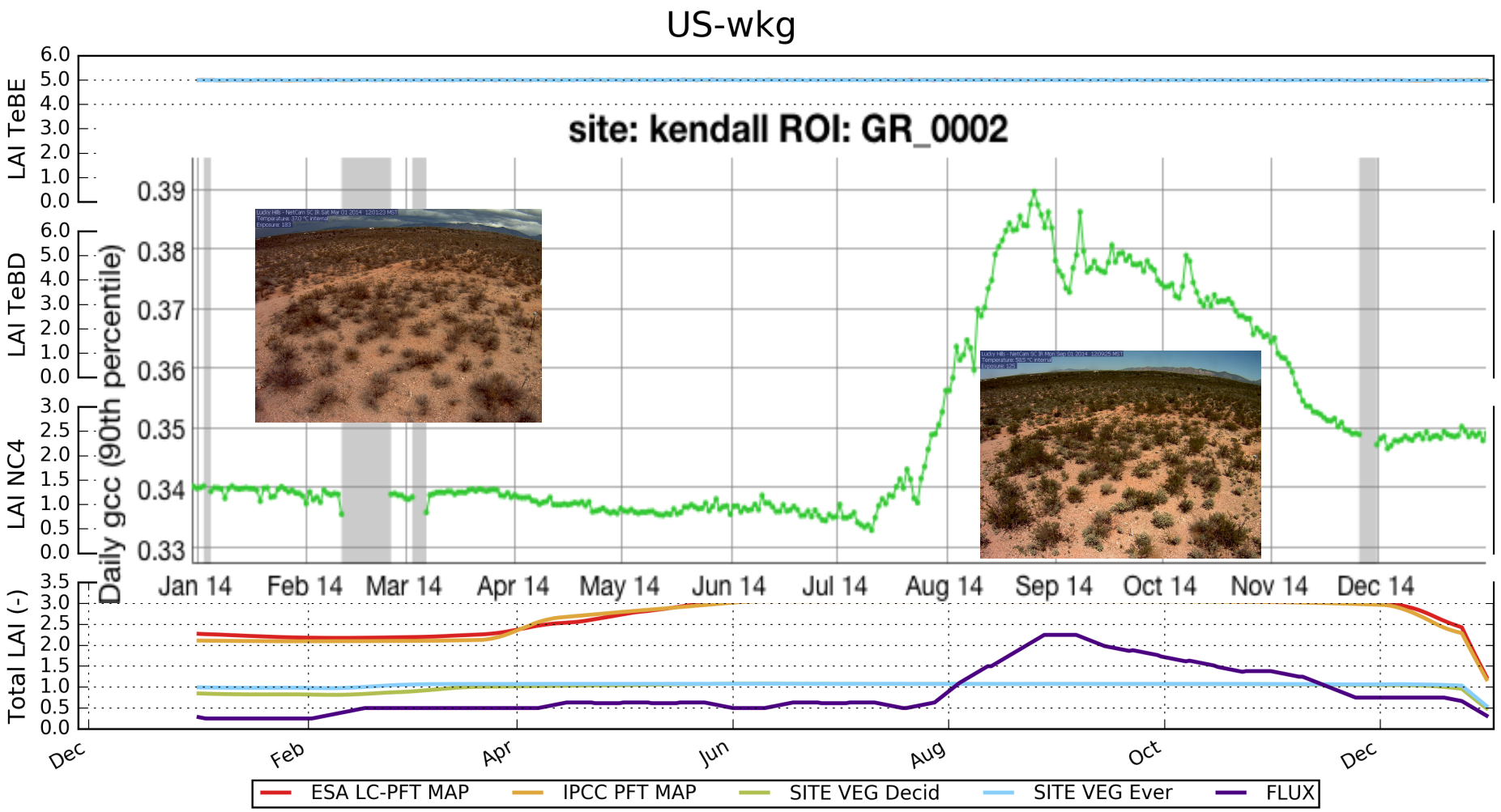


- *Do these patterns hold across all biomes/elevations in the semi-arid SW US?*

