

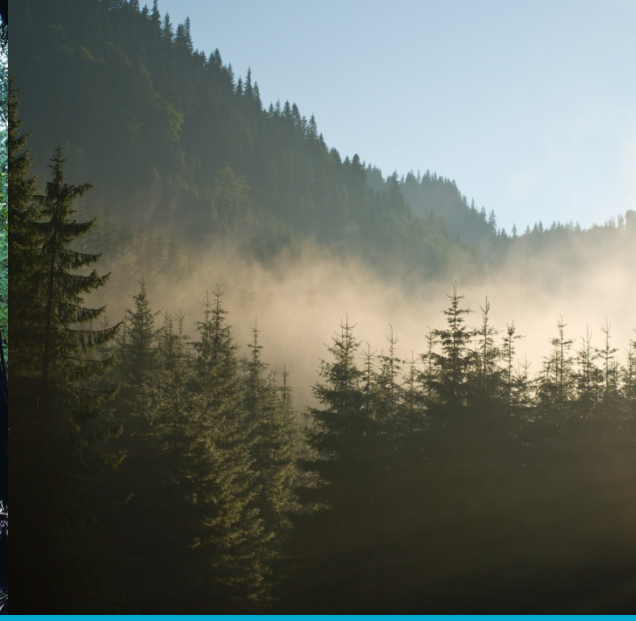

Higher than expected CO_2 fertilisation inferred from leaf to global observations

Vanessa Haverd, Ben Smith, Pep Canadell, Matthias Cuntz, Sara Mikaloff-Fletcher, Graham Farquhar, William Woodgate, Peter Briggs, Cathy Trudinger

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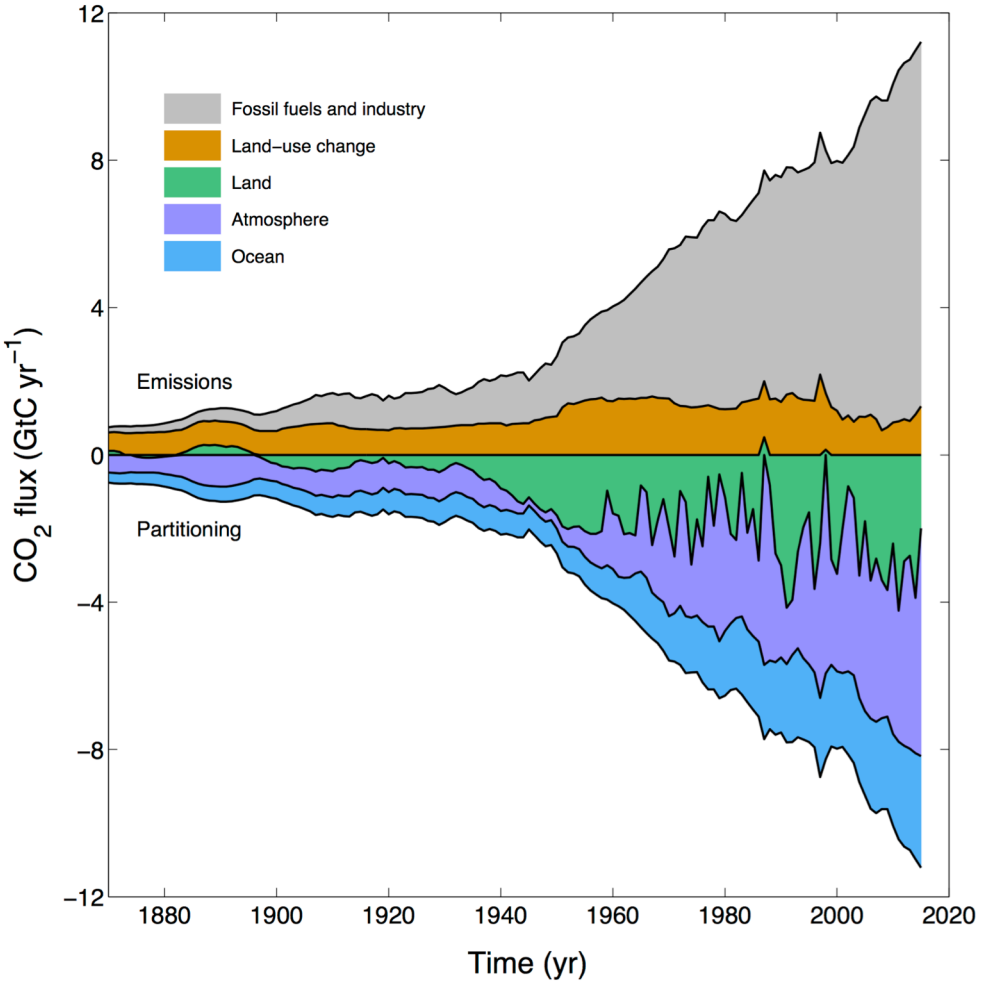
Net global land carbon sink increasing at 0.06±0.02 Pg(C) a^{-1} (Le Quéré *et al.* ESSD 2016)



