

## XIV Séminaire STICS 2026 – Louvain-la-Neuve

# Assessing wheat crop model adequacy for future climates

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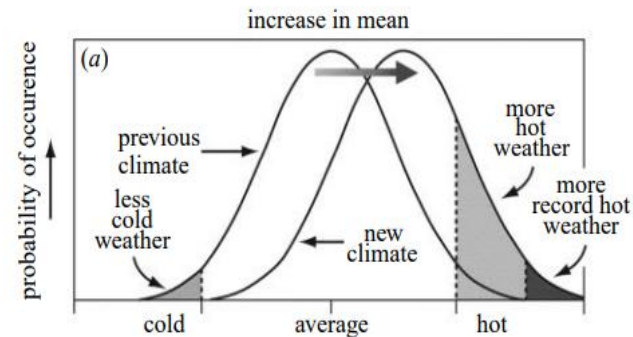
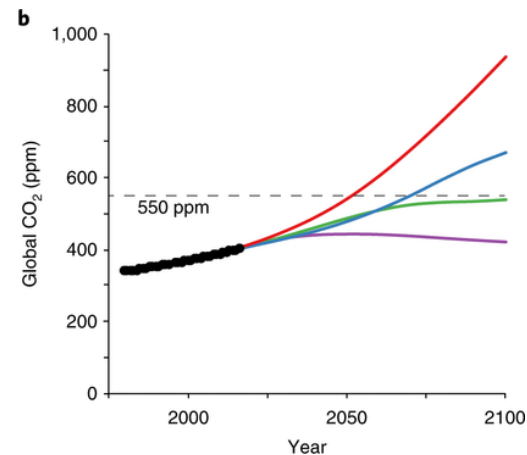
## Effects of climate change on wheat crops

- Climate change = combination of factors
  - Increase in CO<sub>2</sub> 340 ppm (1980) → 540-970 ppm (2100)
  - Increase in mean temperatures +2-4°C in 2100
  - Intensification of thermal and water stress

➔ Understand the effects on wheat growth and production

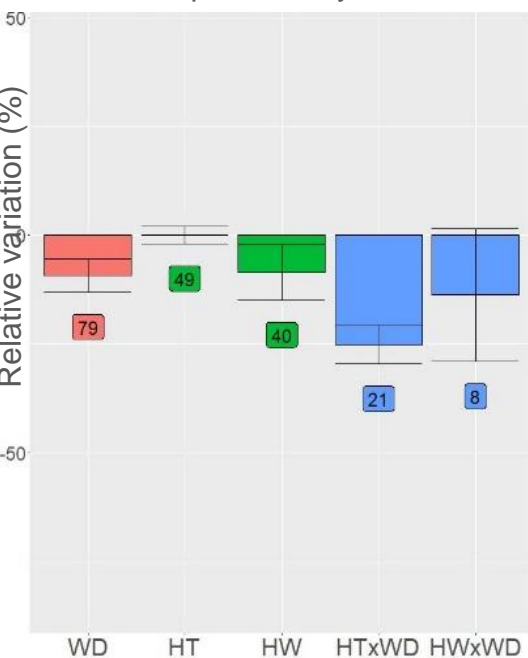
➔ Experiments and modeling

- Diverse experimental facilities
  - Growth chambers
  - Greenhouses
  - Open-top-chambers
  - FACE (Free-Air CO<sub>2</sub> Enrichment)