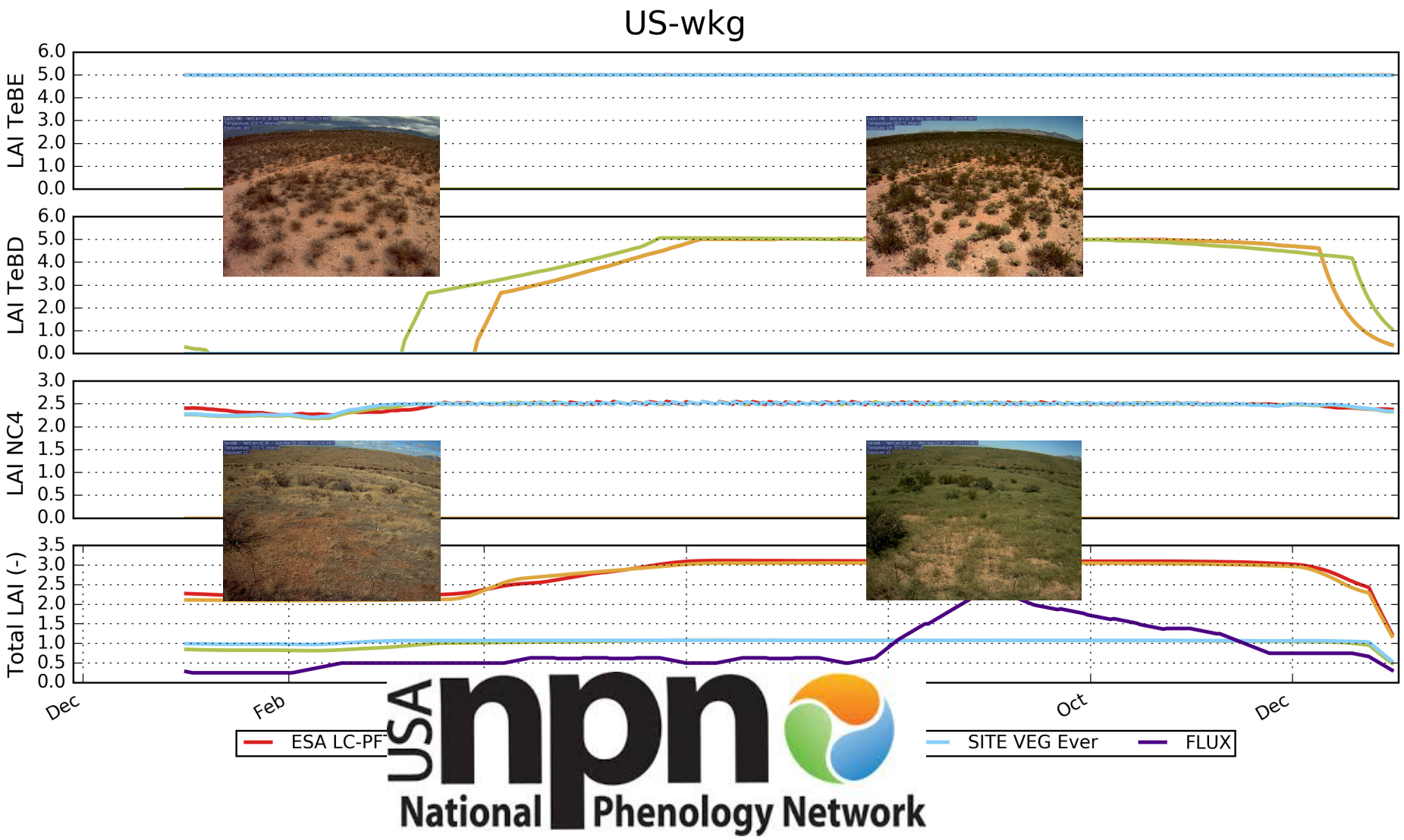
Which processes might be responsible for the model data misfit?