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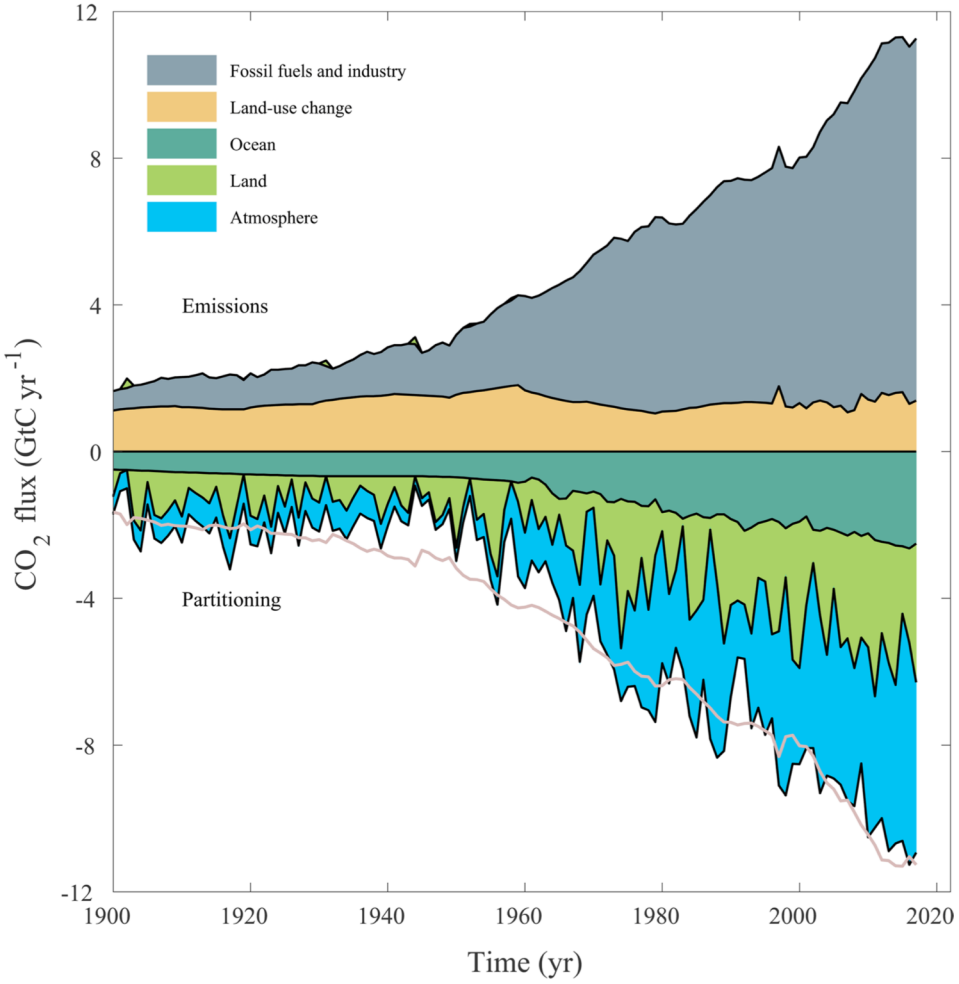
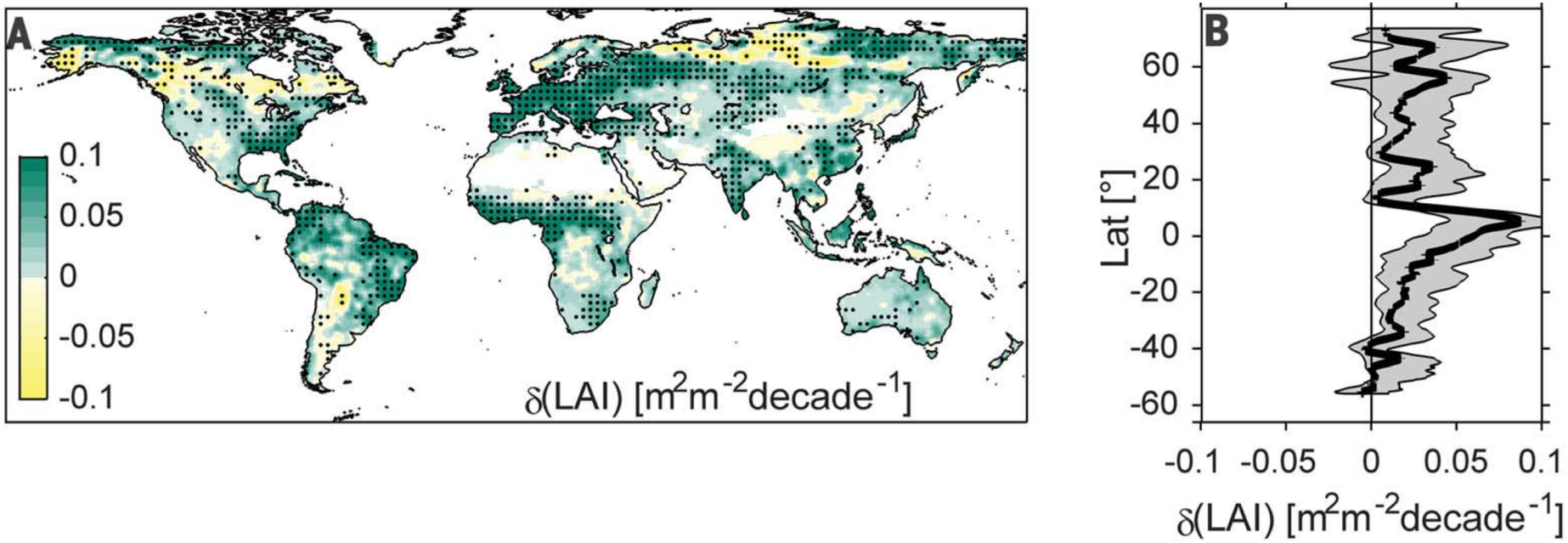
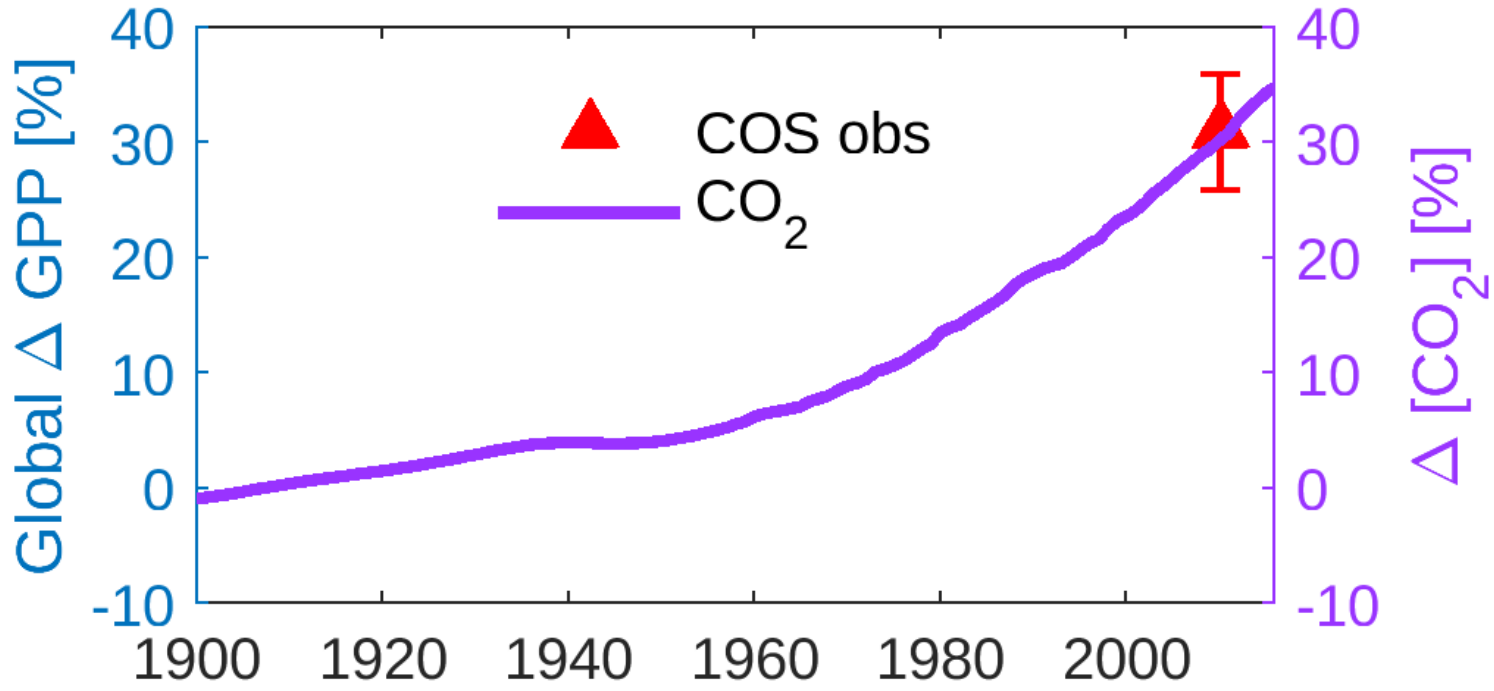


