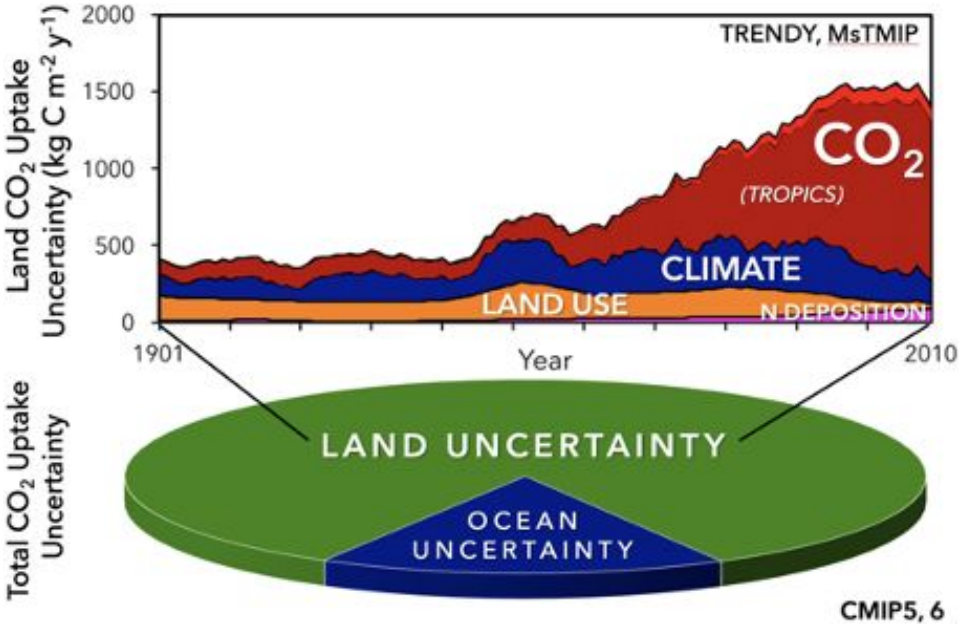
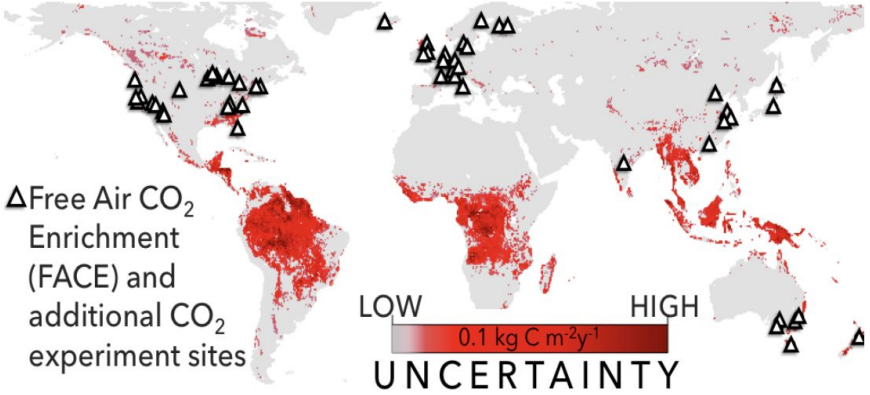
Tropical Decadal-Scale CO_2 Fertilization: New Data for One of the Largest Model Uncertainties

Lianlei Fu & Joshua B. Fisher
Chapman University

INTRODUCTION | Current model responses of CO_2 are highly uncertain



- The tropical CO_2 effect dominates uncertainties in global net CO_2 uptake.
- FACE experiments have been conducted primarily not in the Tropics.



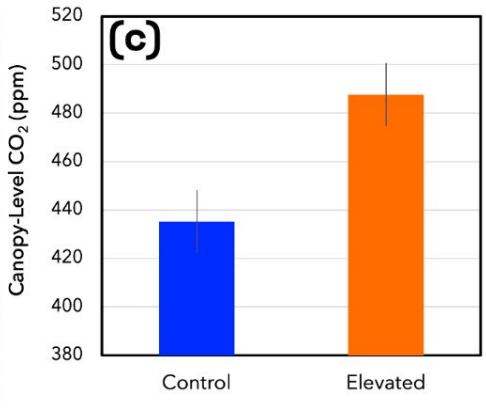
Long-term CO_2 fertilization data in the Tropics is required!

