Challenging models with data from a multi-factor CO_2 & warming experiment

Martin De Kauwe & friends ...
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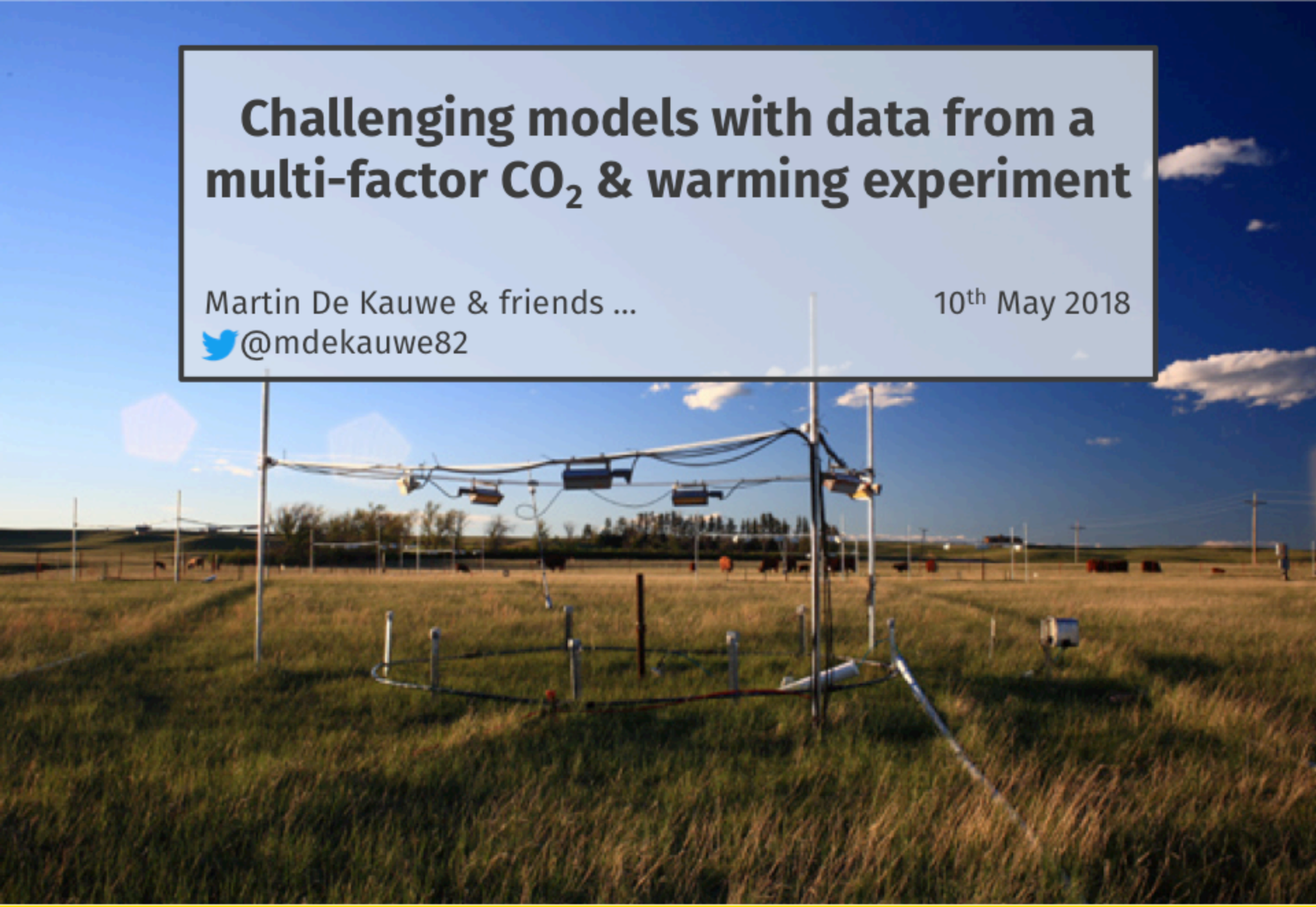
10th May 2018



climate extremes
ARC centre of excellence
Australian Government
Australian Research Council
UNSW SYDNEY

Multi-factor experiments

- Widely advocated as important for evaluating model predictions in response to global change.

- But models are rarely evaluated against more than a single factor!
  - Lack of **ecosystem** scale multi-factor experiments

ECOLOGY LETTERS

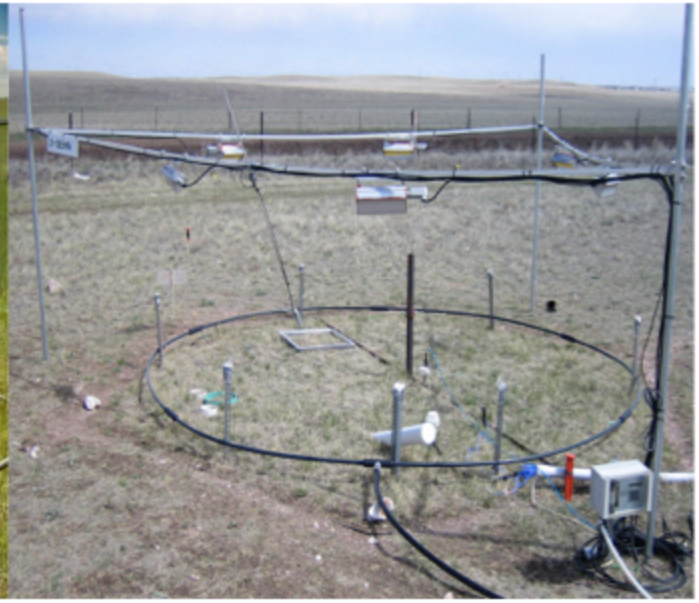
Ecology Letters, (2016) **19**: 956–966 doi: 10.1111/ele.12634