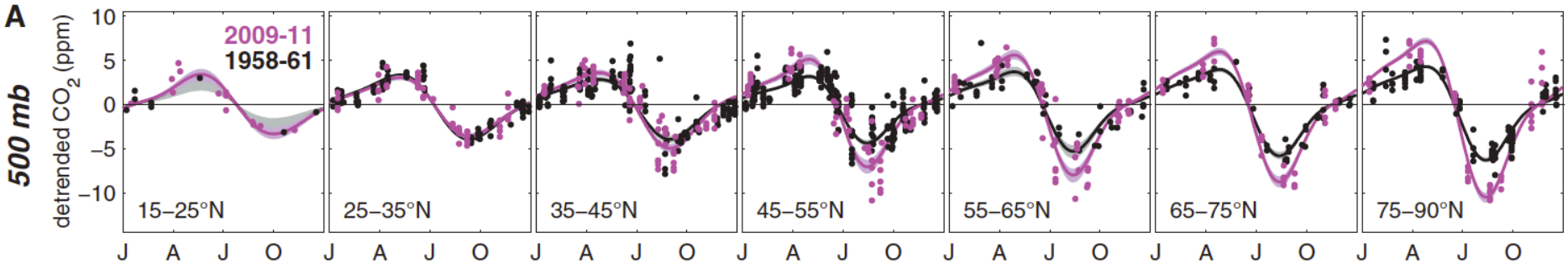
Increasing trends in satellite-observed vegetation cover (Forzieri *et al.* Science 2017)

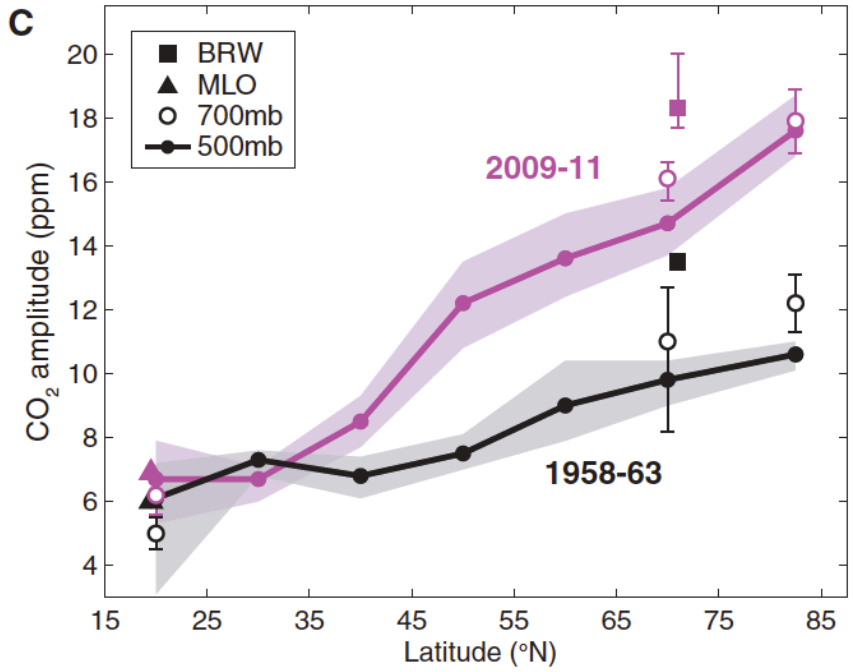


Carbonyl sulfide in air and ice ⇒ 31 ± 5% increase in GPP 1900-2010 (Campbell *et al.* Nature 2017)