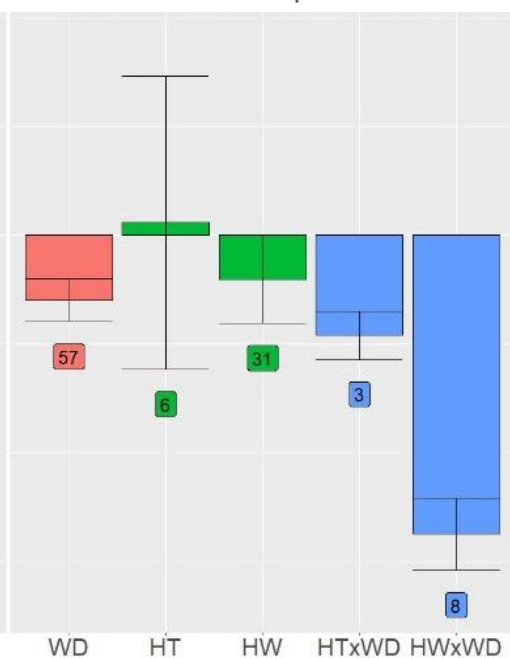


## Review of experiments on wheat (Gawinowski et al., 2025)

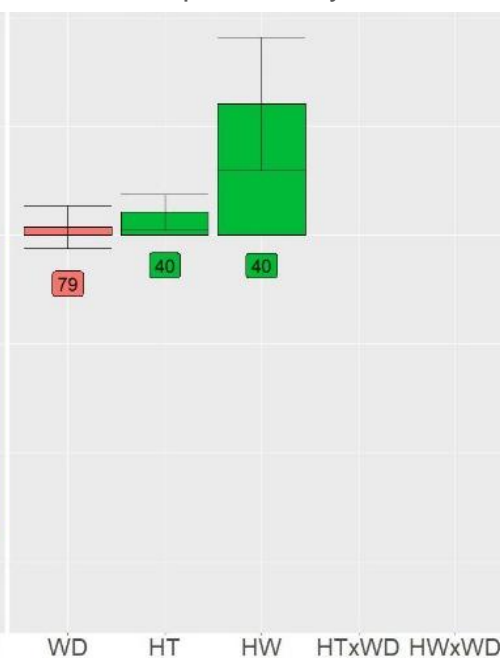
A. CO<sub>2</sub> compensation on productivity



B. CO<sub>2</sub> compensation on water consumption



C. CO<sub>2</sub> interaction on productivity



Water deficit (WD)

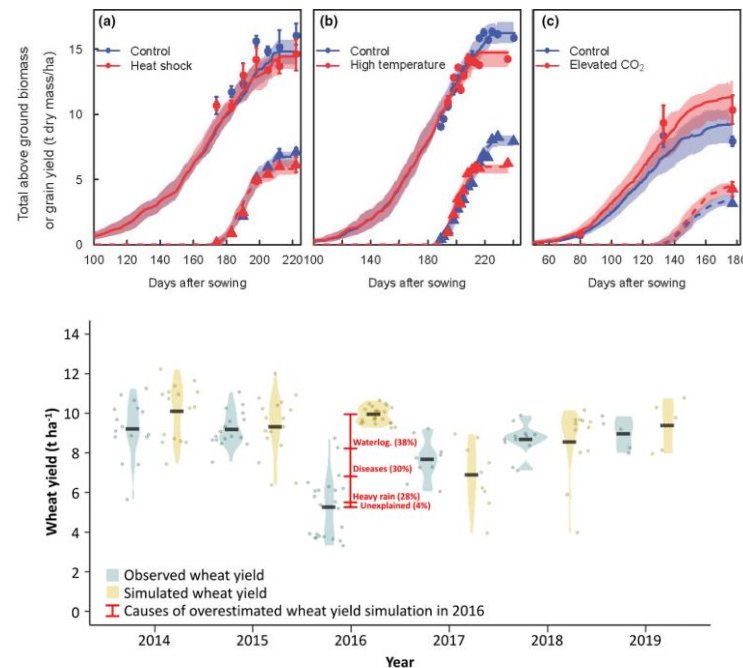
High temperature (HT)  
heatwave (HW)

WD x temperature

## State of the art and limitations for crop modeling approaches

- Predict effects of climate change on crops (Chenu et al., 2017)
- Many studies with crop model ensembles (AgMIP)
  - Median = good predictor of crop response → wheat under eCO<sub>2</sub> x high temperatures x water deficit
  - Evaluation restricted to few studies
  - Important variability between models
- Possible underestimation of climate change effects in crop models
  - Overestimation of CO<sub>2</sub> effect (experimental calibration, CO<sub>2</sub> acclimation)
  - Underestimation of high temperatures and water stress (Webber et al., 2025)

→ General lack of quantitative validation against experimental data under future climatic conditions