Impacts of warming and elevated CO_2 on a semi-arid grassland are non-additive, shift with precipitation, and reverse over time

K. E. Mueller,[1]* D. M. Blumenthal,[1]
E. Pendall,[2] Y. Carrillo,[2]
F. A. Dijkstra,[3] D. G. Williams,[4]
R. F. Follett[5] and J. A. Morgan[1]

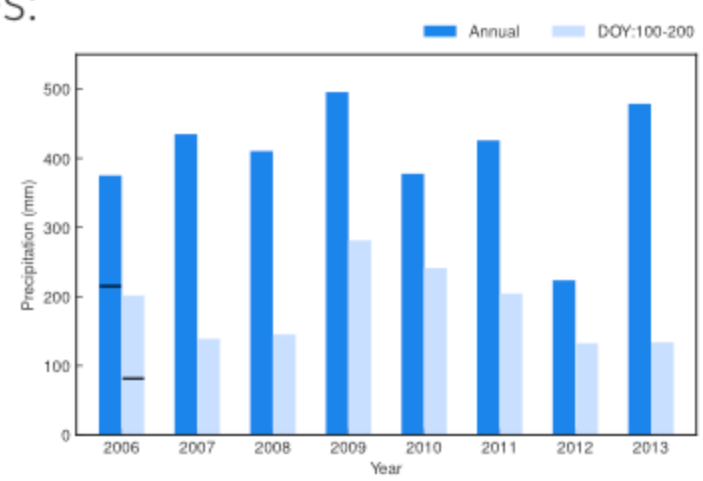
Prairie Heating and CO_2 Enrichment

- PHACE experiment (Wyoming, USA).



- 8 years, full factorial design with 5 replicates:
  - Mixed C_3 and C_4 grass prairie.
  - CO_2: 600 ppm vs. 385 ppm.
  - Warming: +1.5°C day / +3.0°C night.

Strong IAV PPT



Model setup

- We applied 10 models to the experiment.
  - CABLE, CLM4.5, DAYCENT, GDAY, ISAM, JULES, LPJ-GUESS, O-CN, ORCHIDEE & SDGVM.

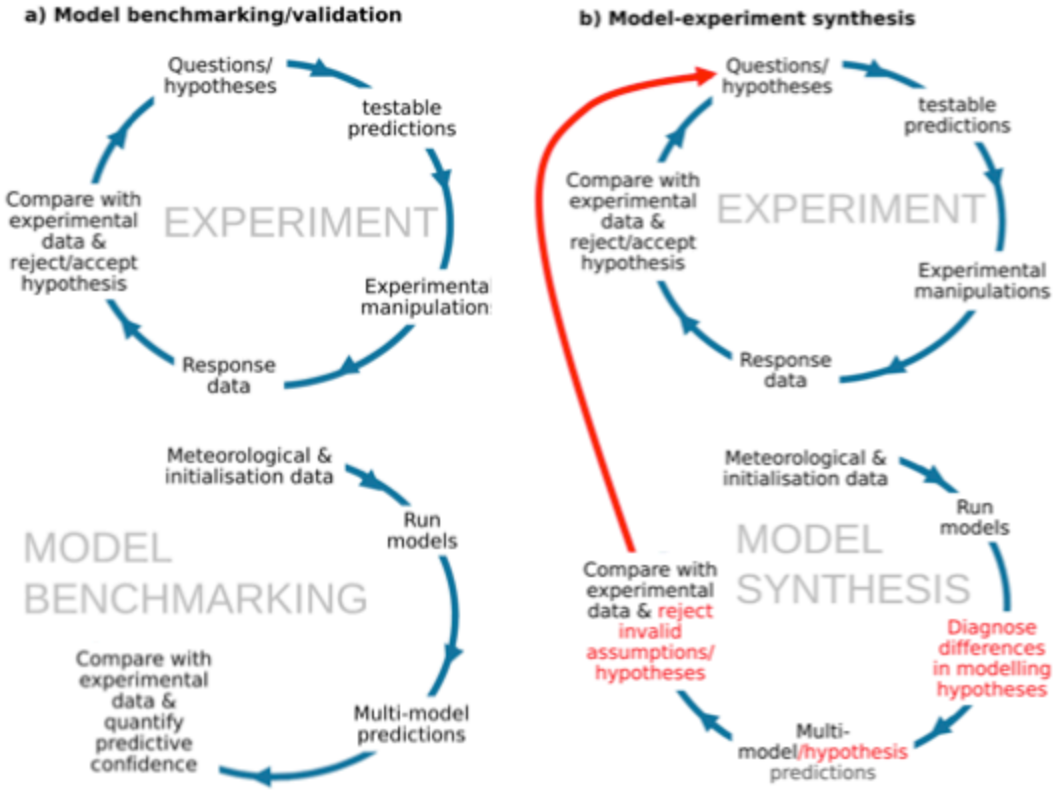
- Modellers were provided with site characteristics to parameterise their models: **representative rather than tuned**.

- Models assumed the same effective soil water buckets.

