Water use and WUE at elevated CO_2: a model-data intercomparison.

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Free-air concentration enrichment (FACE) experiment

- Two temperate forest sites:

Oak Ridge, Tennessee

Duke, North Carolina

- $\sim$40 % step increase in CO_2.
- $\sim$10 years of measurements.
- 11 models of varying complexity ...

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Theory

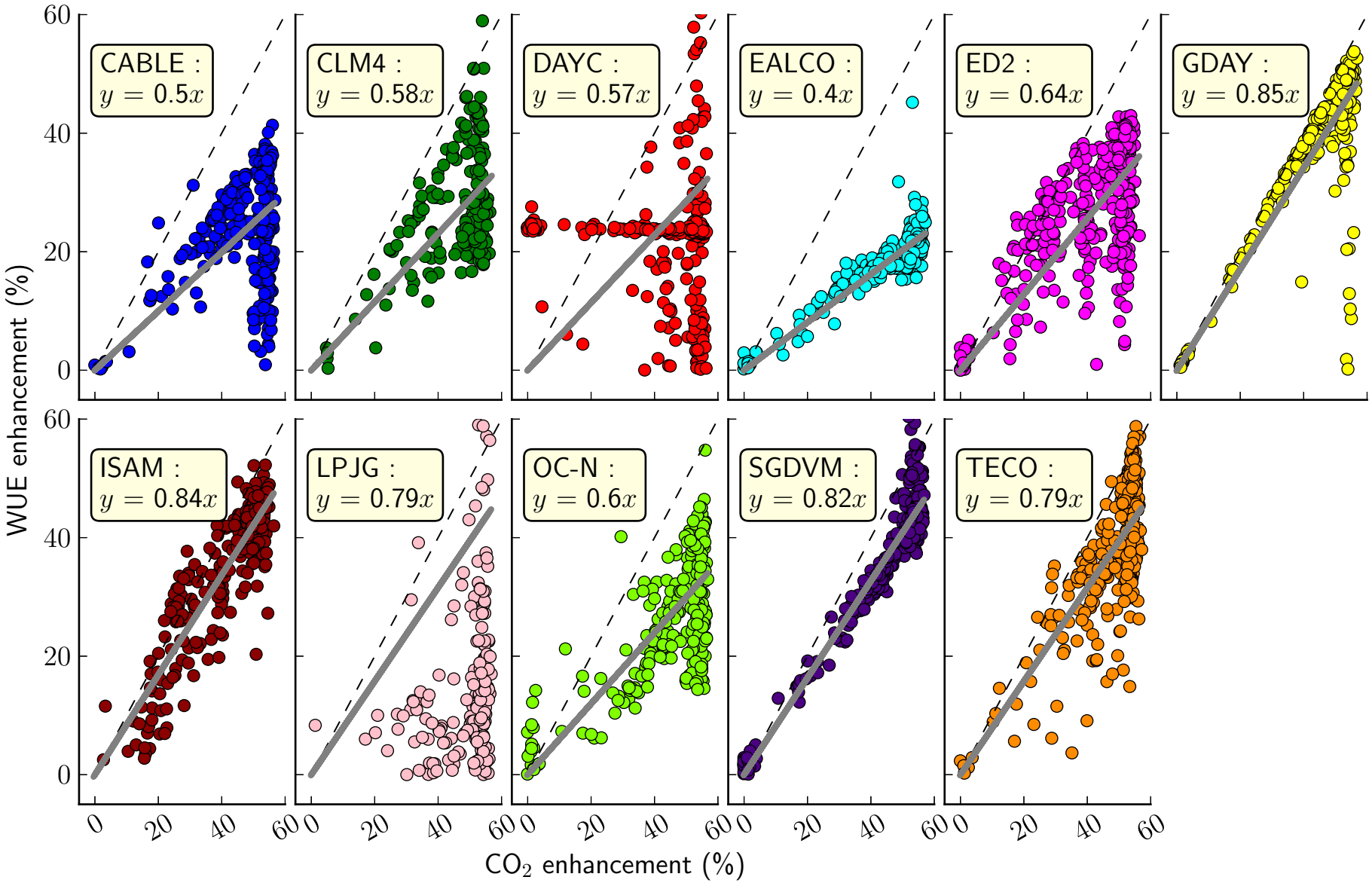
- Most models link A–g_s using a Ball-Berry/Leuning type g_s model. Equation can be rearranged (Medlyn g_s model shown):