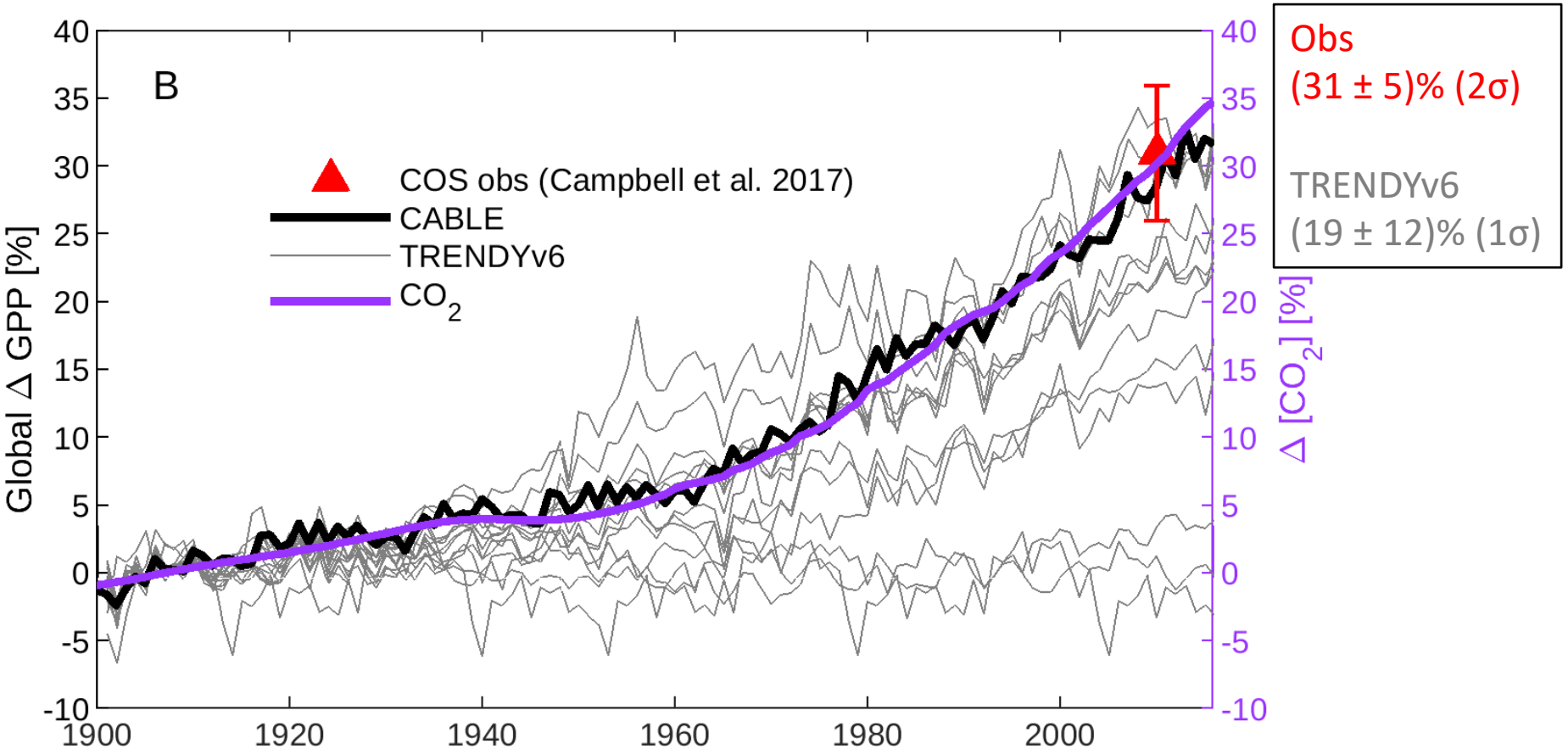


Amplitude of seasonal cycle of NH CO_2 increased 56% from 1960 to 2010 (Graven *et al.* Science 2013)

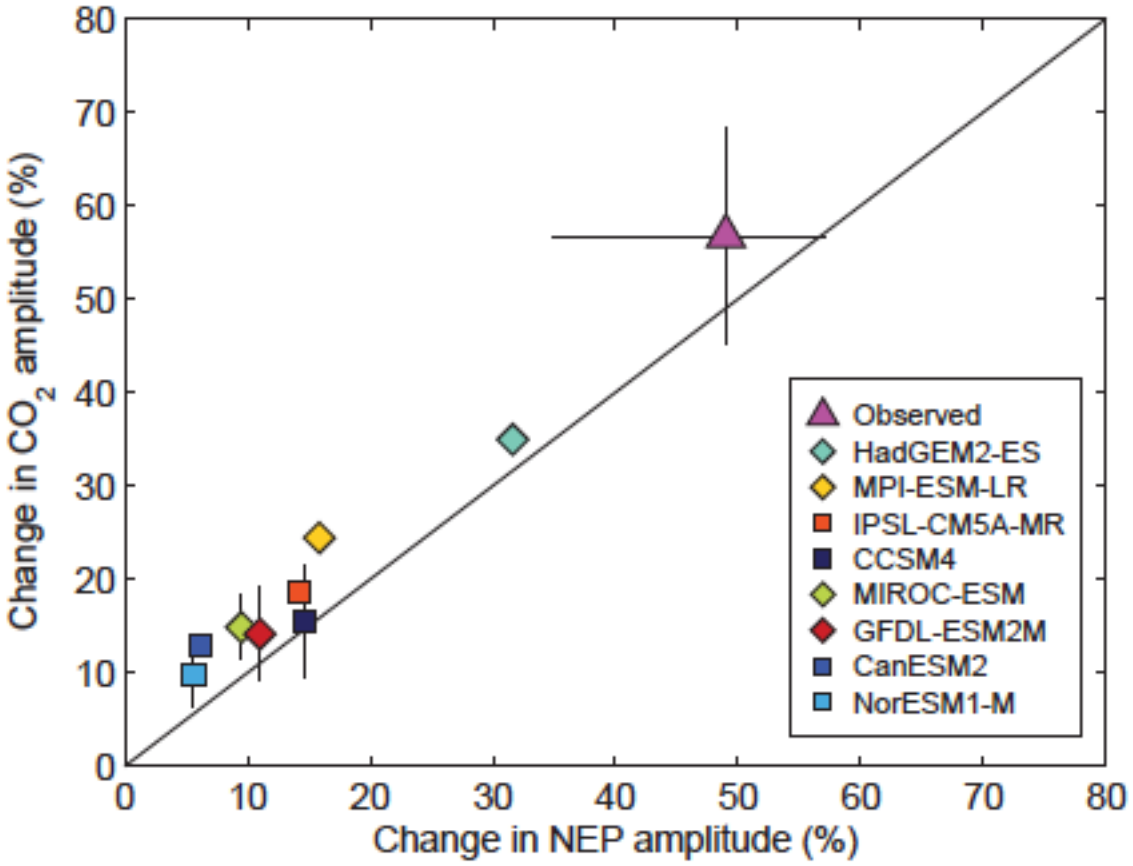




Under-prediction of global GPP increase
⇒ about one third of growth is unaccounted



Predicted increase in NH CO_2 amplitude under-estimated compared with aircraft observations



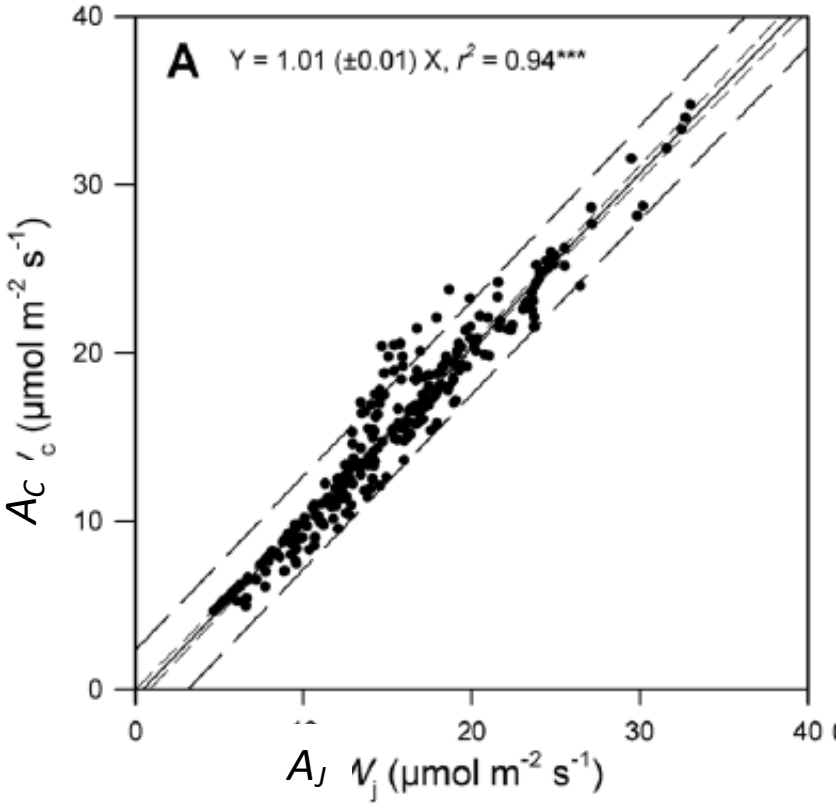
Possible explanations for observed trend:

1. CO_2 fertilization
2. High-latitude warming effects on biome distribution and plant productivity
3. Agricultural intensification

Graven *et al.* Science 2013

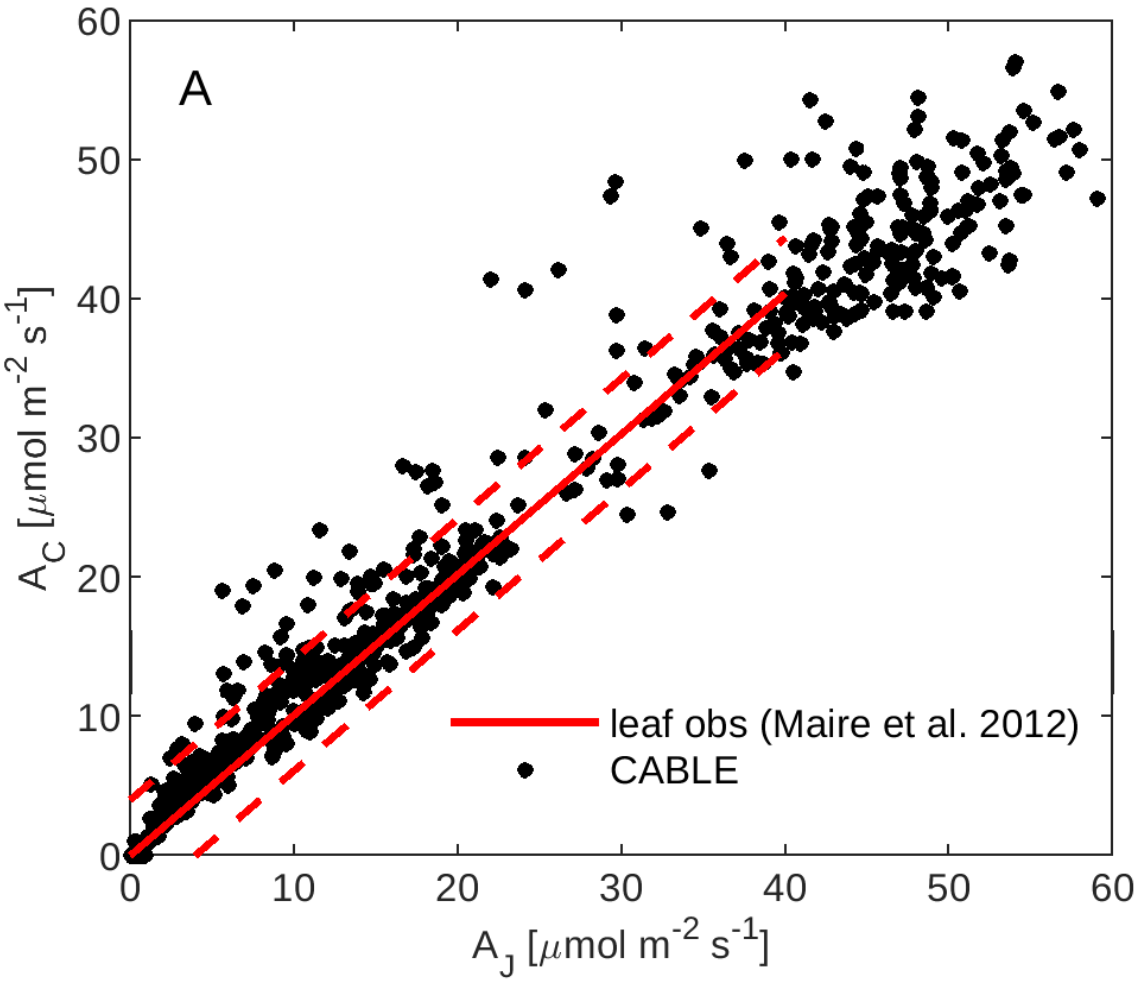
Co-ordination hypothesis: plants optimise productivity by relative nitrogen investment in electron transport (A_j) and Rubisco-limited (A_c) steps in the photosynthesis chain, such that they are co-limiting.

$A_c \simeq A_j$ under last month's average plant growth conditions



Maire *et al.* PloS One 2012

Constraints on trends in global-scale terrestrial biospheric activity (Haverd *et al.* GCB 2020)