Model benchmarking / evaluation

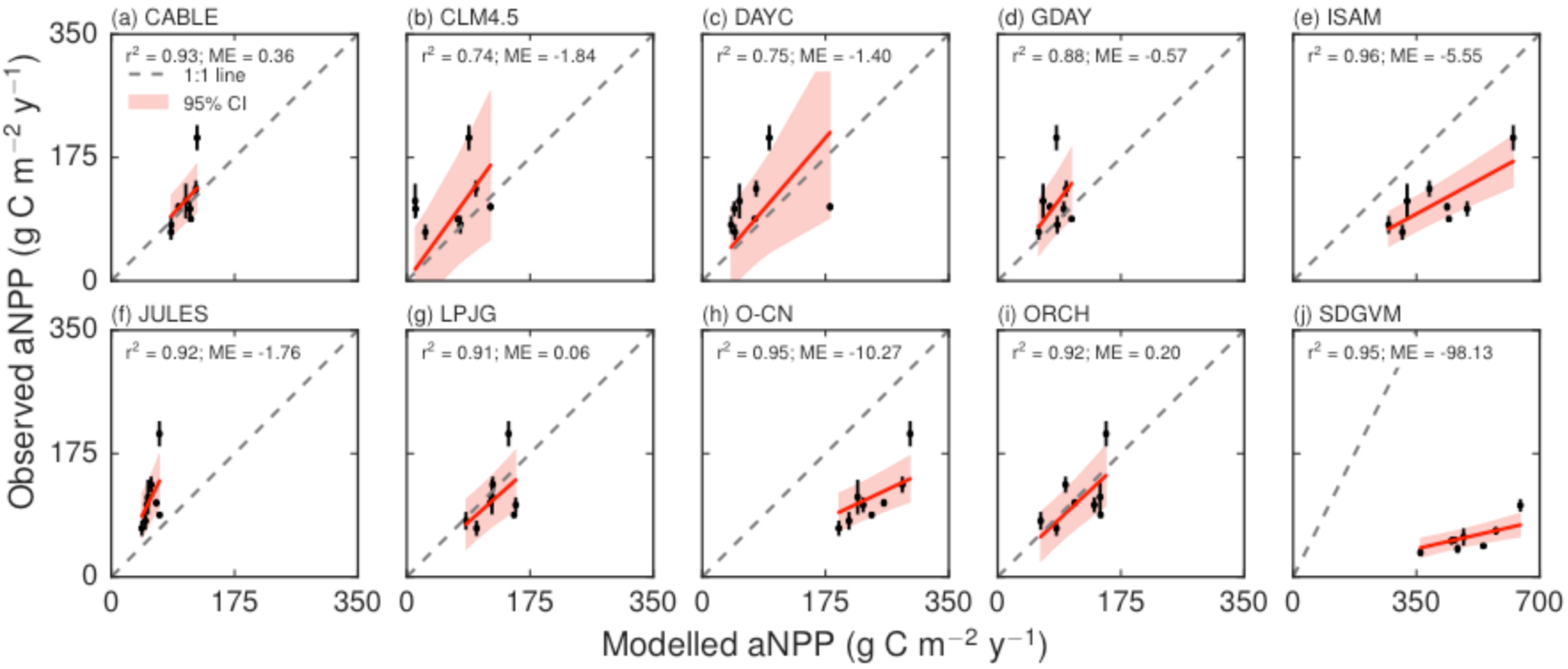
Aim was not to find the “best” model …

“Assumption-centred modelling”



- Explain model behaviour in terms of assumptions made
- Test competing model hypotheses with observations
- Identify key weaknesses where new data / theory / experiments are needed

