Calibration of rice parameters in JULES 7.4 based on O_3-FACE experiment in China

Beiyao Xu

Steven Dobbie, Huiyi Yang, Lianxin Yang, Yu Jiang, Andrew Challinor, Yunxia Wang, Karina Williams, Tijian Wang

The importance of rice

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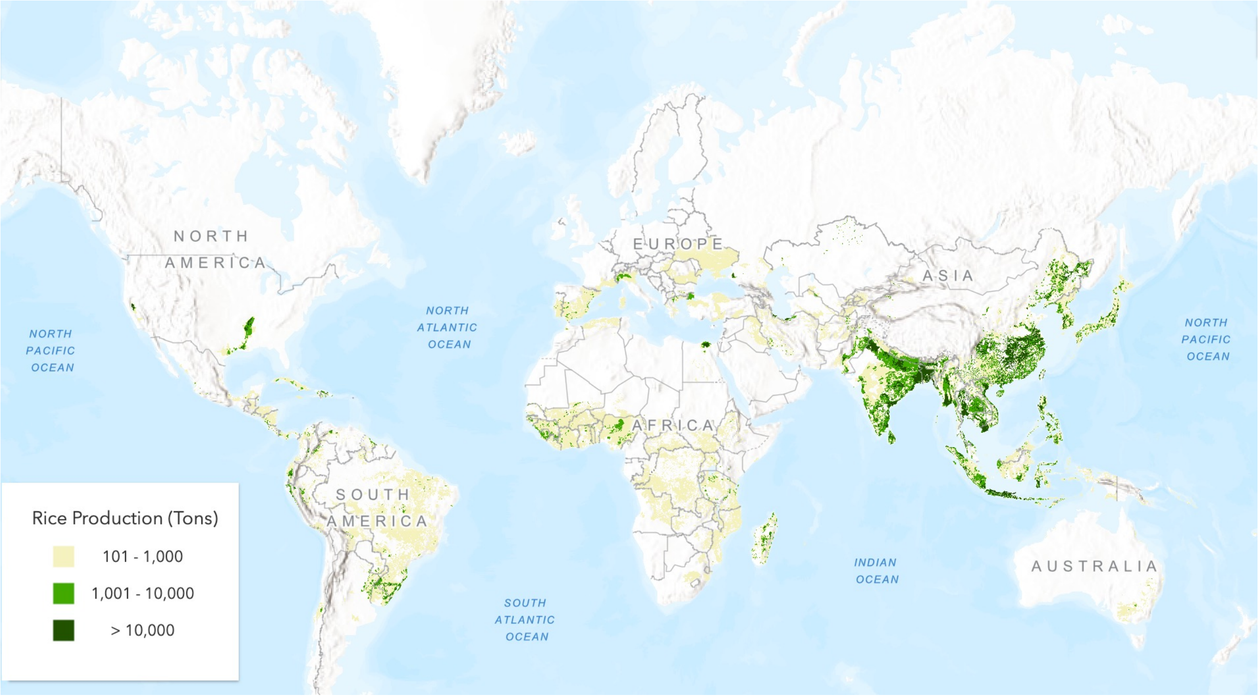
Rice (*Oryza sativa* L.) is one of the most important crops in the world, feeding more than **half** of the world's population.