Process		APSIM NG	STICS
CO <sub>2</sub>	RUE	$fCO_2 = \frac{(CO_2 - C_i)(350 + 2C_i)}{(CO_2 + 2C_i)(350 - C_i)}$	$fCO_2 = 2 - \exp(\log(2 - \alpha) \times \frac{CO_2 - 350}{600 - 350})$
	gs	$fCO_{2s} = \frac{fCO_2(350 - C_i)}{CO_2 - C_i}$	$fCO_{2s} = \frac{1}{1 + 0,77(1 - \frac{fCO_2}{2,5})(1 - \frac{CO_2}{350})}$
	Nitrogen	+7% between 350 and 700 ppm	None
Temperature	Development	Thermal time accumulation controlled by 3 thresholds	
	Leaf expansion	Leaf expansion controlled by 3 thresholds	
	RUE	Multiplier controlled by 4 thresholds	
	Grain filling	None	Multiplier controlled by 2 thresholds
Water deficit	Turgescence	Daily growth rate, potential size	$turfac = \max(swfacmin, \frac{teta}{teturg})$
	RUE	Linear reduction based on transpiration demand	$swfac = \max(swfacmin, \frac{teta}{tetstomate})$
	Senescence	Based on transpiration demand	$senfac = \max(swfacmin, \frac{teta}{tetsen})$

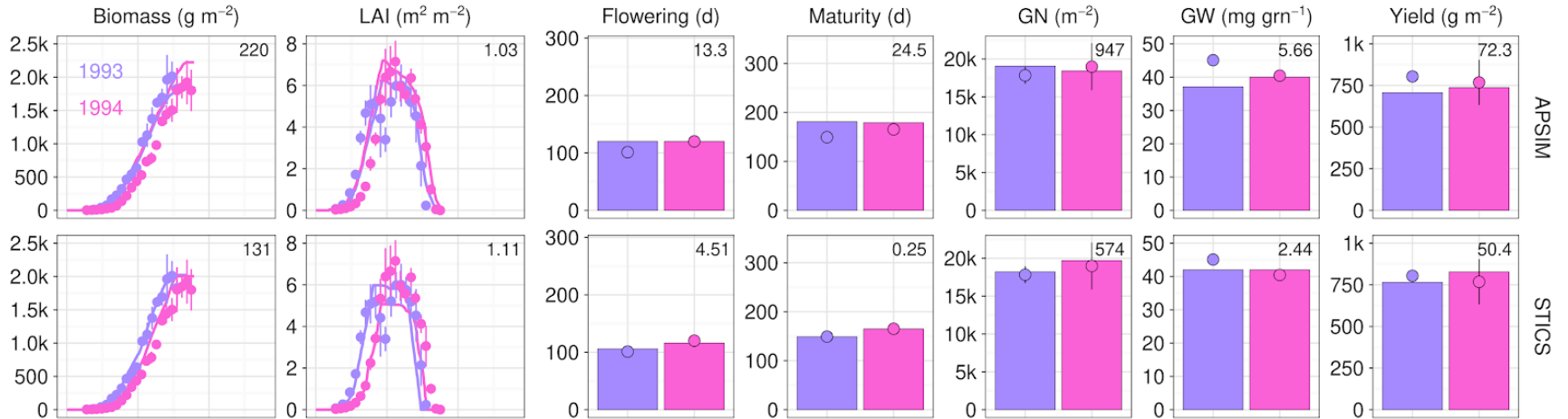
## Three targeted FACE experiments replicated *in silico*

- Maricopa (1993, 1994) : CO<sub>2</sub> (370 vs 550 ppm) and water deficit (rained vs irrigated), cv Yecoja Rojo (Kimball et al., 1996)
- Braunschweig (2013, 2014) : CO<sub>2</sub> (393 vs 600 ppm) and high temperatures during grain filling (+0, +1.5, 3°C), cv Batis (Manderscheid et al., 2020)
- Horsham (2007, 2008, 2009) : CO<sub>2</sub> (385 vs 550 ppm), high temperatures (early and late sowing dates) and water deficit (rainfed vs irrigated) (Fitzgerald et al., 2016), cv Yitpi

→ Calibrate cultivars on control conditions (aCO<sub>2</sub>, aT, WW) and validation on conditions with climatic fluctuations (eCO<sub>2</sub>, HT, WD)