Ambient aNPP



$$aNPP = GPP_u \cdot CUE \cdot A_b \cdot \beta \cdot LAI_r \cdot LAP_p$$

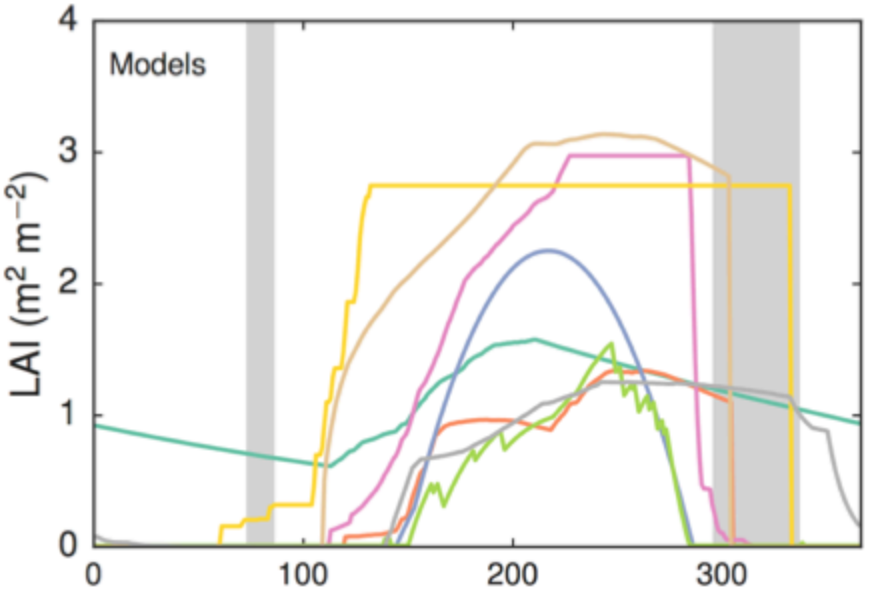
A_b : 0.16 – 0.92

β : 0.17 – 0.97

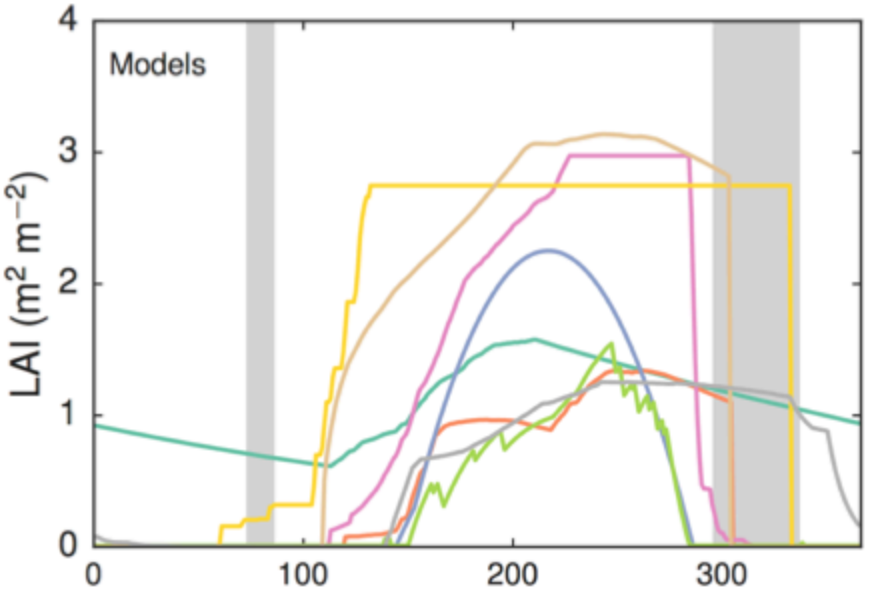
LAI_r : 77 – 256 days

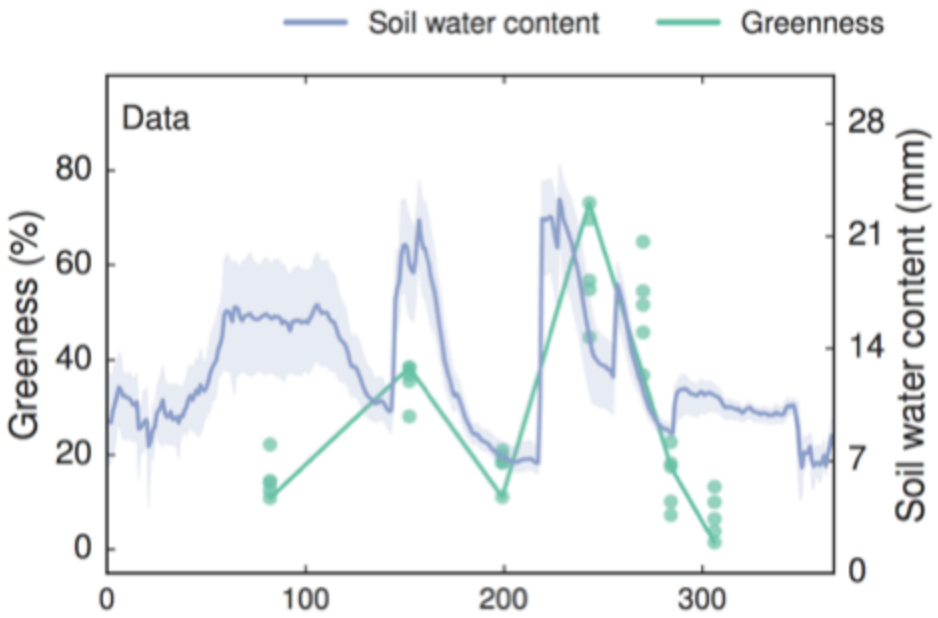
LAP_p : 1.21 – 6.1 $m^2\ m^{-2}$

Phenology

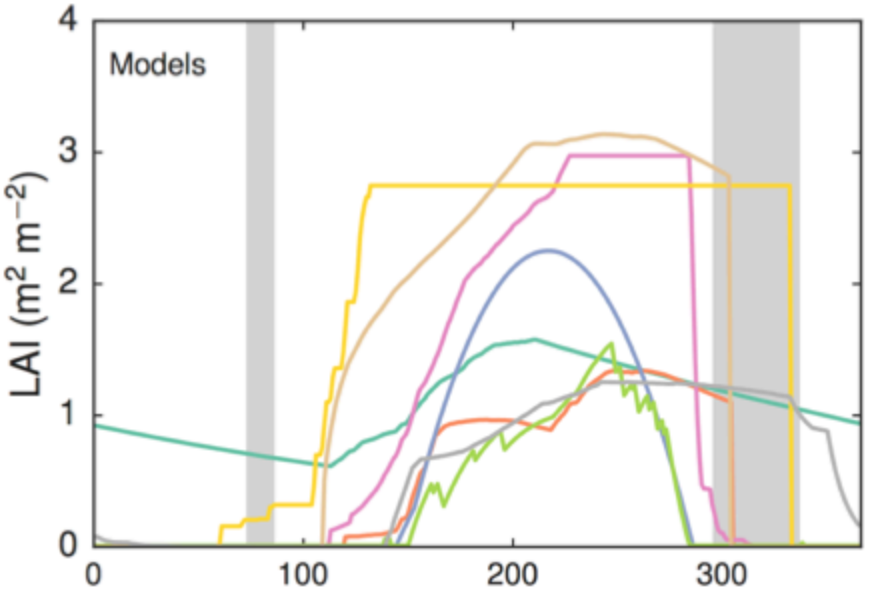


Phenology


Models
LAI (m² m⁻²)
0
1
2
3
4
0
100
200
300


Soil water content
Greenness
Data
Greeness (%)
0
20
40
60
80
Soil water content (mm)
0
7
14
21
28
0
100
200
300