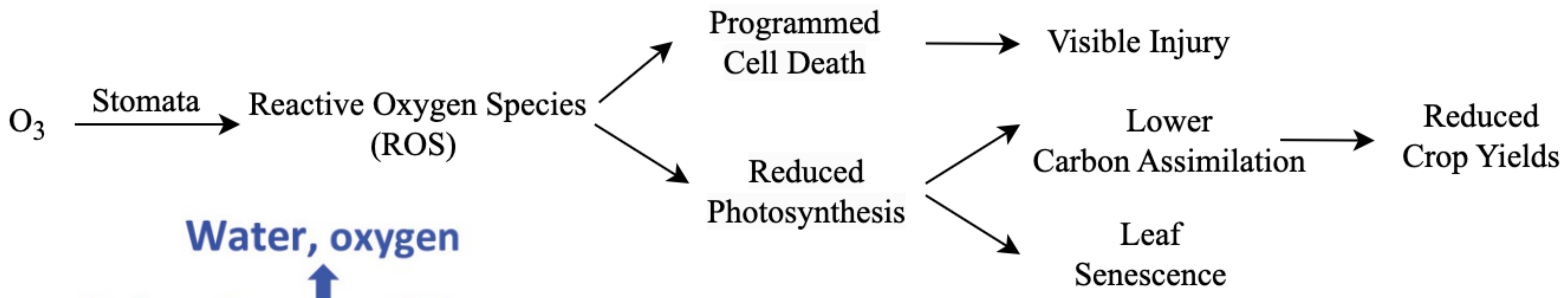


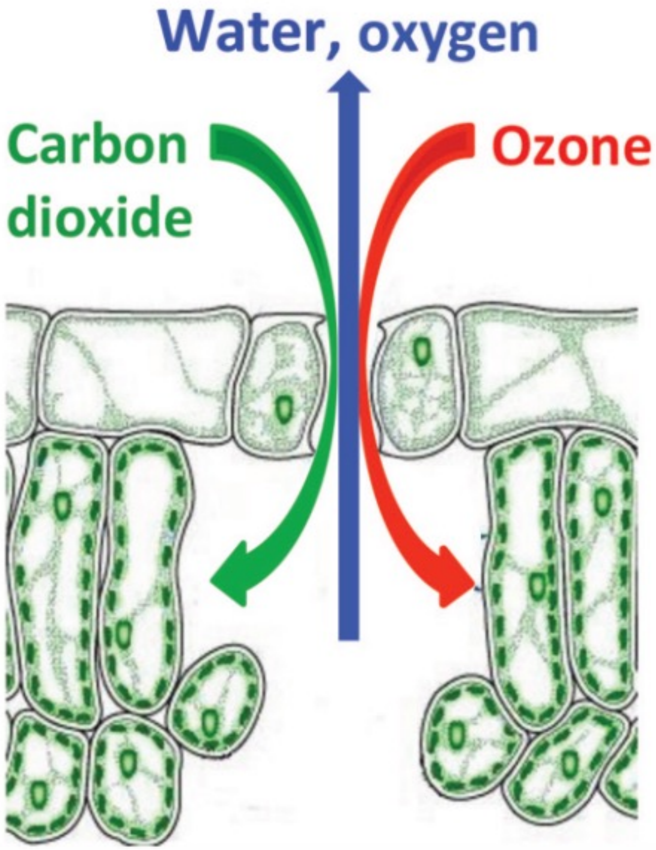
Rice's World Production in 2023 is 518,067 (10^3 MT). China is the main producer of rice in the world, accounting for **29%** of the total rice production (149,000 (10^3 MT)).

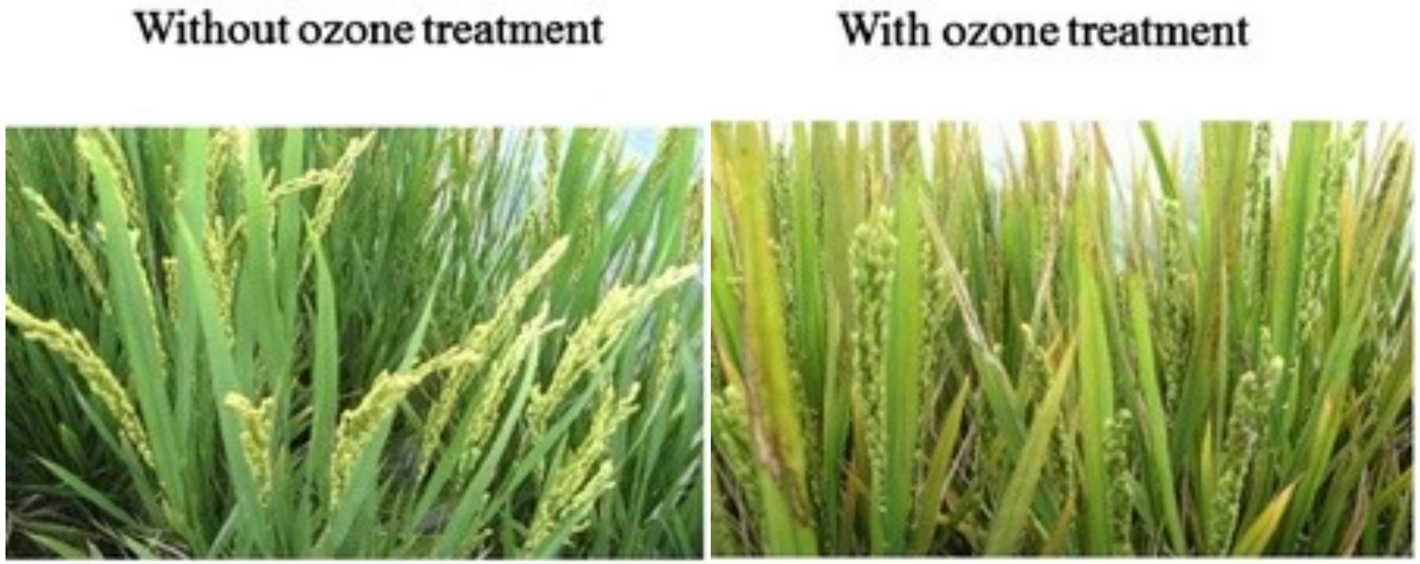
Source: Foreign Agricultural Service (FAS)