$$WUE = \frac{A}{E} = \frac{C_a}{g_1\sqrt{VPD}} = \frac{GPP}{T}$$

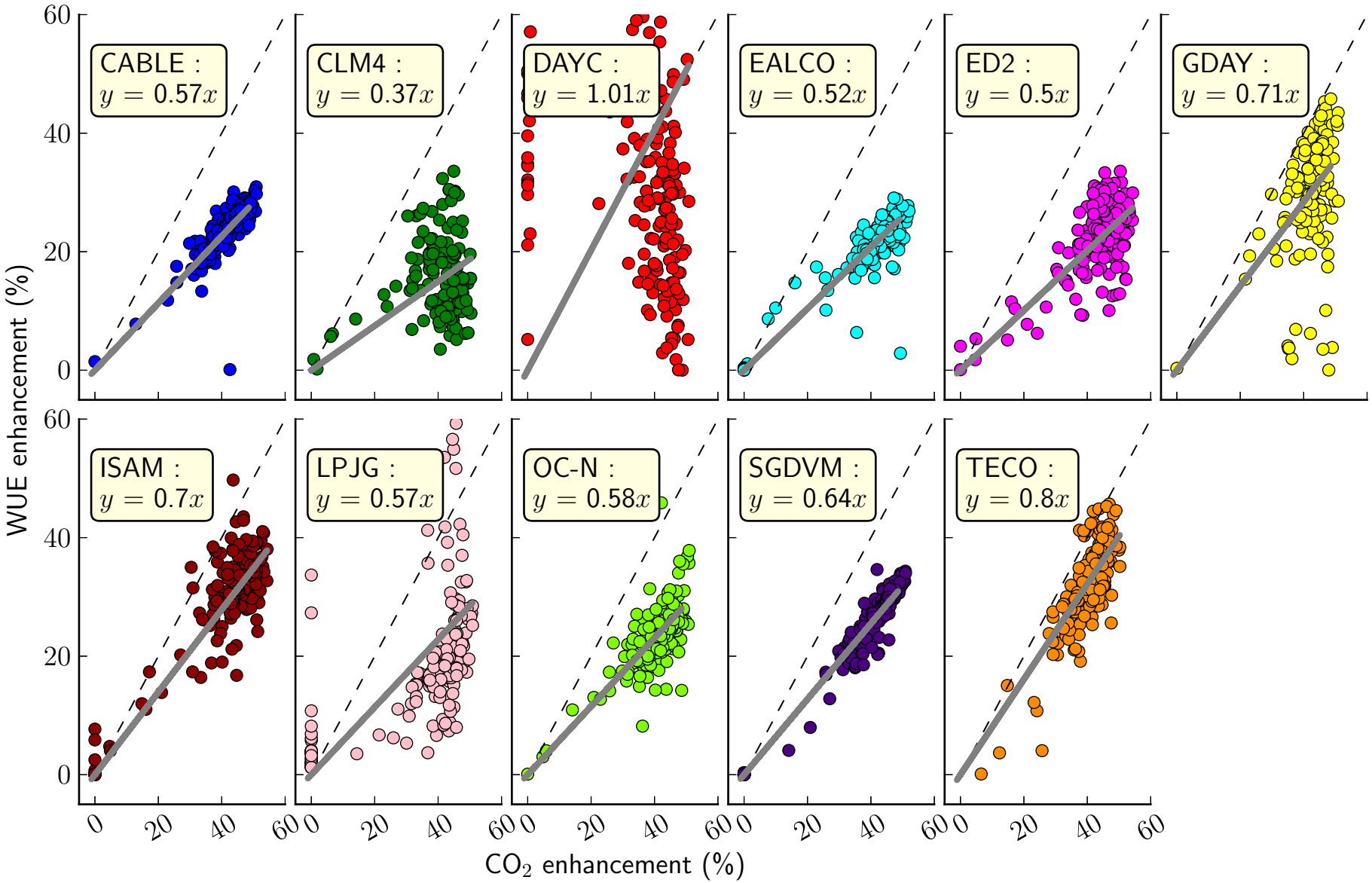
- If g_1 and VPD do not change with CO_2 treatment ... **then most models should predict WUE $\propto$ Ca**. This prediction is independent of [LAI], PAR and N.

- We can use this **"simple model"** to test the predictions by the other models!!