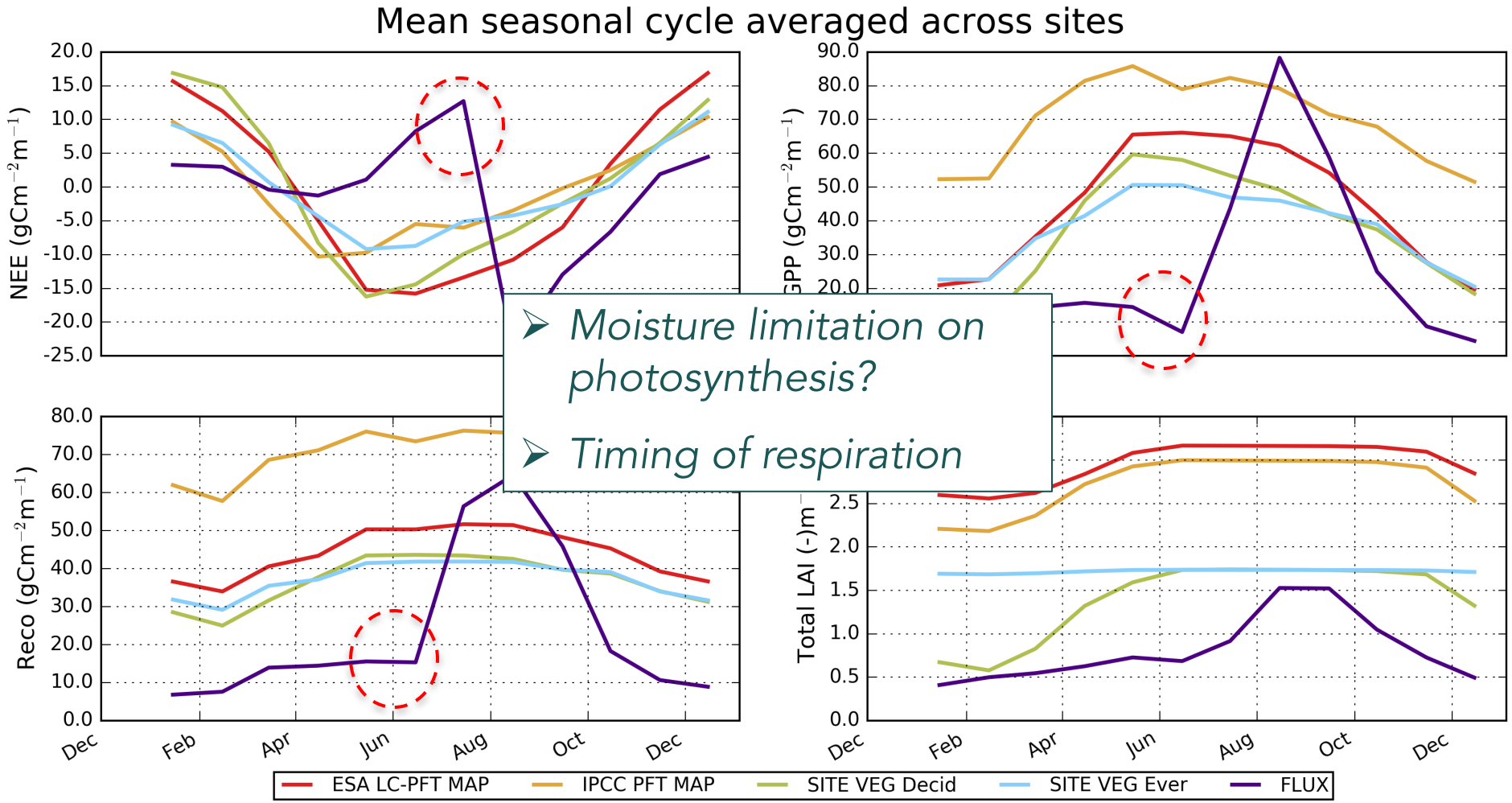
Which processes might be responsible for the model data misfit?



Which processes might be responsible for the model data misfit?



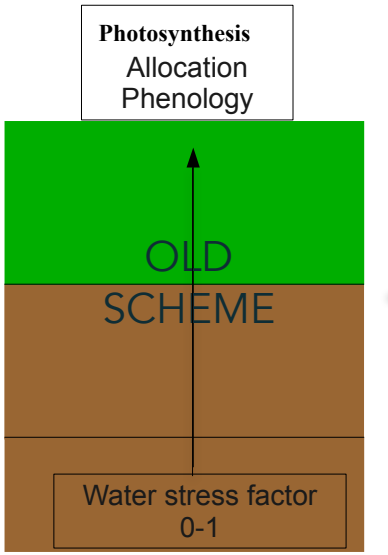
Which processes might be responsible for the model data misfit?