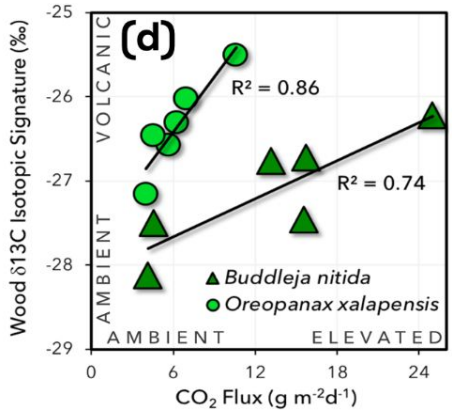
INTRODUCTION | Introduce ELEVATE project

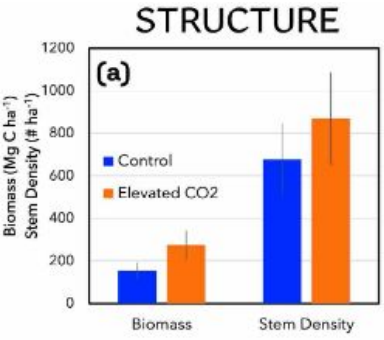
- ELEVATE was a program established by NASA JPL to investigate synergies between Costa Rica's tropical rainforests and its volcanoes.
- Mapping efforts found that throughout Costa Rica's protected forests were fumarolic vents leading back to volcanic centers far from the volcanic craters themselves.
- Of particular note was that many of these vents were continuously emitting elevated CO_2 in very high concentrations, with no other gas emissions.
- Plots were established to compare ecosystem characteristics in elevated CO_2 areas relative to ambient CO_2 areas to determine if these vents could act as **natural FACE experiments**, but with three added benefits:
  - i) elevated CO_2 exposure was long-term (i.e., multi-decadal);
  - ii) there were much larger areas of exposure relative to FACE sites; and,
  - iii) they were in tropical forests.

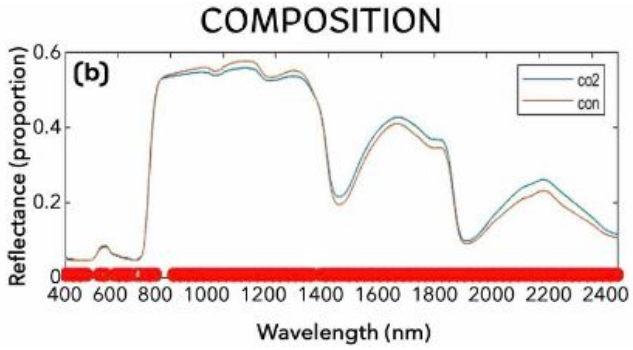
  Moreover, geologically-sourced CO_2 has a unique isotopic signature that is retained in tree wood, enabling tracking of CO_2 exposure at the individual tree level in both space and time.

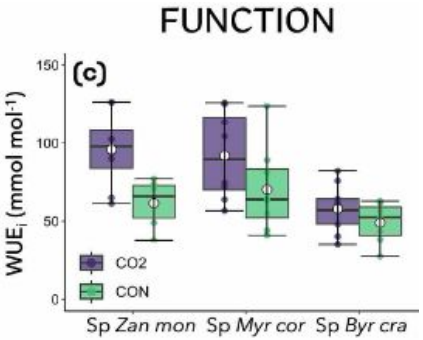
INTRODUCTION | Observation data in ELEVATE project