Rice terrace in Zhejiang, China

Negative effects of elevated ozone on crops

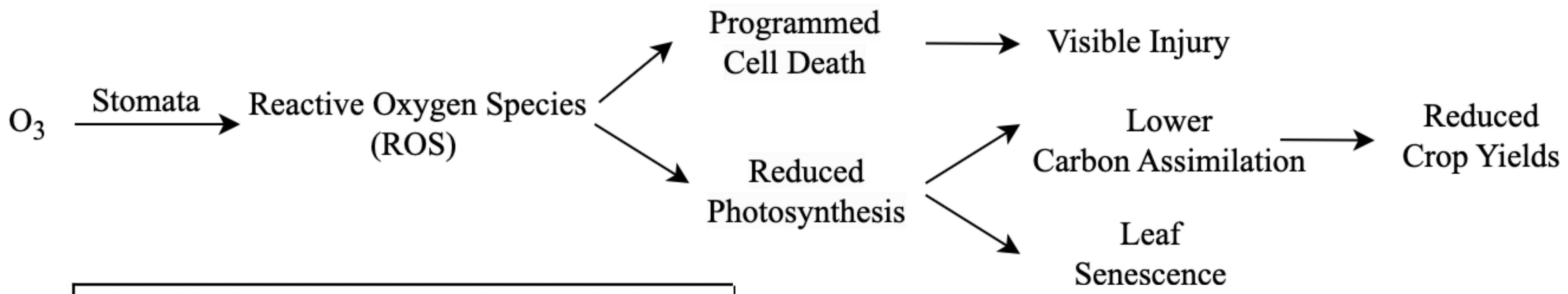


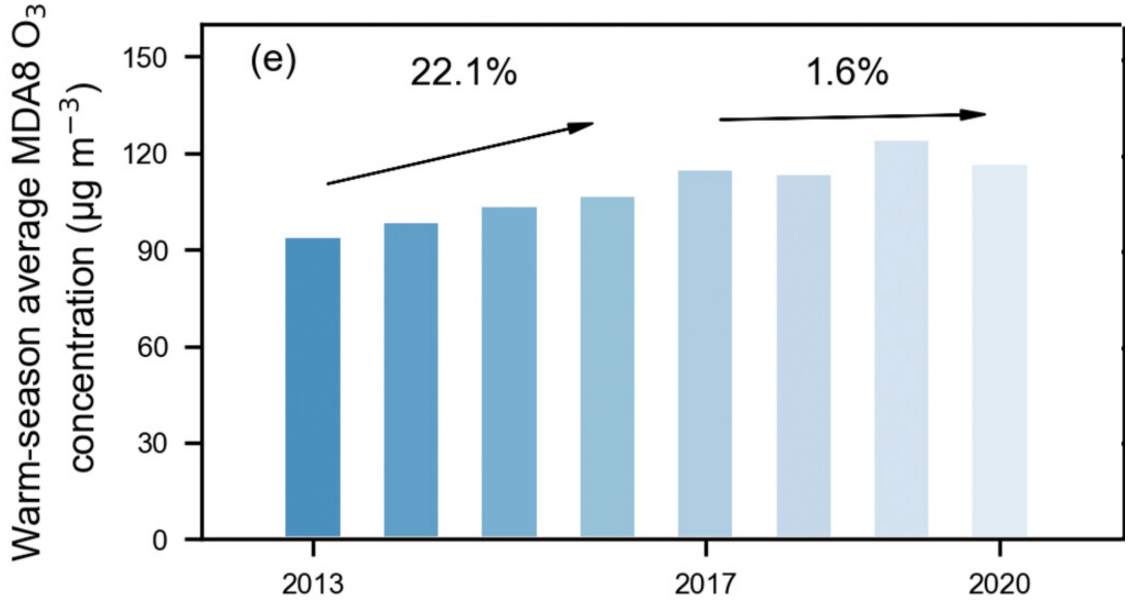




Tian et al., 2016

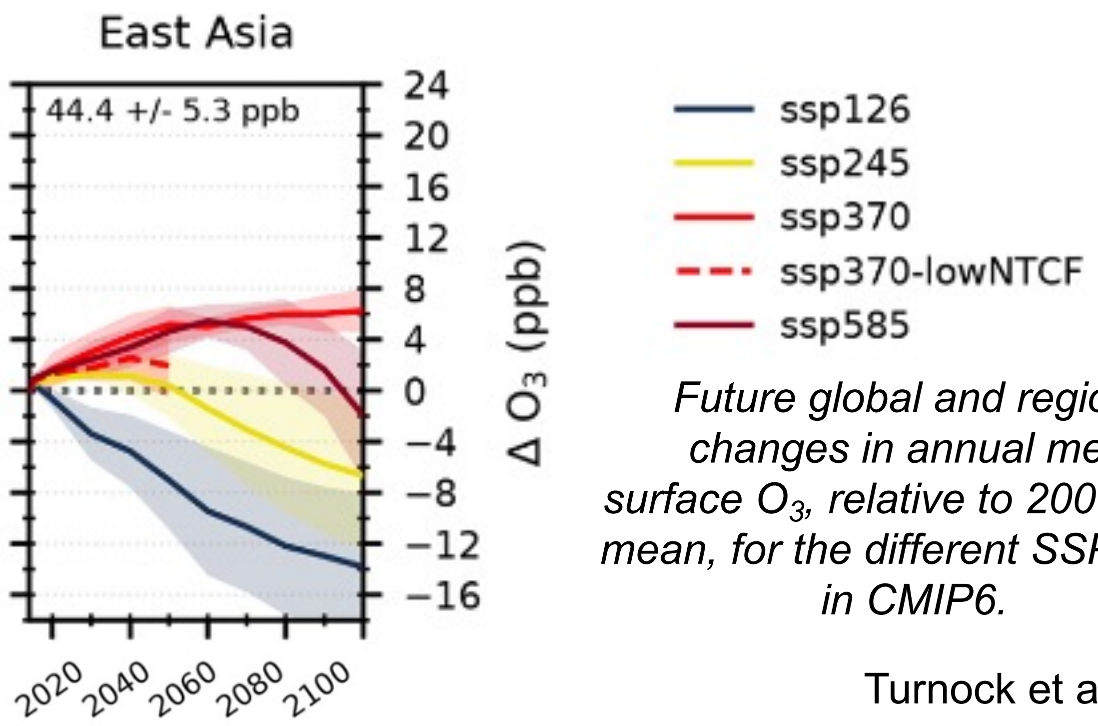
Negative effects of elevated ozone on crops





Ozone concentration trend in China during Warm-season (Apr.–Sep.)

Liu et al., 2023



Future global and regional changes in annual mean surface O_3, relative to 2005–2014 mean, for the different SSPs used in CMIP6.