Phenology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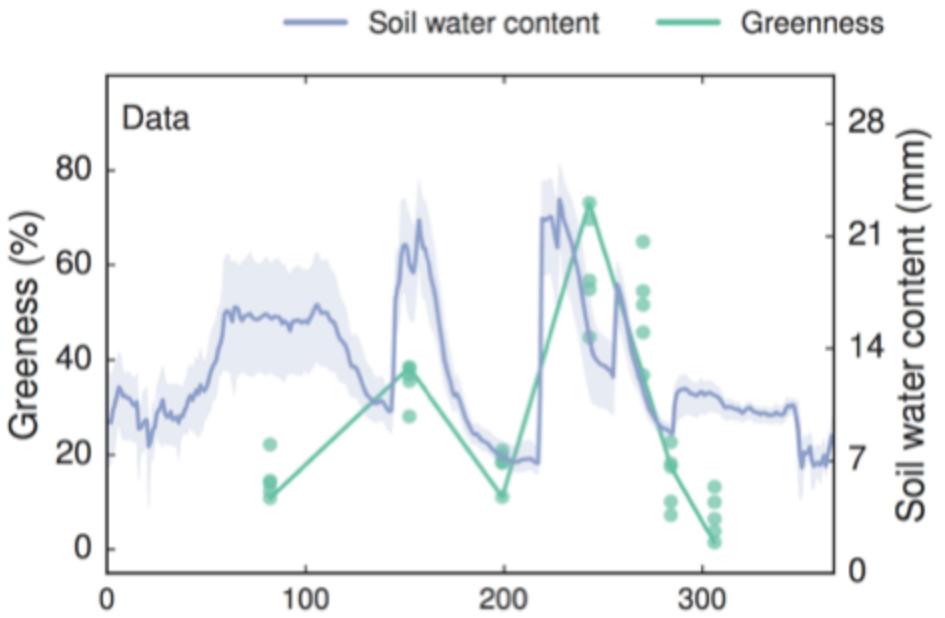
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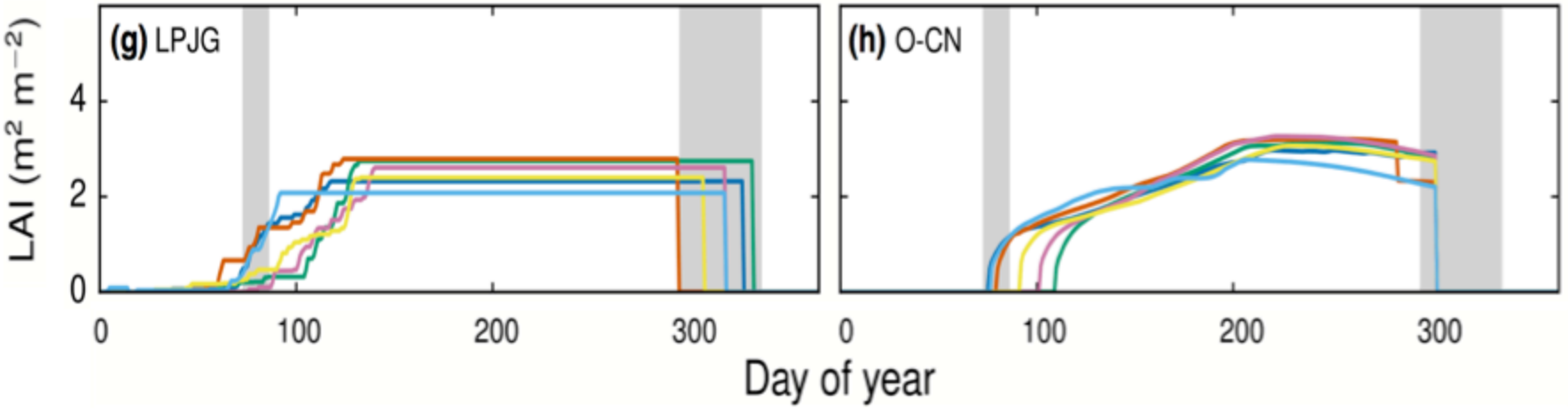
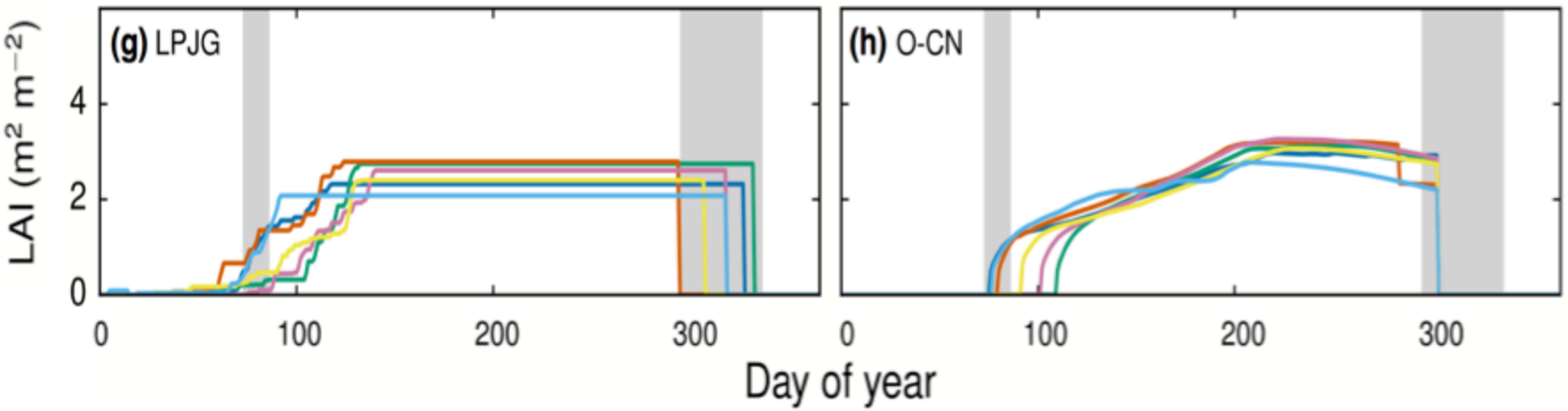

(g) LPJG
(h) O-CN
LAI (m² m⁻²)
0
2
4
0
100
200
300
Day of year

LETTER

doi:10.1038/nature10274

C_4 grasses prosper as carbon dioxide eliminates desiccation in warmed semi-arid grassland