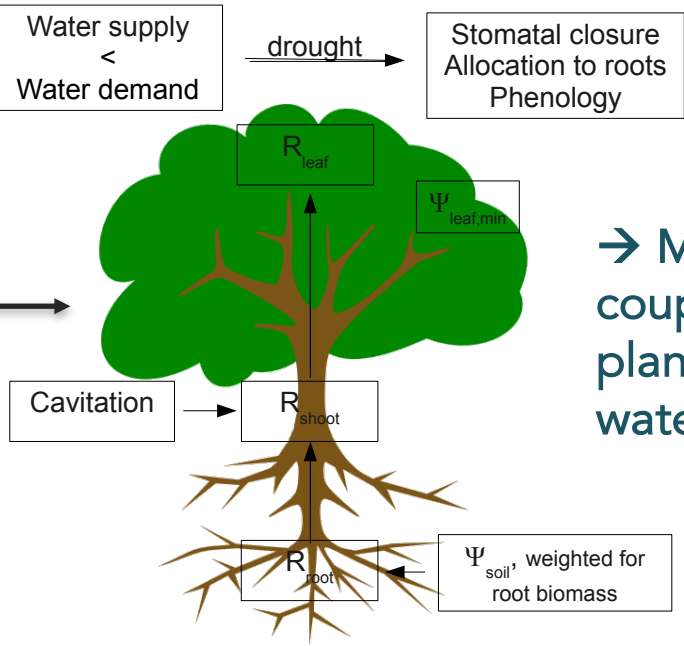


- *Moisture limitation on photosynthesis?*
- *Timing of respiration*

Latest model developments → mechanistic plant water transport

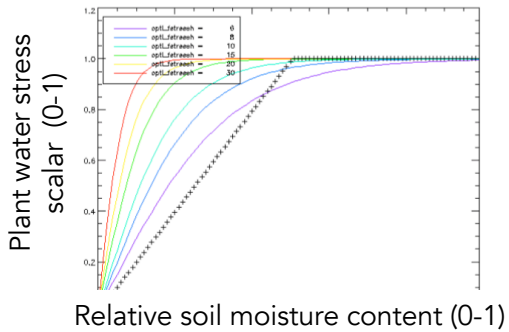
- Latest processes added to ORCHIDEE include plant hydraulic architecture





→ Mechanistic coupling between plant carbon and water cycles

De Kauwe et al. (2015) → empirical plant water stress functions in LSMs don't capture drought well



Geoscientific Model Development
Open Access
Geosci. Model Dev., 8, 2035–2065, 2015

A vertically discretised canopy description for ORCHIDEE (SVN r2290) and the modifications to the energy, water and carbon fluxes

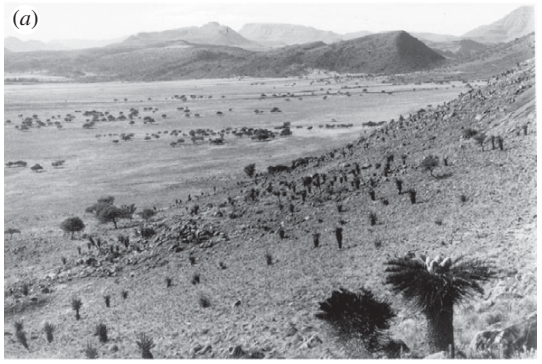
K. Naudts[1,14], J. Ryder[1], M. J. McGrath[1], J. Otto[1,10], Y. Chen[1], A. Valade[1], V. Bellasen[2], G. Berhongaray[3], G. Bönisch[4], M. Campioli[3], J. Ghattas[1], T. De Groote[3,11], V. Haverd[5], J. Kattge[4], N. MacBean[1], F. Maignan[1],

Trends in dryland regions – missing processes?

- Woody encroachment a problem in many areas (including US!)

- Possible causes (or interplay):
  - Increasing CO_2?
  - Fire suppression?
  - Animal grazing?

- Human interaction with long-term trends…
  - Couple dynamic vegetation with grassland management (including grazing).



Summary

- Contriubution of semi-arid regions becoming more apparent in global C budget
- Need better understanding of satellite data and up-scaling products
- Need to improve process-based knowledge in models, in particular related to phenology and water-limitation on photosynthesis
- Consider the role of changing vegetation distribution on long-term trends

Thank you for listening! Any questions?

→ *Can we use models to find ways to mitigate effects of anthropogenic change via carbon/water management?*

Acknowledgements

- LSCE (France): Philippe Peylin, Fabienne Maignan, Cédric Bacour and ORCHIDEE Project Team