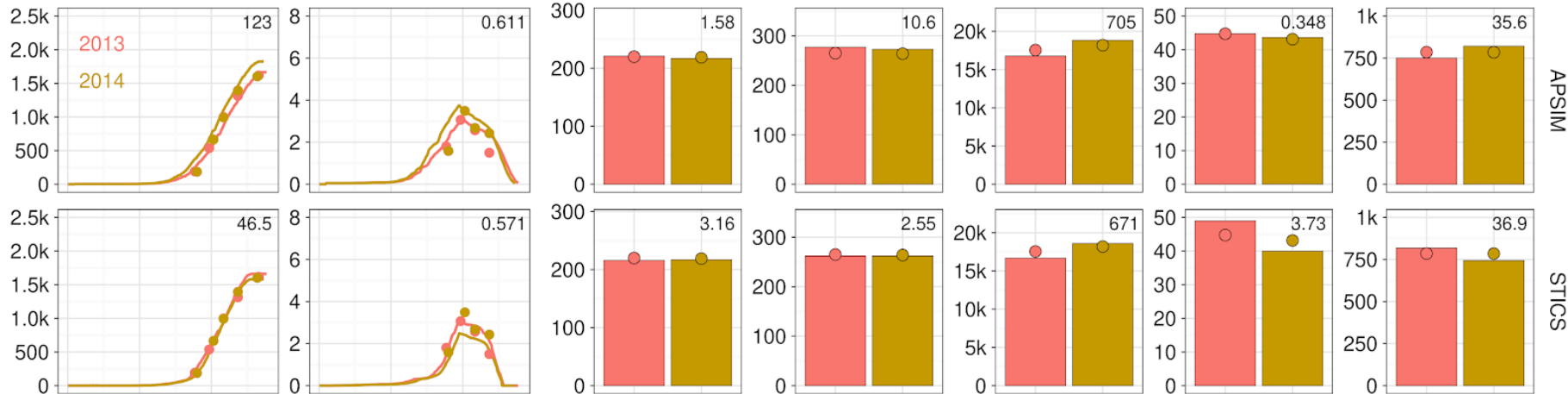
## Calibrated simulations

Maricopa

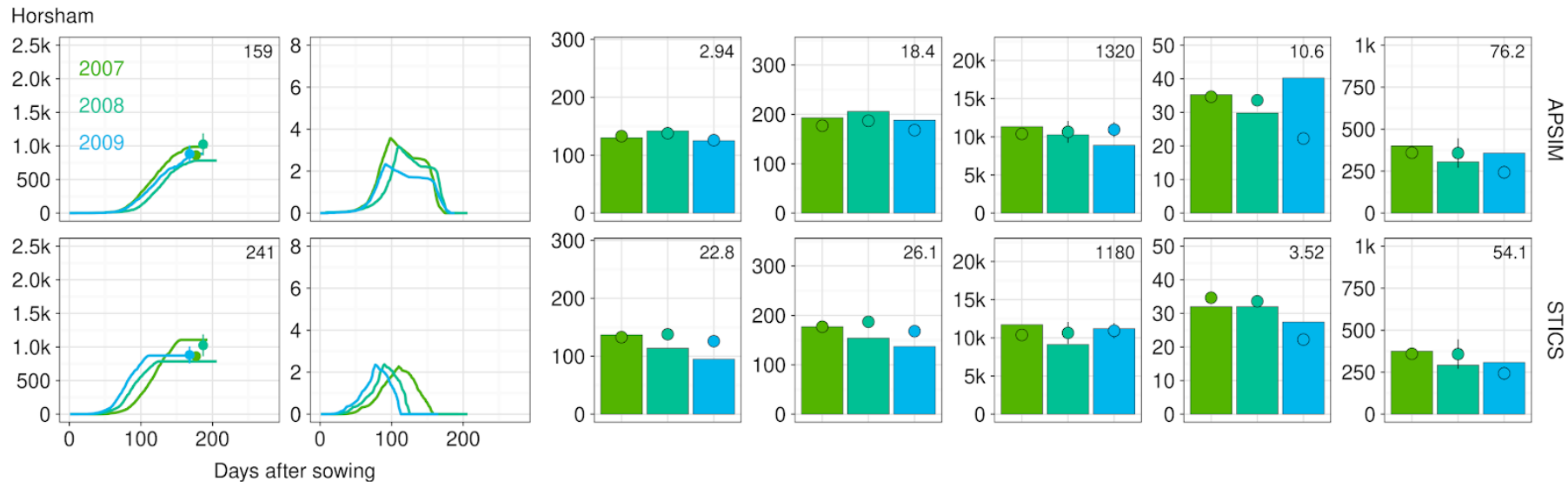


## Calibrated simulations

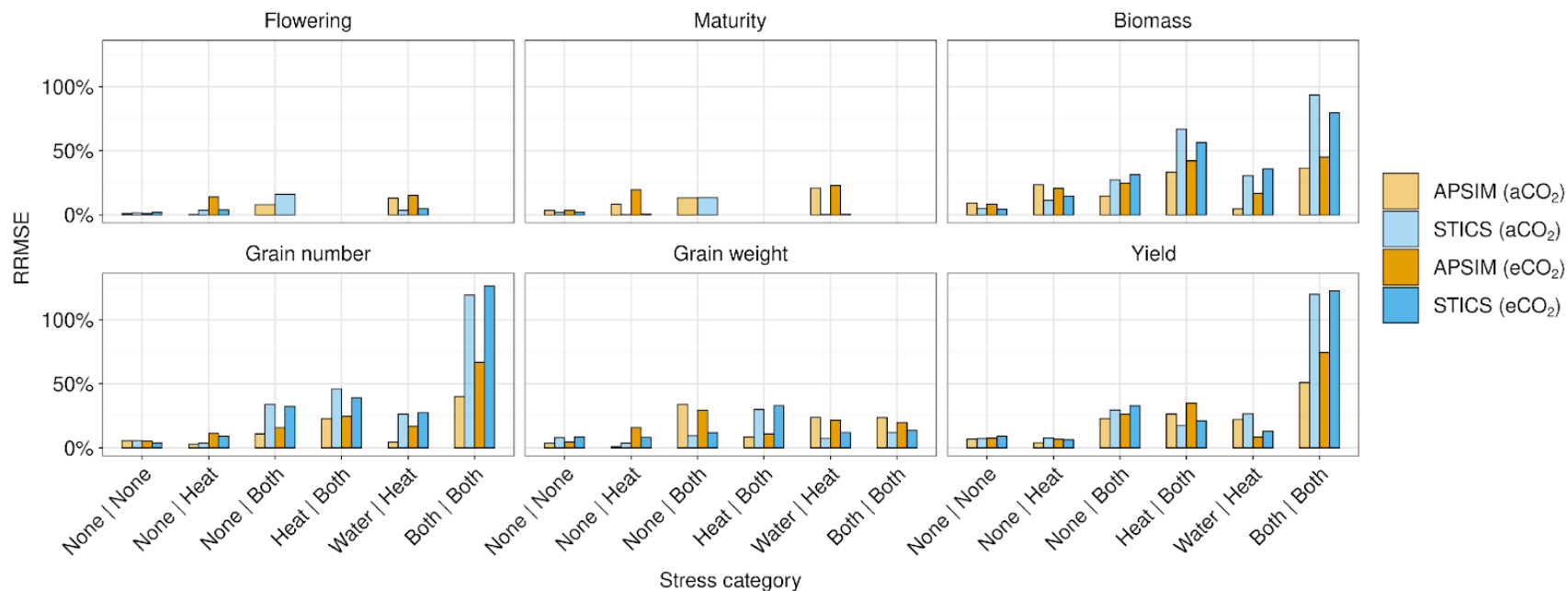
Braunschweig



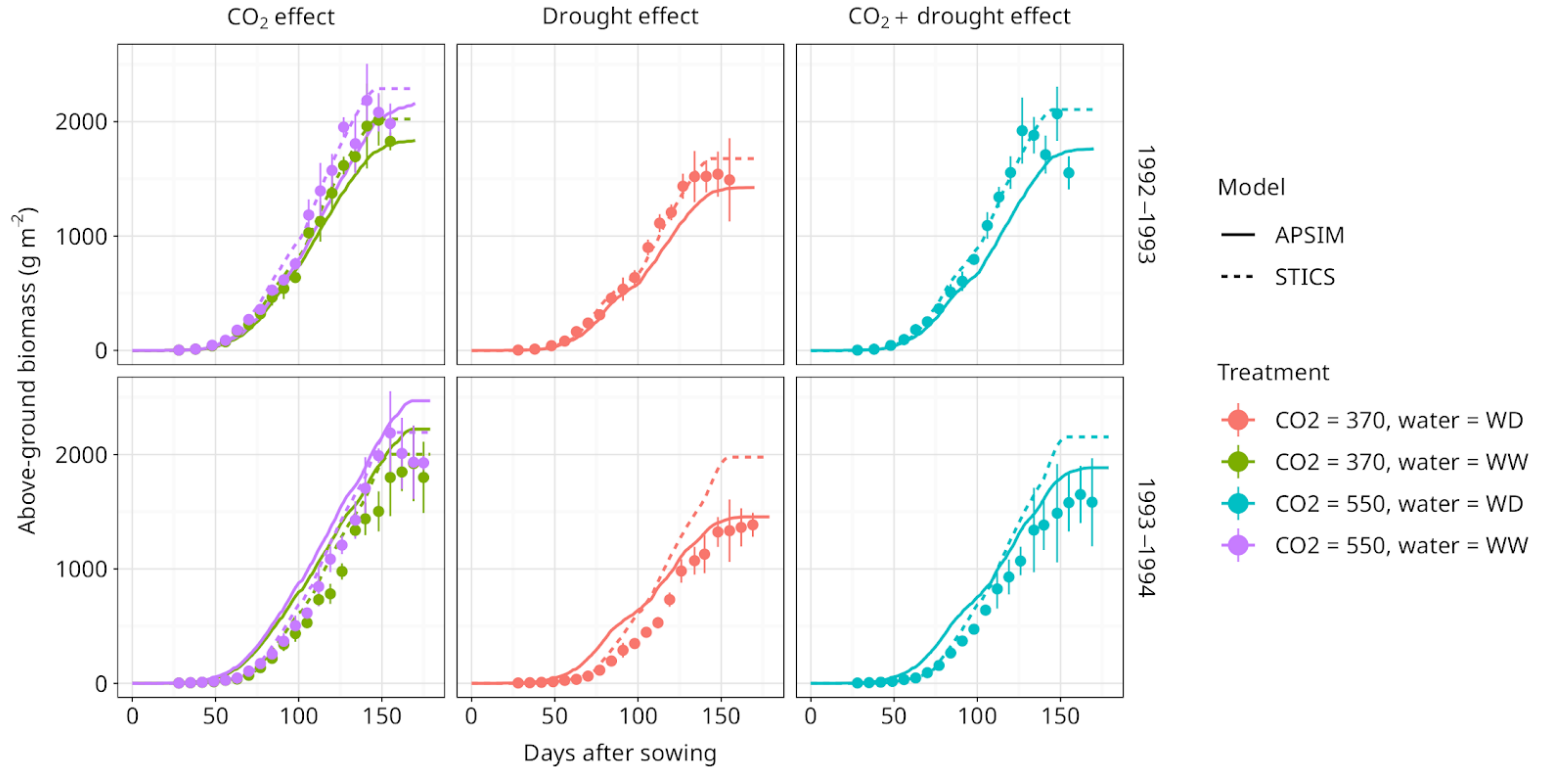
## Calibrated simulations



## RRMSE under « climate change » conditions



# Plant biomass in Maricopa





- Maricopa
  - APSIM NG ok
  - STICS : consequent underestimation of water stress
  - Method for evapo-transpiration: Shuttleworth & Wallace (STICS) vs Penman (APSIM NG)
  - Known « oasis » effect
  - Similar issues for other models : CERES-Wheat (Tubiello et al., 1999), LINTULCC2, AFRWHEAT2 and Sirius (Ewert et al., 2002)
- Branschweig
  - No thermal stress really experimented
  - Experimental observations might not be significant
  - Biomass and yield underestimated in some conditions (eCO<sub>2</sub>, +1.5°C)
- Horsham
  - Poor response to eCO<sub>2</sub> with STICS
  - Control conditions are also stressed
  - Consequent biomass overestimation in simulations under multiple stress with both models

- More experimental data is required → broader range of stress combinations, including varying intensities, timings and durations of multiple stressors
- Individual model evaluation is essential and complementary to AgMIP approaches to enable significant improvements in crop models
- Webber et al. (2025): drought stress is often underestimated by wheat crop models → systematic bias due to underestimated evapotranspiration
- New calibration methodologies are also required to deal with such heterogeneous data !

**Thank you for your attention !**

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