Turnock et al., 2020

Brief introduction of JULES-crop

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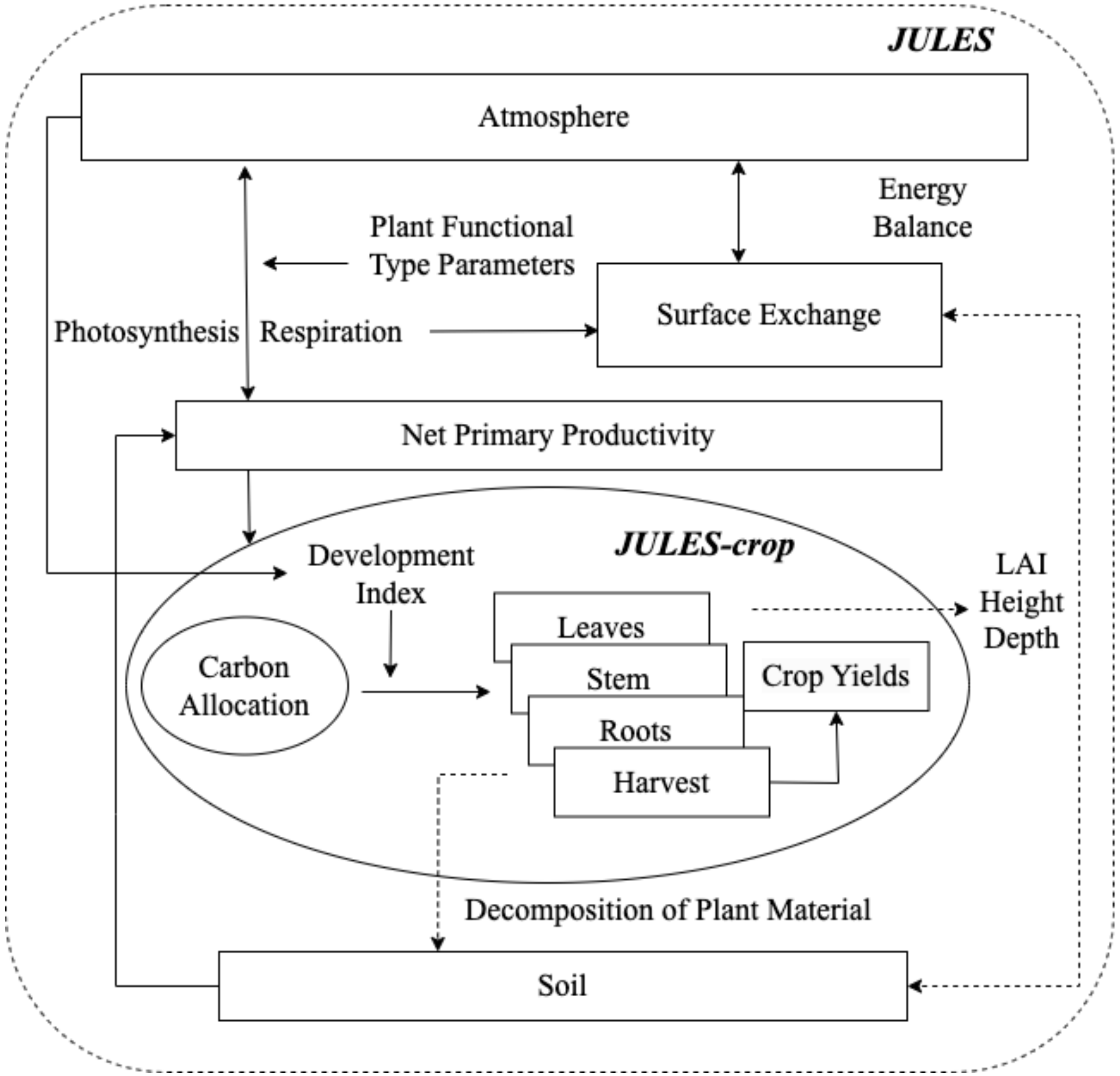
JULES-crop is a parameterization of crops within JULES which was developed with the dual aim of being able to simulate the impact of weather and climate on crop productivity and the impact that croplands have on weather and climate (Osborne et al., 2015).

So far, **winter wheat** (Yang et al., to be submitted), **maize** (Williams et al., 2017), and **soybean** (Leung et al., 2020) in JULES-crop have been calibrated against observations.



Schematic of JULES-crop

Ozone damage scheme in JULES

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The O_3 flux F_{O_3} (nmol m^{-2} s^{-1}) is calculated as (Sitch *et al.*, 2007) :

$$F_{O_3} = \frac{[O_3]}{R_a + R_b + [\frac{\kappa_{O_3}}{g_l}]}$$

$[O_3]$ (nmol m^{-3}) molar O_3 concentration at reference level,
R_a (s m^{-1}) aerodynamic resistance
R_b (s m^{-1}) boundary layer resistance
κ_{O_3} ratio of leaf conductance for to leaf conductance for water vapour

g_l linear function of photosynthetic rate:

$$g_l = g_l^* F$$

g_l^* leaf conductance in the absence of O_3 effects
F reduction factor:

$$F = 1 - a \cdot max\left[F_{O_3} - F_{O_3crit}, 0\right]$$

F_{O_3crit} plant type specific threshold, a is sensitivity parameters.