Do the models predict WUE $\propto$ CO_2? – DUKE

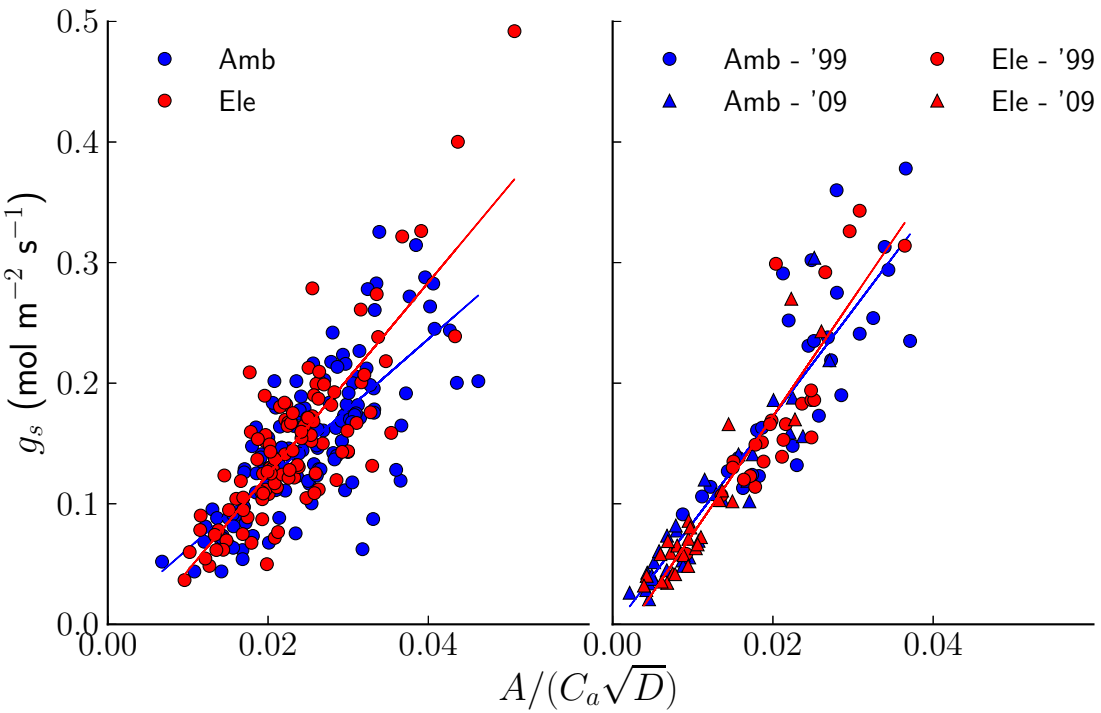


Do the models predict WUE $\propto$ CO_2? – ORNL



$CO_2 \propto A$ / g_s?

- CLM4 + DAYCENT decouple A–g_s.
- EALCO and O-CN have different A/g_s responses to CO_2 than "standard" BB-type models.
- Unsupported by site data: meta-analysis, slope C.I. = (0.9, 1.07).



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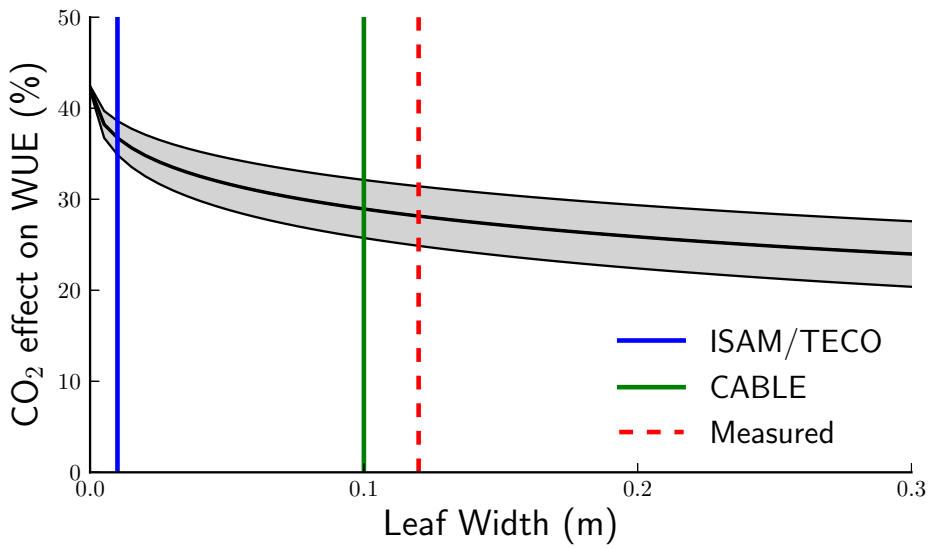
Impact of boundary layer - $E \propto g_s$?