Jack A. Morgan[1], Daniel R. LeCain[1], Elise Pendall[2], Dana M. Blumenthal[1], Bruce A. Kimball[3], Yolima Carrillo[2], David G. Williams[4], Jana Heisler-White[4], Feike A. Dijkstra[1,5] & Mark West[1]



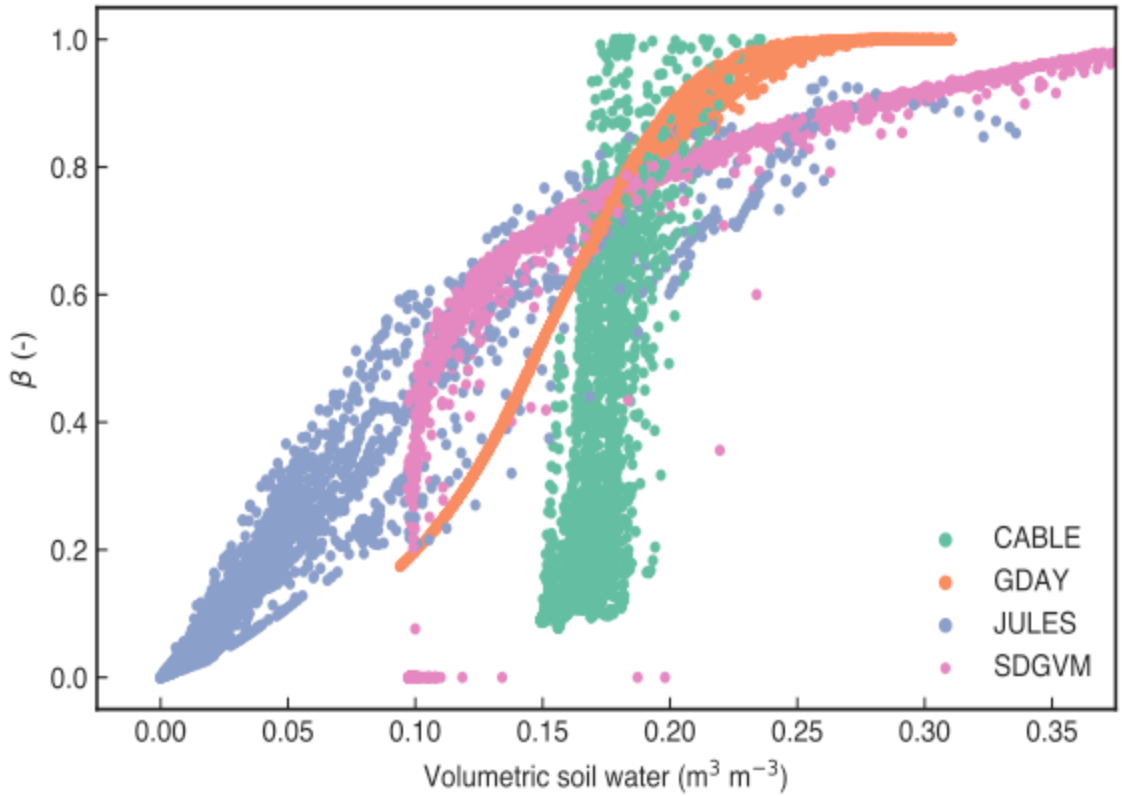
Models disagree about water stress

Differences due to:

1.LAI: 1–3 m^2 m^{-2} (GSL=77-256 d yr^{-1})

2.Soil evaporation: 43–256 mm yr^{-1}

3.Water stress function, β



What do we expect from a model?

CO_2

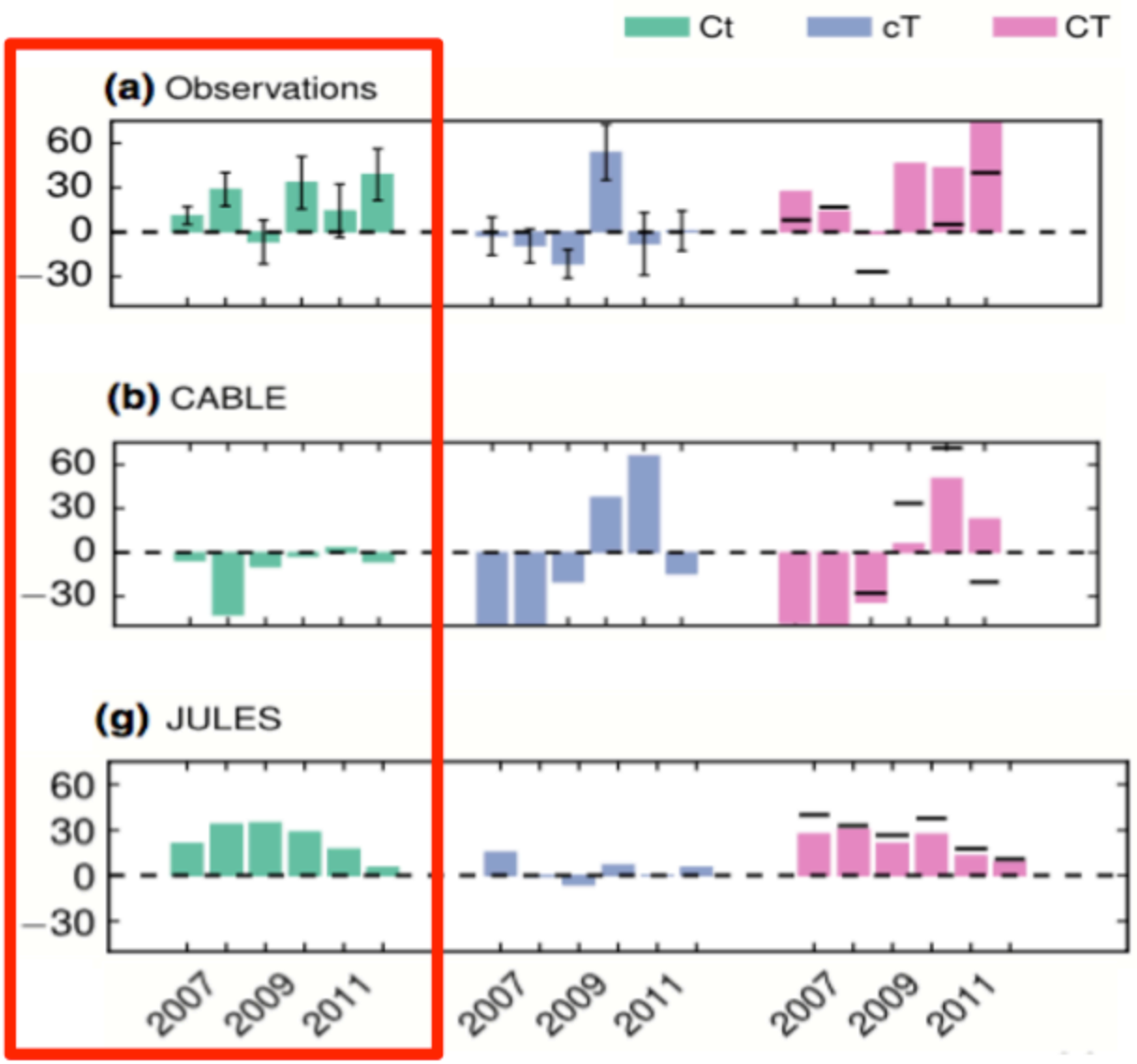
- Direct effect: ↑photosynthesis (≤ 25–30%)
- Indirect effects: ↑soil moisture/ ↑LAI) (≤ 36%).
- Upper limit: ~70% (1.25 × 1.36).