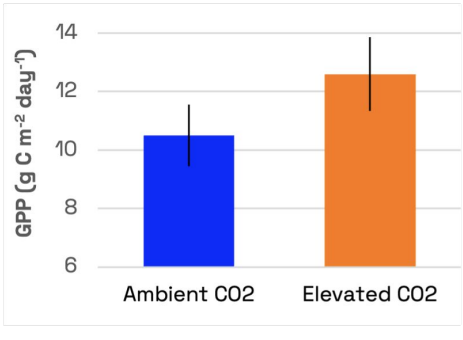








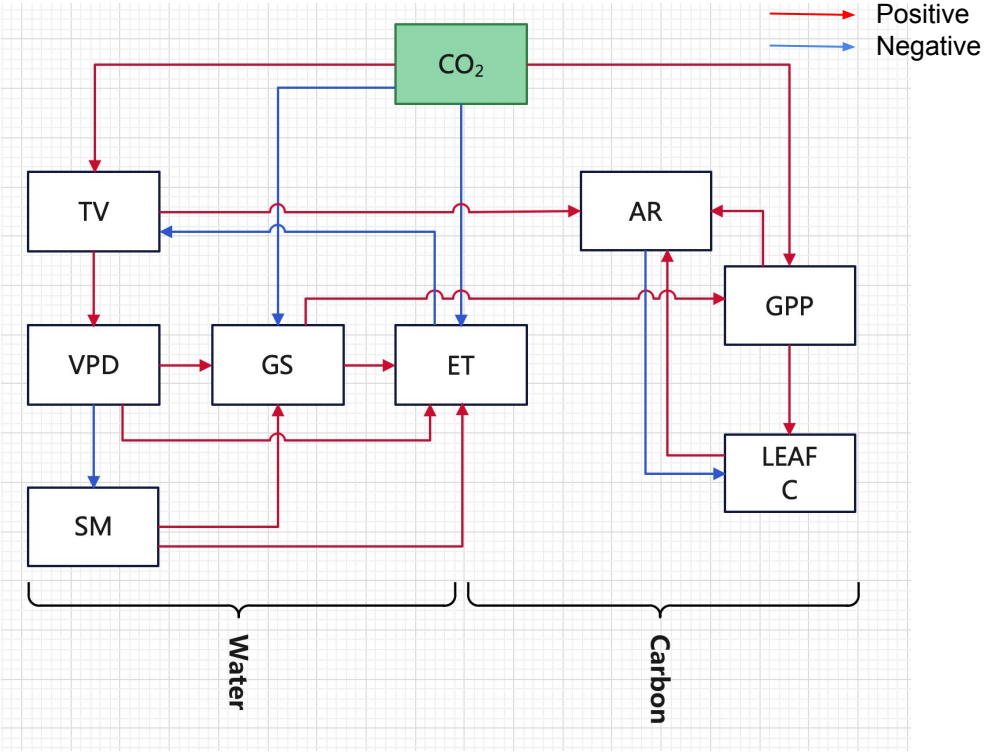




INTRODUCTION | ELEVATE and CLM

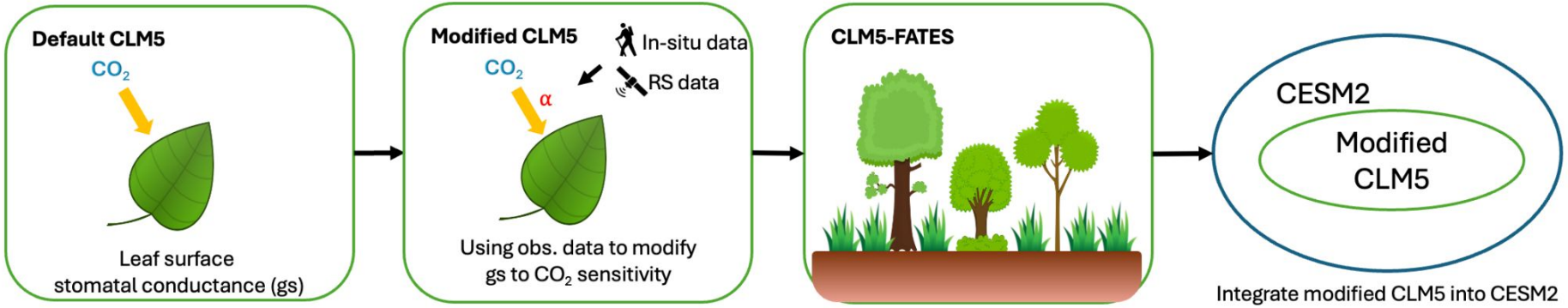
- ELEVATE can address one of the largest uncertainties in carbon-climate feedbacks: **the response of tropical forests to elevated CO_2**.
- **Earth System Models** fundamentally drive the science of ELEVATE.
- For this presentation, I focus on **ECOSTRESS** data at the Rincón de la Vieja ELEVATE sites for **CLM 5.0**.