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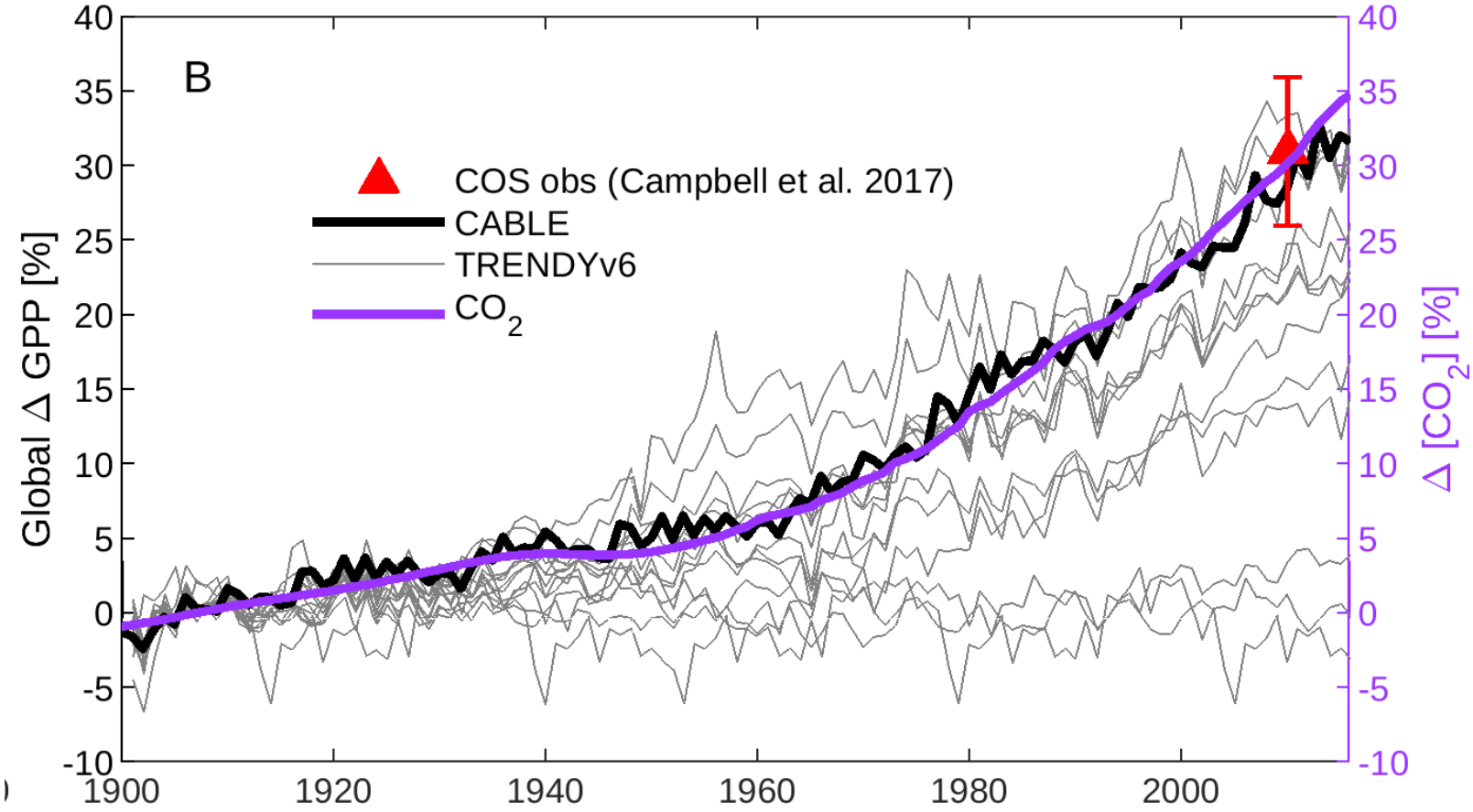

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