Warming

- ↑ Photosynthesis (below T_{opt}).
- ↑ Decomposition → ↑ N availability.
- ↑ Soil evaporation → ↑ water stress.

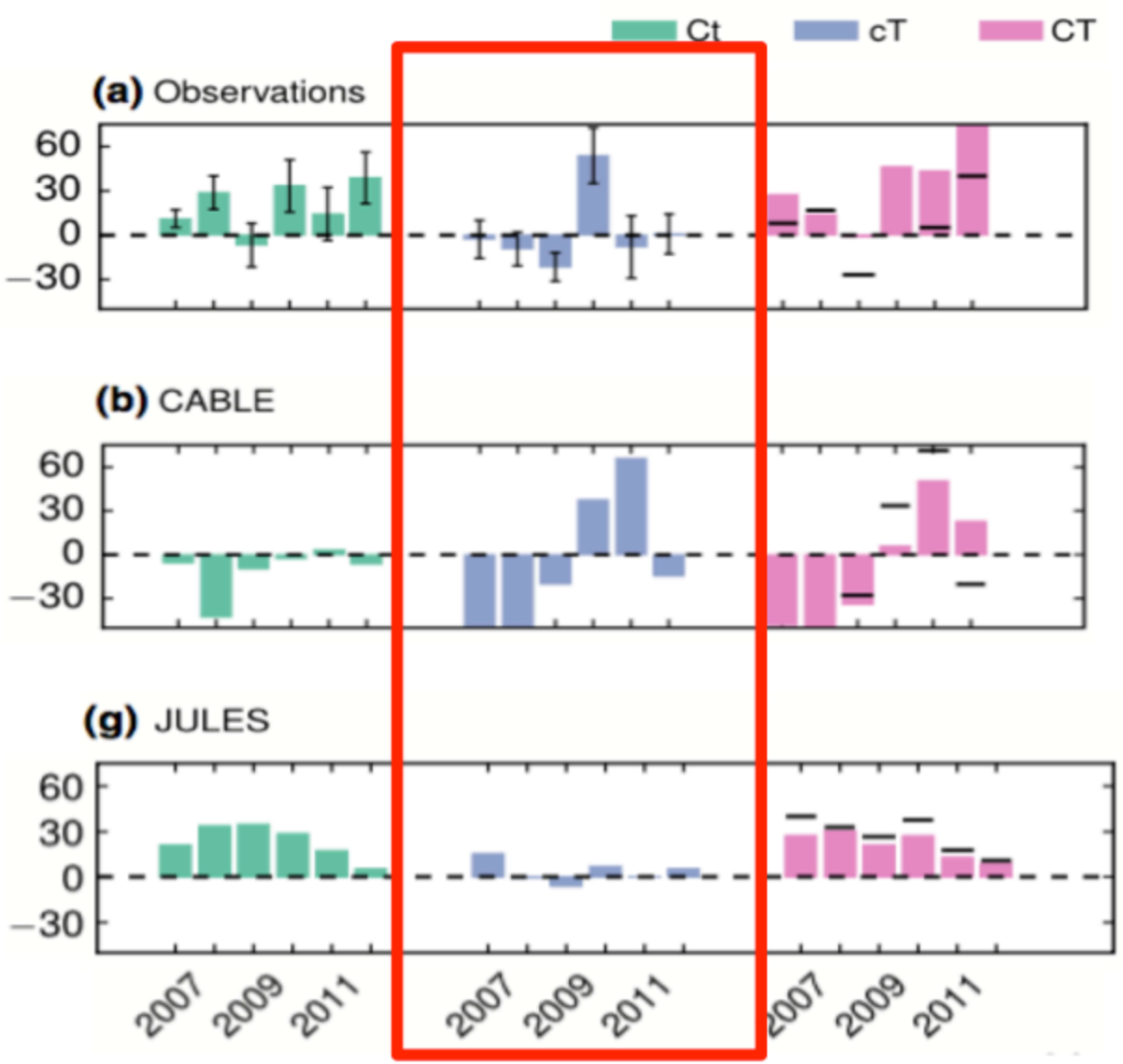
A tale of two LSMs ... CO_2

- OBS: mean response 16% (-6–39%).
- MOD (C_3): mean response 29% (-12–63%).