INTRODUCTION | Explore the mechanism of ET regulating water and carbon dynamic under CO2 fertilization.



- CO_2 fertilization affects water and carbon cycle.
- ET as an important variable links water and carbon dynamics.
- Stomatal conductance decreases with CO_2 concentration.

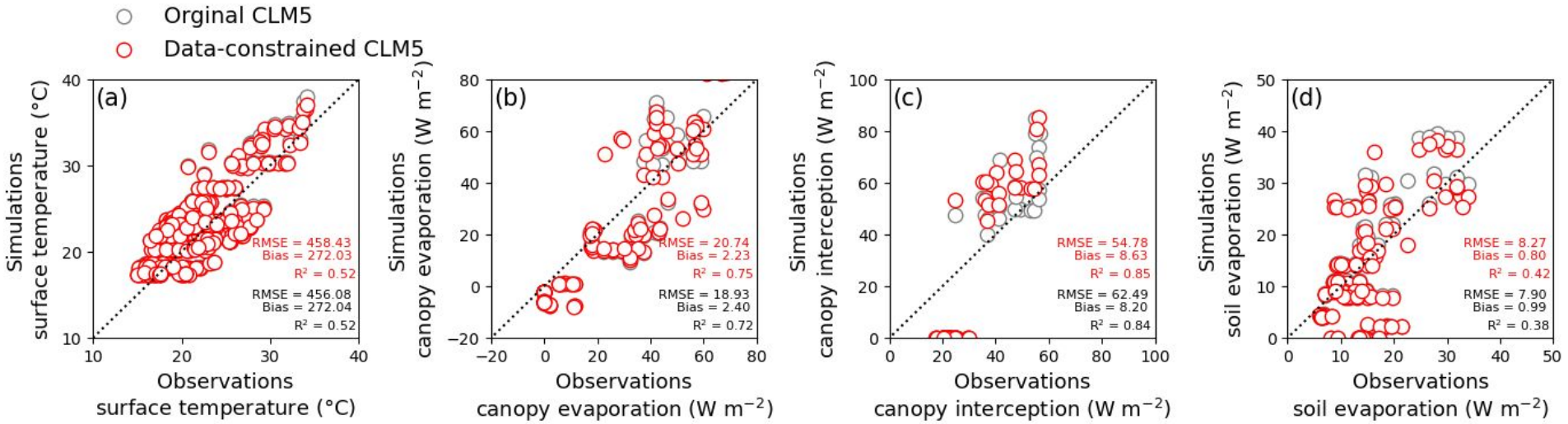
METHODS | Workflow and model improvement



In order to constrain model uncertainty,
I **added a scalar adjustment (α)** to the stomatal conductance (g_s) equation and modify the sensitivity of g_s to CO_2:

$$g_s = g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A_n}{\alpha C_s / P_{atm}}$$