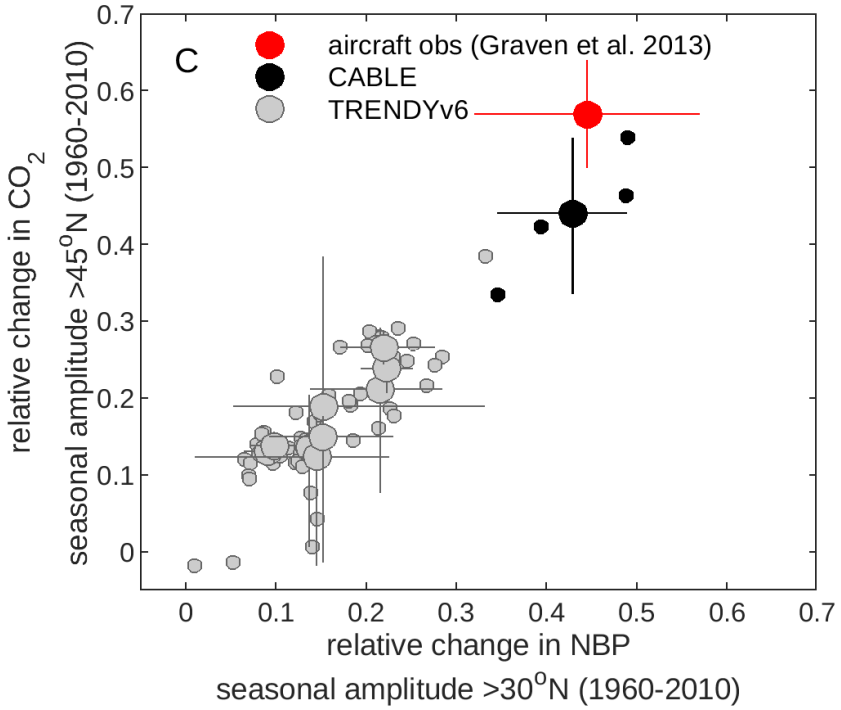
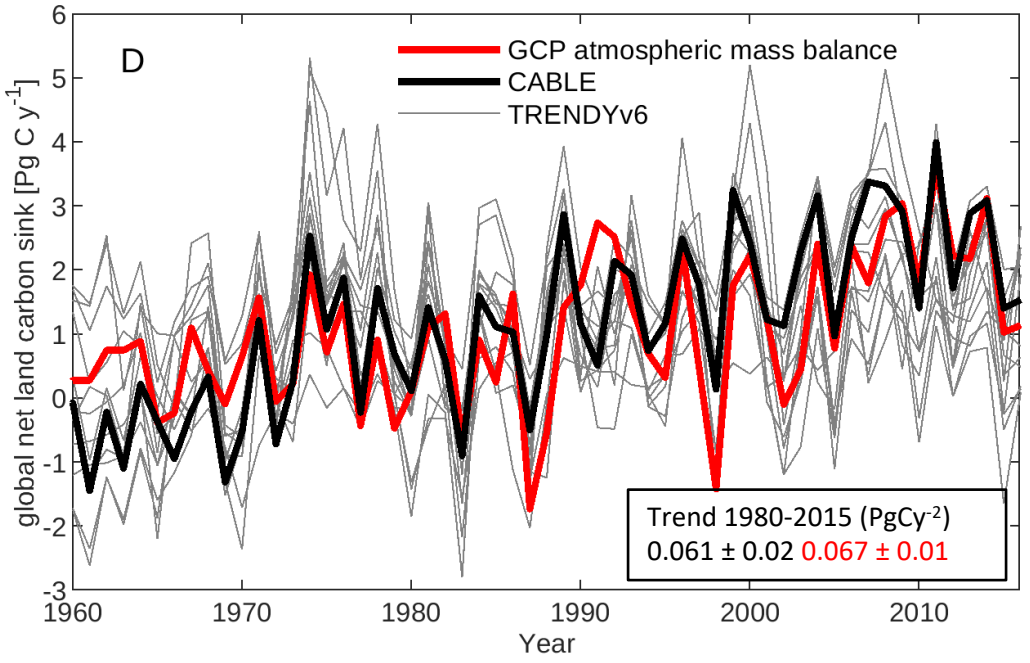
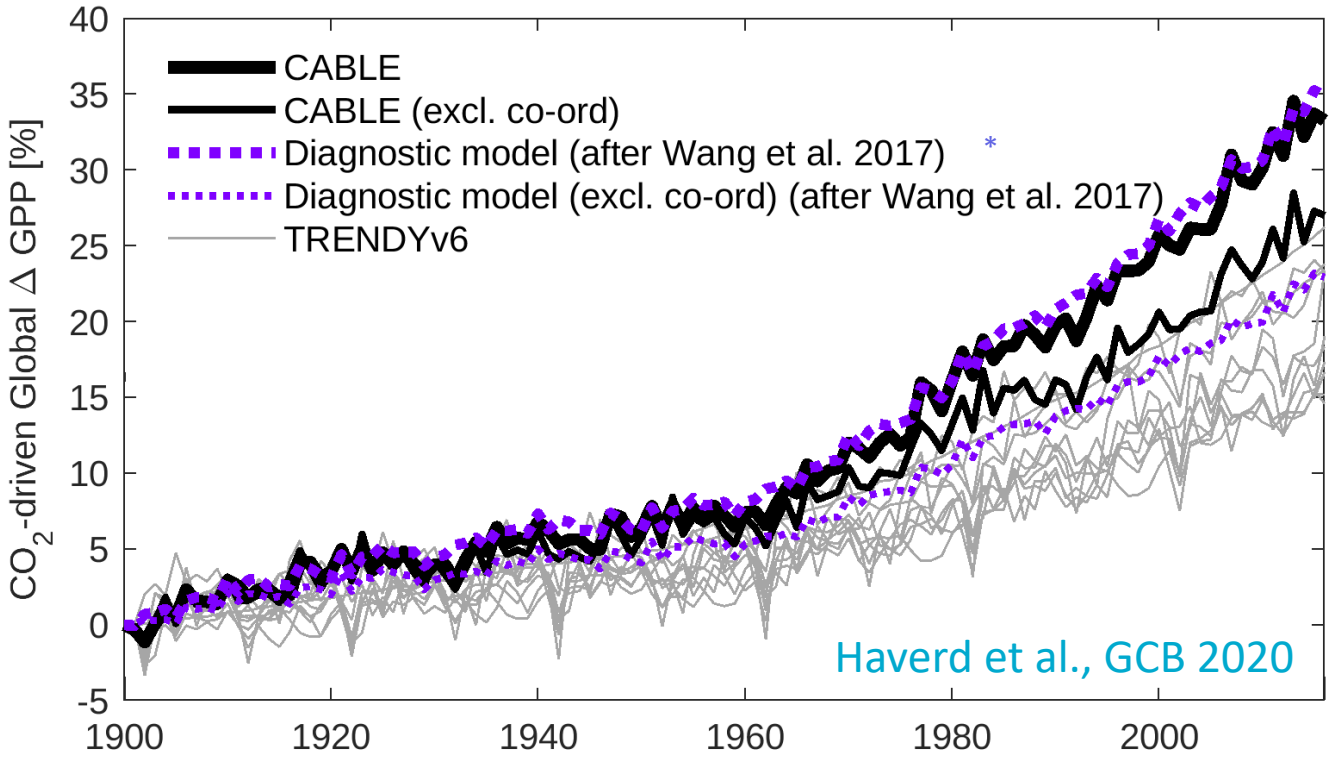