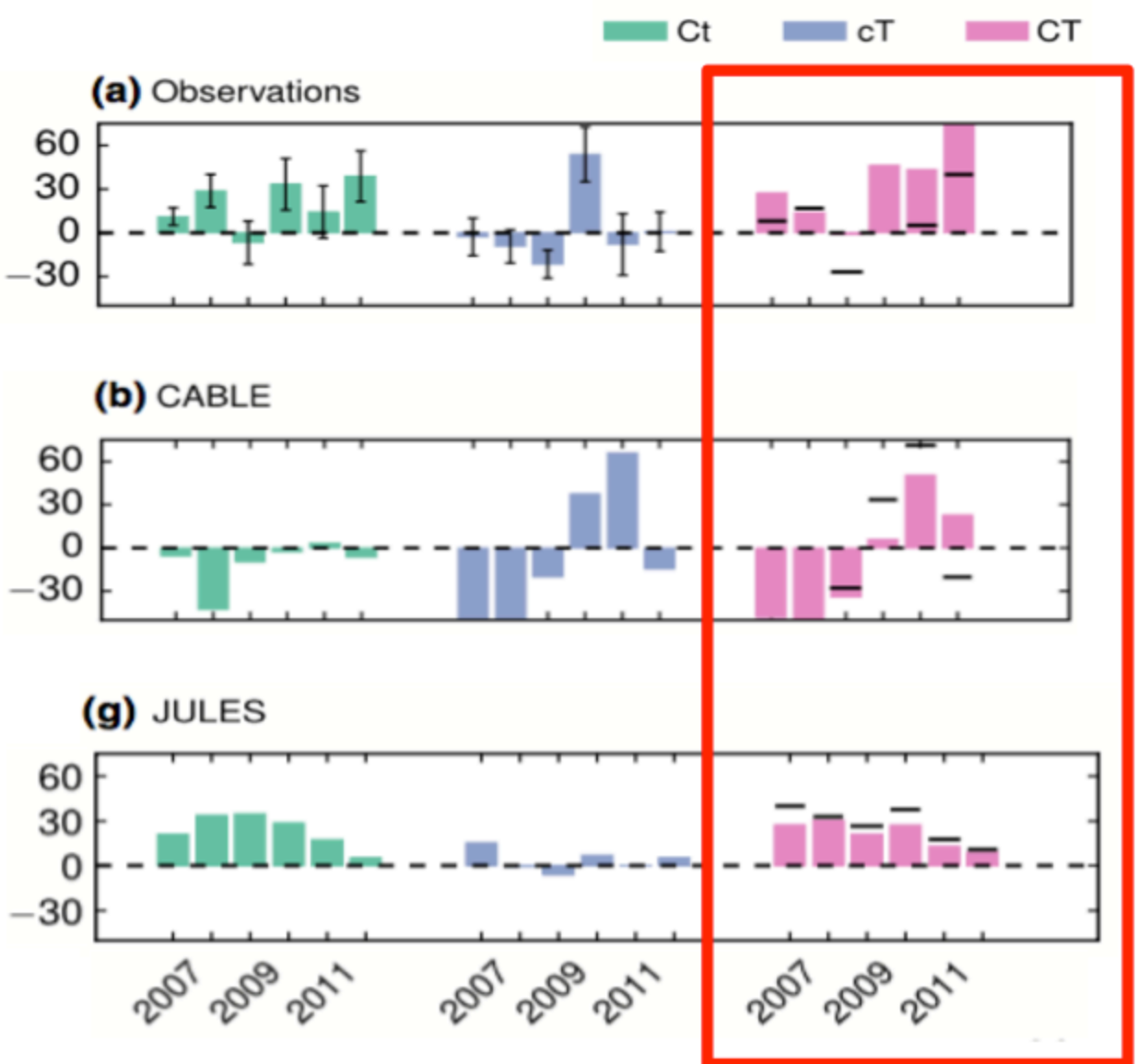
A tale of two LSMs ... warming

- OBS: Broadly negative, but large uncertainty!



A tale of two LSMs … CO_2 x warming

- OBS: broadly, greater than additive.



Conclusions

- Results provide a framework to understand responses of other model experiments (e.g. CMIP) to global change factors.
- Model responses can be explained by contrasting water & nutrient availability.
- Resolving the role of SW is critical to improving models.
- Models unable to capture IAV in aNPP in response to CO_2.
  - How does the timing of growth relate to photosynthetic uptake?

Questions?

Global Change Biology

Global Change Biology (2017) **23**, 3623–3645, doi: 10.1111/gcb.13643

Challenging terrestrial biosphere models with data from the long-term multifactor Prairie Heating and CO_2 Enrichment experiment

MARTIN G. DE KAUWE[1], BELINDA E. MEDLYN[2], ANTHONY P. WALKER[3], SÖNKE ZAEHLE[4], SHINICHI ASAO[5], BERTRAND GUENET[6], ANNA B. HARPER[7], THOMAS HICKLER[8,9], ATUL K. JAIN[10], YIQI LUO[11], XINGJIE LU[12], KRISTINA LUUS[4], WILLIAM J. PARTON[5], SHIJIE SHU[10], YING-PING WANG[12], CHRISTIAN WERNER[8], JIANYANG XIA[13], ELISE PENDALL[2], JACK A. MORGAN[14], EDMUND M. RYAN[15], YOLIMA CARRILLO[2], FEIKE A. DIJKSTRA[16], TAMARA J. ZELIKOVA[17] and RICHARD J. NORBY[3]

Poster: D-19 - Are we underestimating the capacity of the vegetation to moderate heat extremes?

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