Two systems to measure the ozone damage on crops

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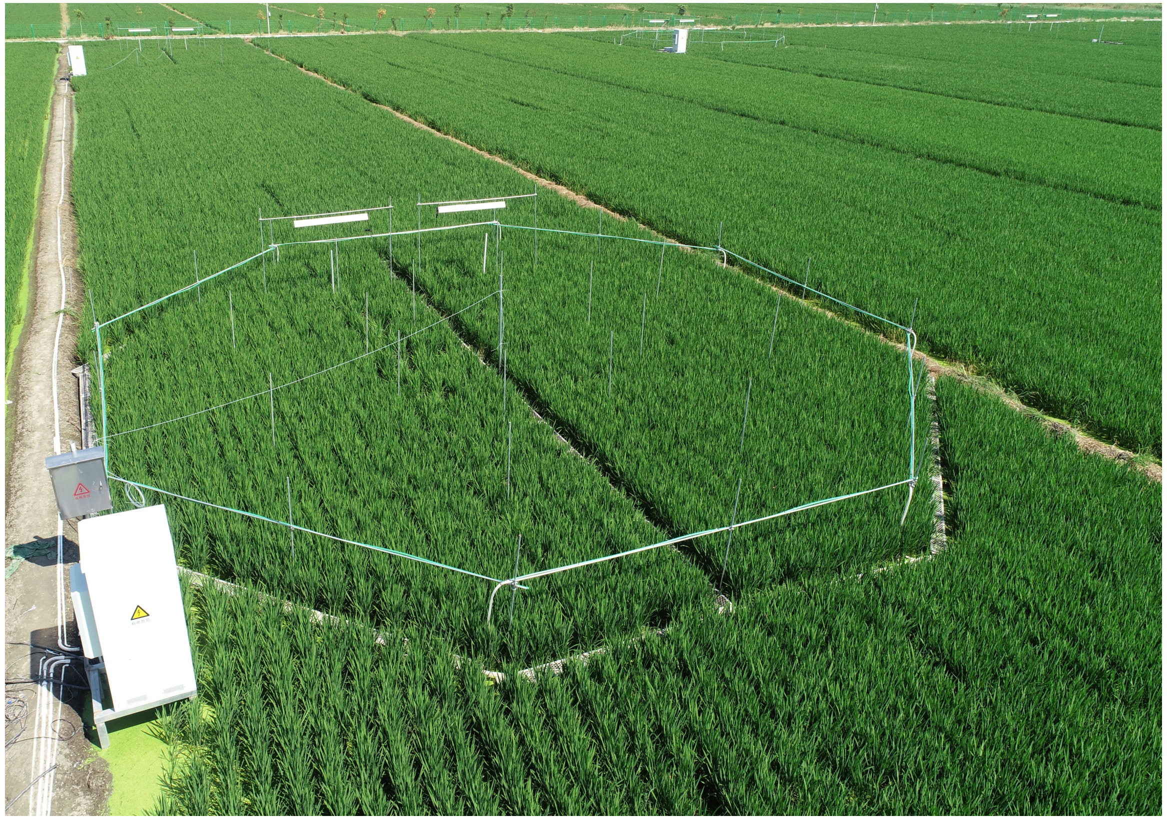
Several environmental variables are altered inside the OTCs:

- ✓ Air Turbulence
- ✓ Light Intensity
- ✓ Air Temperature
- ✓ Humidity

Feng et al., 2018

Open-top Chambers (OTCs).



Free Air Concentration Enrichment (FACE) experiment in China

Unique O3-FACE system in China

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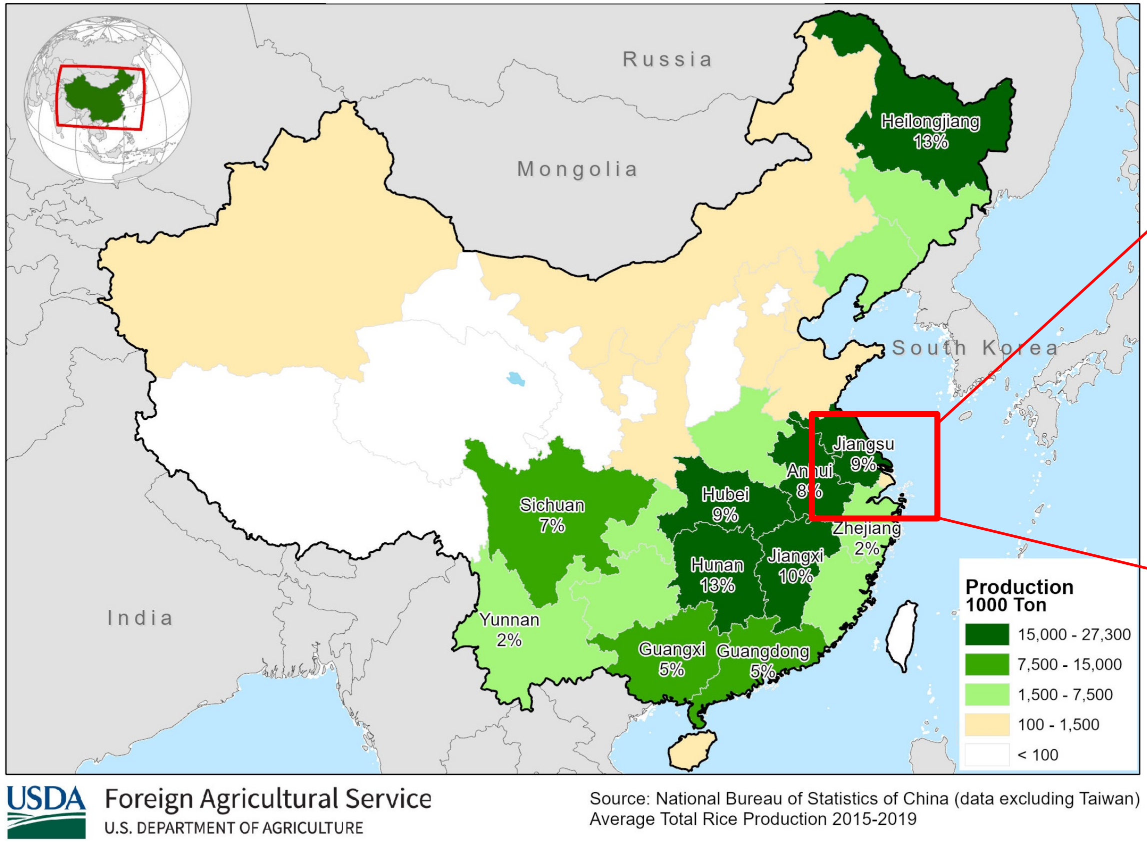