Simulated CO_2 fertilisation effect on photosynthesis is significantly higher than current estimates



ΔGPP 1900-2010

CABLE 30%

Diagnostic Model 31%

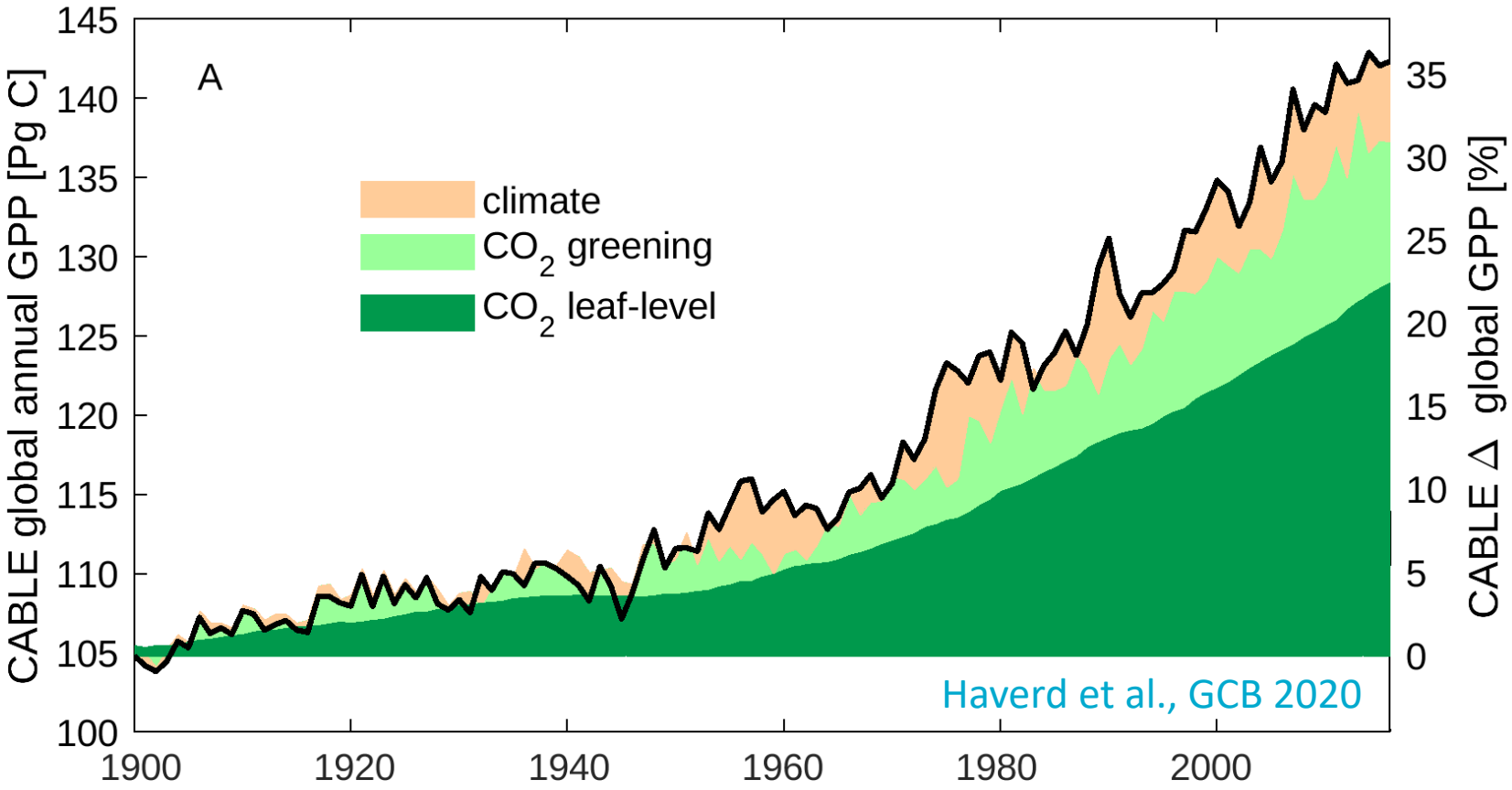
CABLE (excl. co-ord) 24%

Diagnostic Model (excl. co-ord) 21%

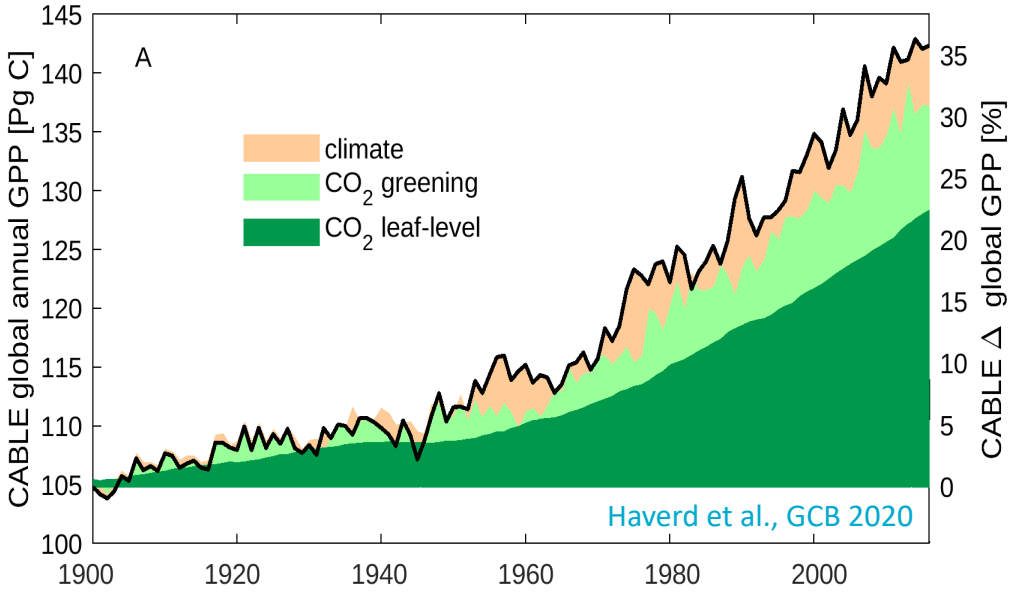
TRENDYv6 (17 ± 4)% (1σ)

Wang et al. Nat Plants, 2017

Global GPP increase predominantly driven by CO_2



Leaf-level CO_2 fertilization effect dominates total GPP increase



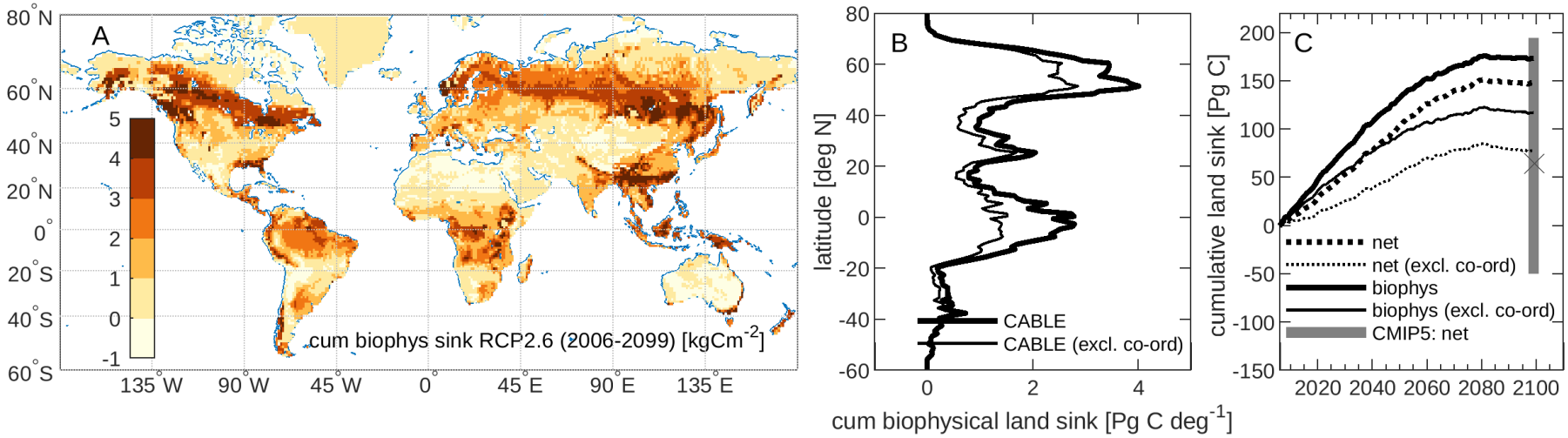
	OBS	CABLE
Semi-arid greening (1982-2010)	11%*	10%
Tropical forest leaf-level GPP increase (1982-2010)	12%§	12%

*Relative change in remote-sensed foliage cover equated with greening enhancement of GPP (Donohue et al. GRL, 40, 3031-3035, 2013)

§ Tropical forest catchment water balance (Yang et al. J. Geophys. Res.-Biogeo., 121, 2125-2140, 2016)

Projected Land Carbon Sink (2° scenario)

Haverd et al., GCB 2020



Conclusion

- We identified a CO_2 fertilisation effect on historical global GPP that is significantly higher than current terrestrial biosphere model estimates
  - Important for the future role of land carbon sinks.
    - under-estimate of CO_2 removal under low emission scenarios consistent with the Paris agreement targets

- Under-prediction of GPP trends is associated with a lack of representation of plant co-ordination of photosynthesis
  - Independent regional studies using CO_2 seasonal cycle data (NH extra-tropics) and catchment water-balance (tropical forests) have also inferred larger CO_2 fertilisation effects than predicted by terrestrial biosphere model ensembles.
    - Causes are poorly known, but biases associated with the representation of nutrient limitations on GPP are invoked. We suggest co-ordination of photosynthesis also plays a role.