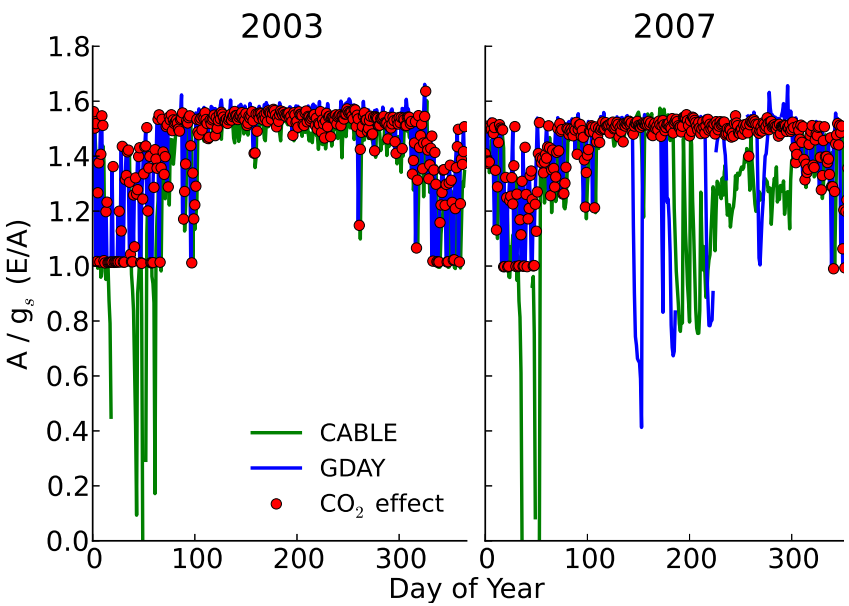
- E is only $\propto g_s$ when the canopy is well-coupled to the atmosphere.
- g_a (GDAY and SDGVM), g_b (TECO) or g_a and g_b (CABLE, CLM4, EALCO, ED2, ISAM, OC-N).
- Different (wrong) leaf width parameterisations.
  - ISAM and TECO vs. CABLE at ORNL.



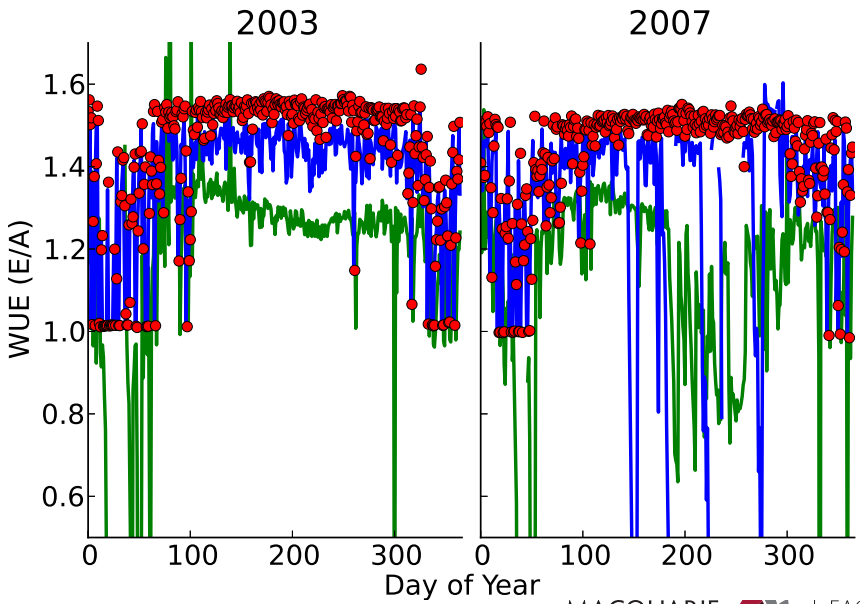
A–g_s/WUE: CABLE vs. GDAY

- Similar A/g_s responses from the 2 models.
- Different WUE responses due to canopy/leaf coupling.

CO_2 effect on A/g_s



CO_2 effect on WUE



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Other things . . .

- **During drought ...**
  - WUE is not $\propto CO_2$ in models that assume a stomatal limitation (modify slope) (e.g. CABLE, GDAY, OC-N).
  - WUE response increases in LPJ-GUESS.
  - WUE unaffected by CO_2 in models that limit photosynthetic capacity (e.g. CLM4, ED2).
- **Interception**:
  - Wet fraction of canopy used to satisfy demand.
  - Large inter-model variability in the fraction of intercepted water, at Duke 2–15 %.
  - Change in LAI due to CO2 becomes an issue...
- C_i vs. C_a, R_d, simulation time-step, CABLE's sheltering factor . . . [all small effects].