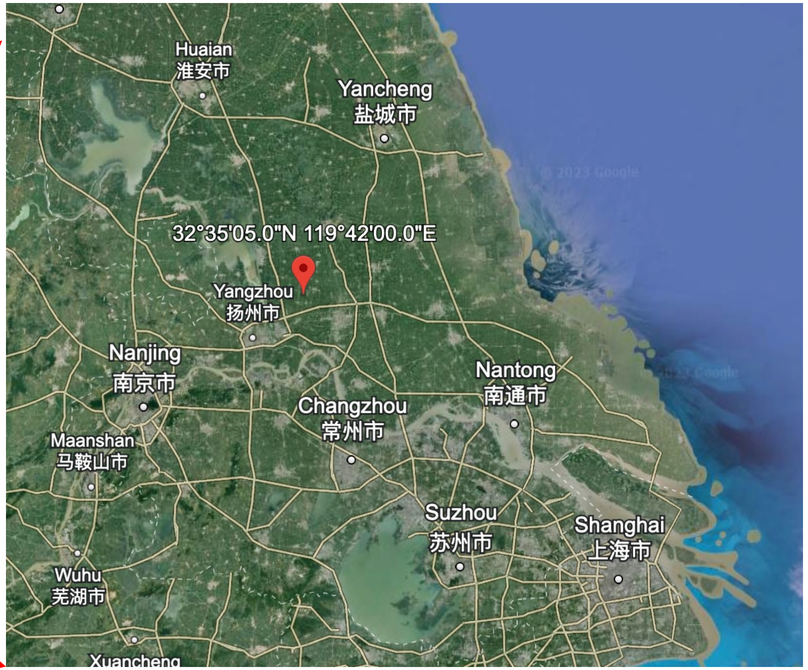

FACE-O_3 experiment is located in Xiaoji, Jiangsu Province, China (32°35'5"N, 119°42'0"E), and it had 4 FACE-O_3 fields and 4 control fields. The effective area of each filed is about 120 m^2.