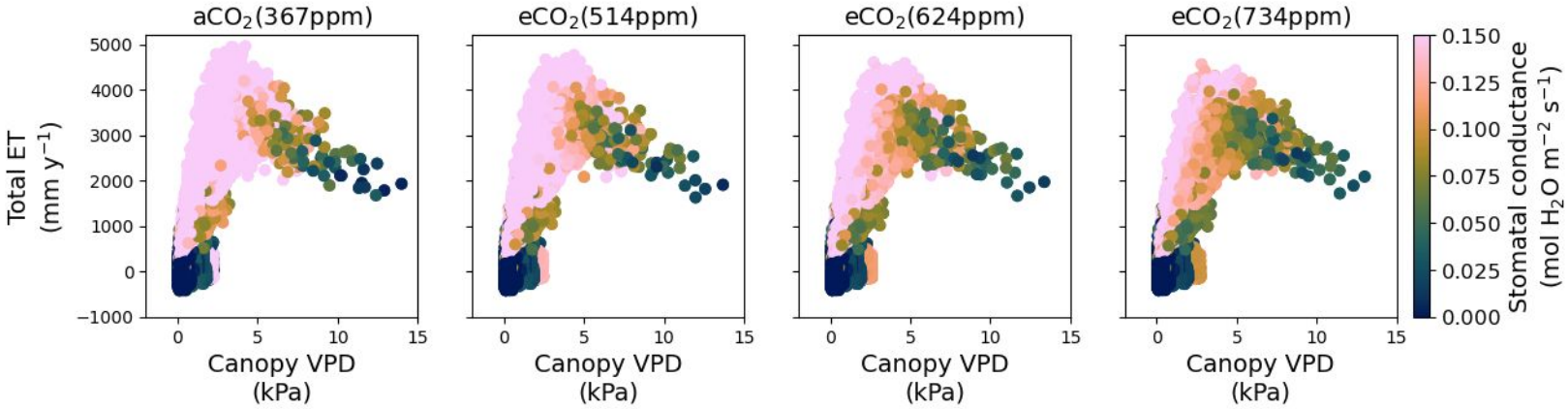
RESULTS | Model validation (obs. source: ECOSTRESS)

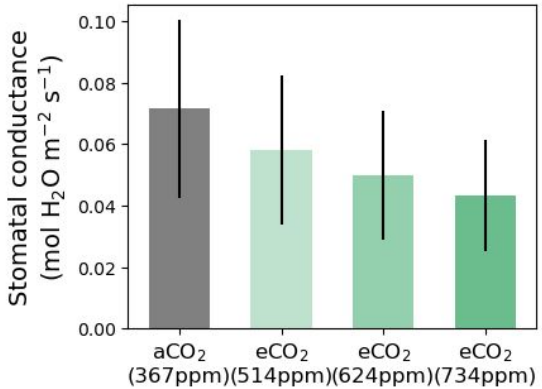


- **ELEVATE data-constrained CLM5 has a higher R^2 than original CLM5.**

RESULTS | Relationship among CO_2, VPD, gs, and ET

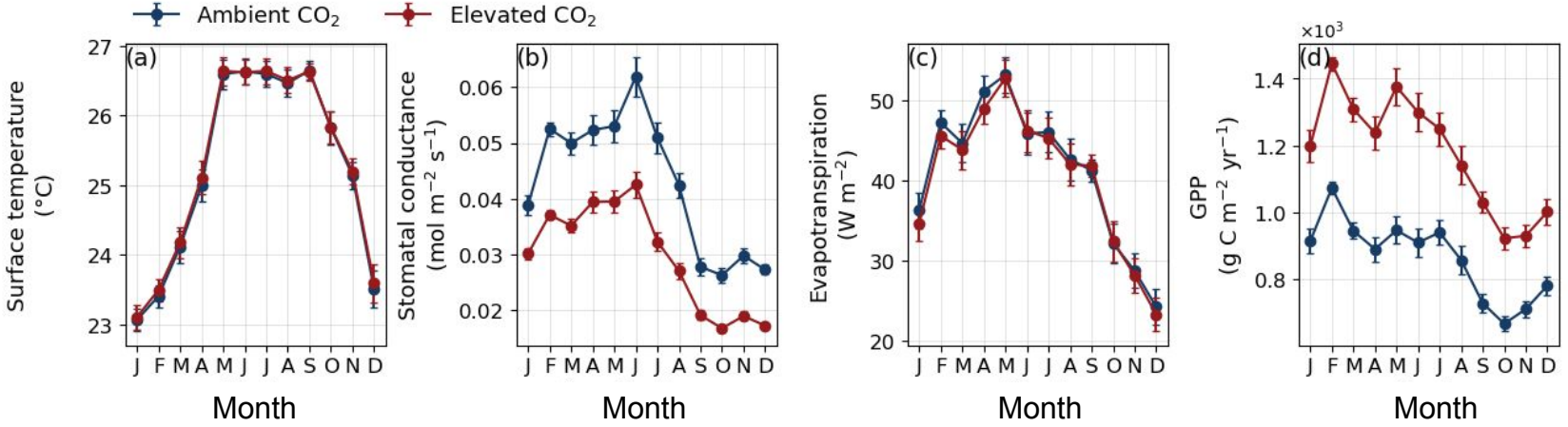
Hourly daytime (5 am - 20 pm) data:





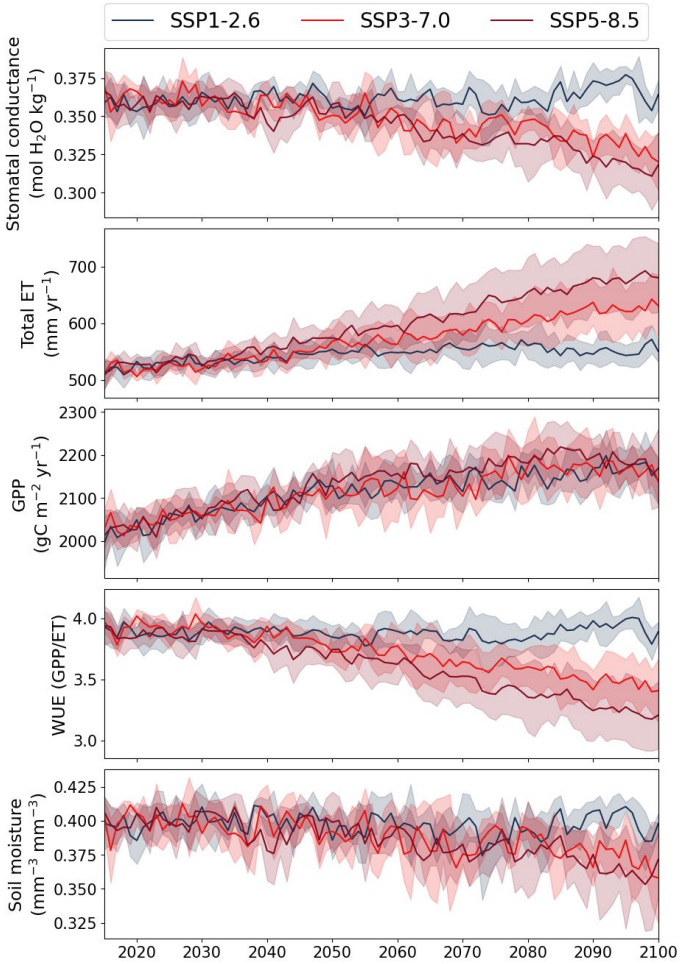
- ET increases with canopy VPD (VPD < 5).
- ET decreases with canopy VPD (VPD > 5).
- Stomatal conductance decreases with CO_2 concentration.

RESULTS | Future scenarios under based CO_2 concentration (367 ppm)



- CO_2 fertilization significantly increases gs and GPP, slightly increases surface temperature.
- CO_2 fertilization decreases ET.
- CO_2 fertilization has a bigger impact in the first half of the year than in the second half.

RESULTS | Future scenarios under based CO_2 concentration (367 ppm)



- Model inputs are derived from **five** representative Earth system models: GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0, and UKESM1-0-LL.
- Stomatal conductance (gs) decreases in ssp370 and ssp585 compared with ssp126.
- ET: ssp585 > ssp370 > ssp126
- GPP: no significant differences
- WUE: ssp126 > ssp370 > ssp585
- Soil moisture: ssp126 > ssp370 > ssp585

NEXT STEPS

- Integrate more ELEVATE data:
  - Soil carbon and nitrogen, leaf and canopy nutrients and traits.
  - Soil and stem respiration.
  - Leaf-level gas exchange (GPP, ET, WUE, gs).
  - Remote sensing:
    - NASA spaceborne: GEDI, EMIT
    - Airborne data: AVUELO (AVIRIS-5)
    - Airborne data: LiDAR
    - Ultra-high resolution commercial imagery: Maxar, ICEYE

- Integrate CLM5-FATES and CESM

Thank you!