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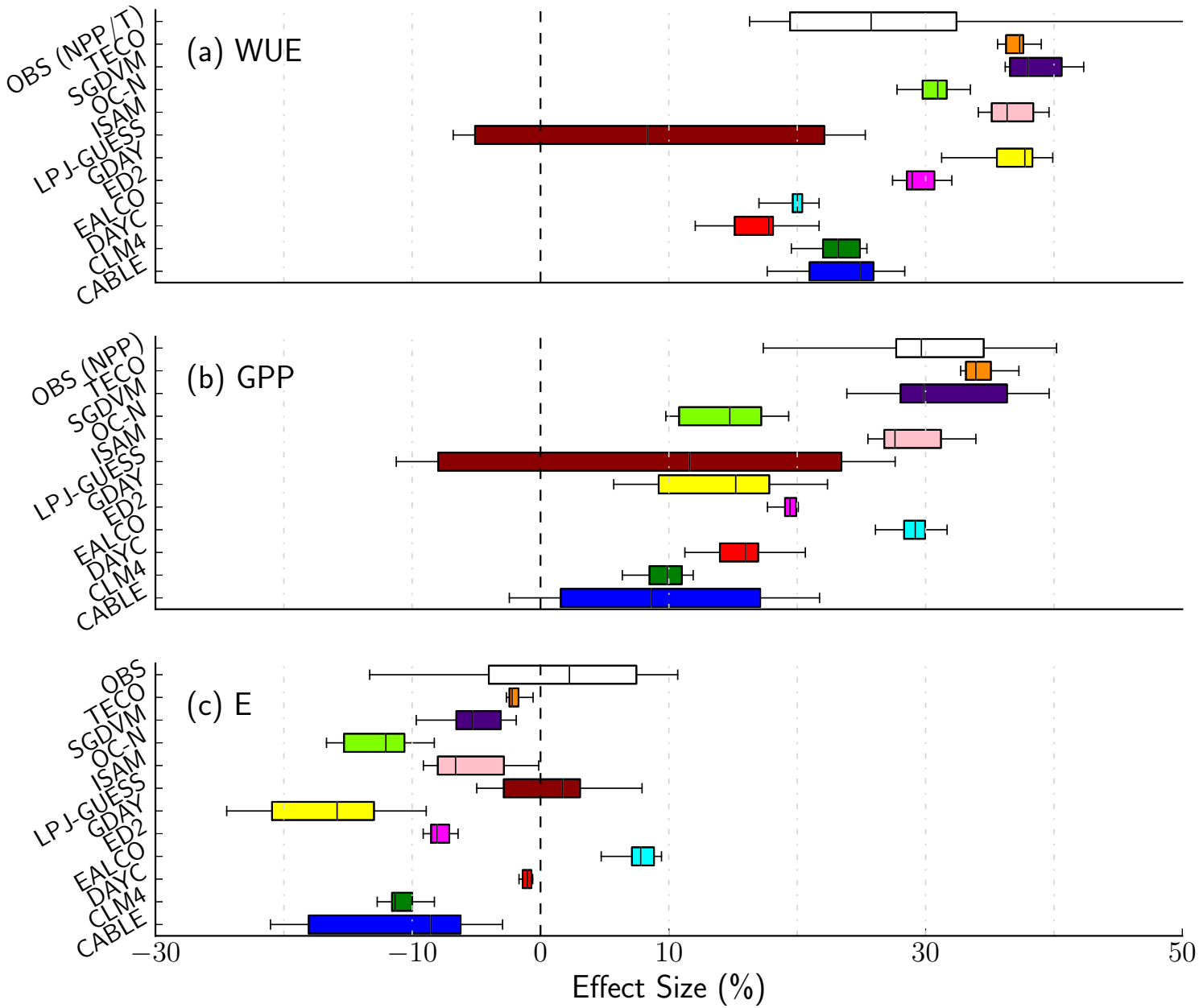
Overall annual responses? – DUKE



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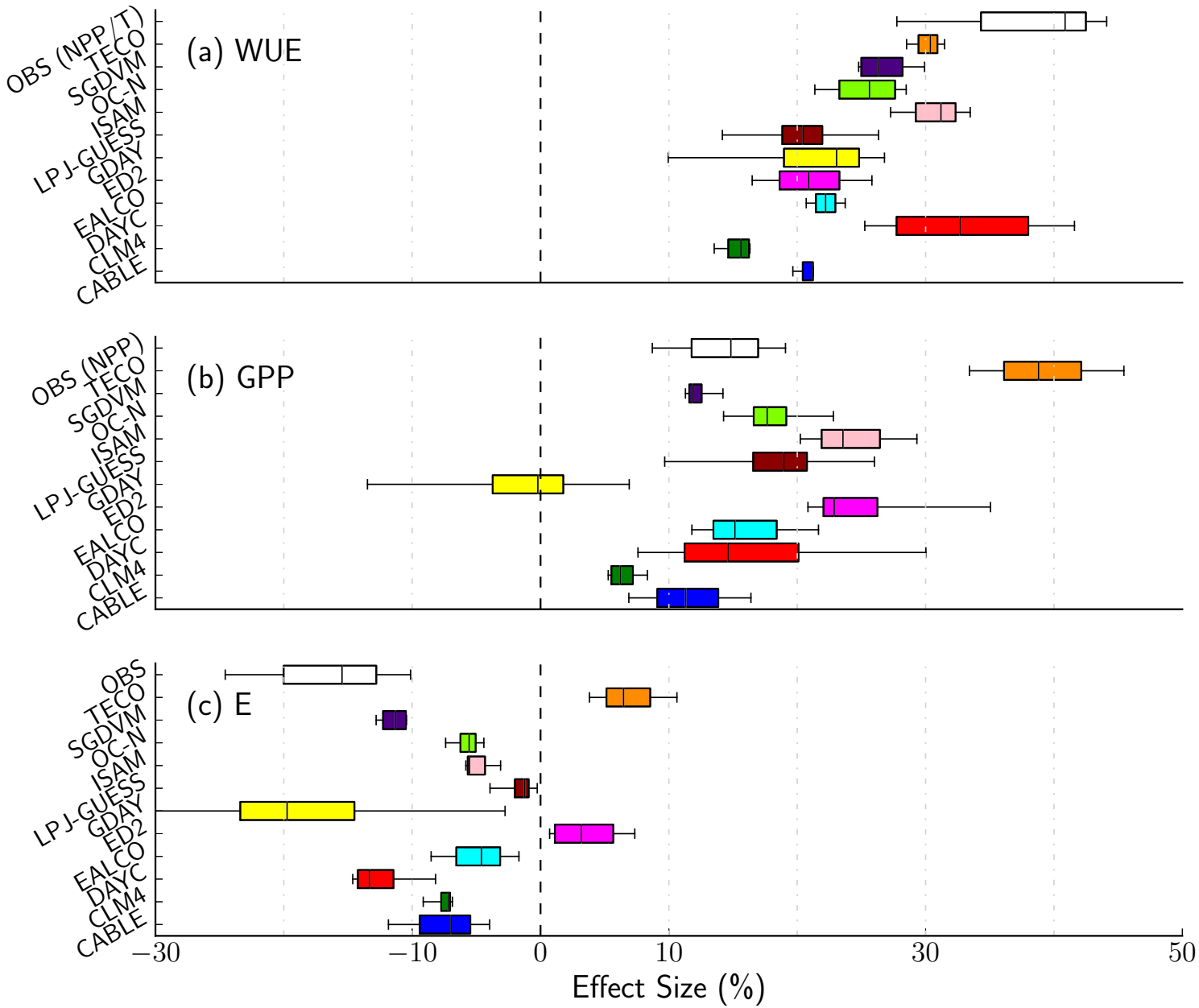
Overall annual responses? – ORNL



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Conclusions

- Effective framework to analyse modelled responses to CO_2.
- Models that deviated most from Ball–Berry style A–g_s models were unsupported by the data.
- The "more complex" models matched the observations best at the well–coupled site, but performed poorly at the deciduous site.
- Large uncertainty in observed "WUE" estimates at Duke.
- How "typical/scalable" are the responses at the two sites? A number of site-specific issues (drought, storms, rooting depth, etc).

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Thanks!

K. Crous, M. Dietze, D. Ellsworth, P. Hanson, T. Hickler, A. Jain, H. S. Kim, Y. Luo, R. Norby, R. Oren, W. Parton, C. Prentice, P. E. Thornton, A. Walker, S. Wang, Y-P. Wang, D. Warlind, J. Warren, E. Weng and S. Zaehle.