Annual
Precipitation ~ 990 mm
Evaporation > 1150 mm

Temperature ~ 15 .1 °C
Sunshine time > 2100 h
Frost-free period ~ 220 d

Photosynthesis rate

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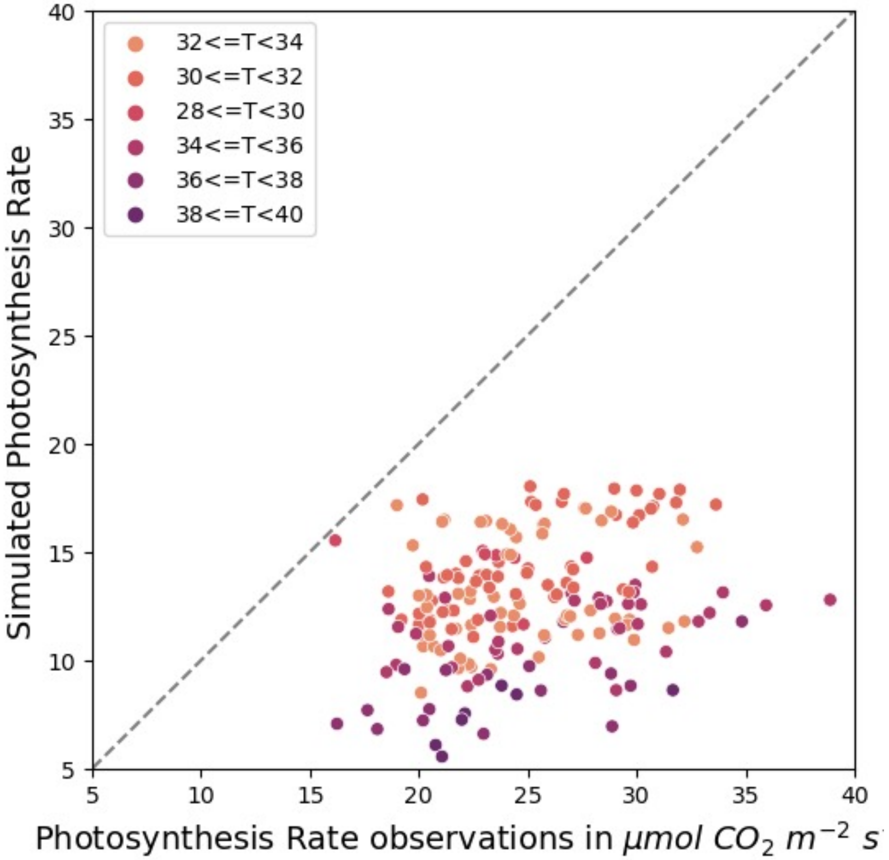
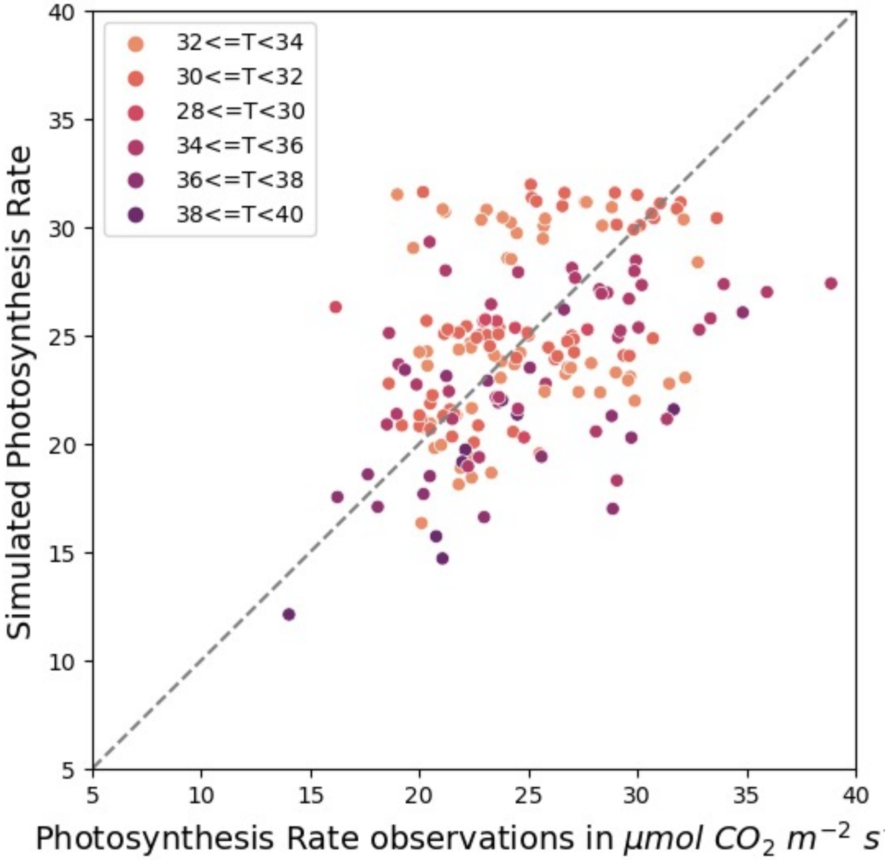
Before Calibration



After Calibration



Simulated photosynthesis rate $(\mu mol\ CO_2\ m^{-2}\ s)$

The dashed line is the 1:1 line.

Growth period and carbon partition

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Once the rice is sown, the developing rate which is defined as development index (DVI) depends on the thermal time prescribed, including the thermal time between sowing, emergence, flowering, and maturity stages. The thermal time (T_{eff}) can be calculated as follows:

$$T_{eff} = \begin{cases} 0 & for\ T < T_b \\ T - T_b & for\ T_b \le T \le T_o \\ (T_o - T_b)\left(1 - \frac{T - T_o}{T_m - T_o}\right) & for\ T_o \le T \le T_m \\ 0 & for\ T \ge T_m \end{cases}$$

where T, T_b, T_o, and T_m are air temperature, base temperature (8 °C), optimum temperature (30 °C), and maximum temperature (42 °C) respectively.

$$p_i = \frac{\exp[\alpha_i + \beta_i \mathrm{DVI}]}{\sum_j \exp[\alpha_j + \beta_j \mathrm{DVI}]},$$

where j = root, stem, leaf, harv. α_i and β_i are numerical constants that are tuned to observational data. α_{harv} and β_{harv} are both set to zero. All other α_i and β_i are set by the user for each crop. Note that $\sum_j p_j = 1$.

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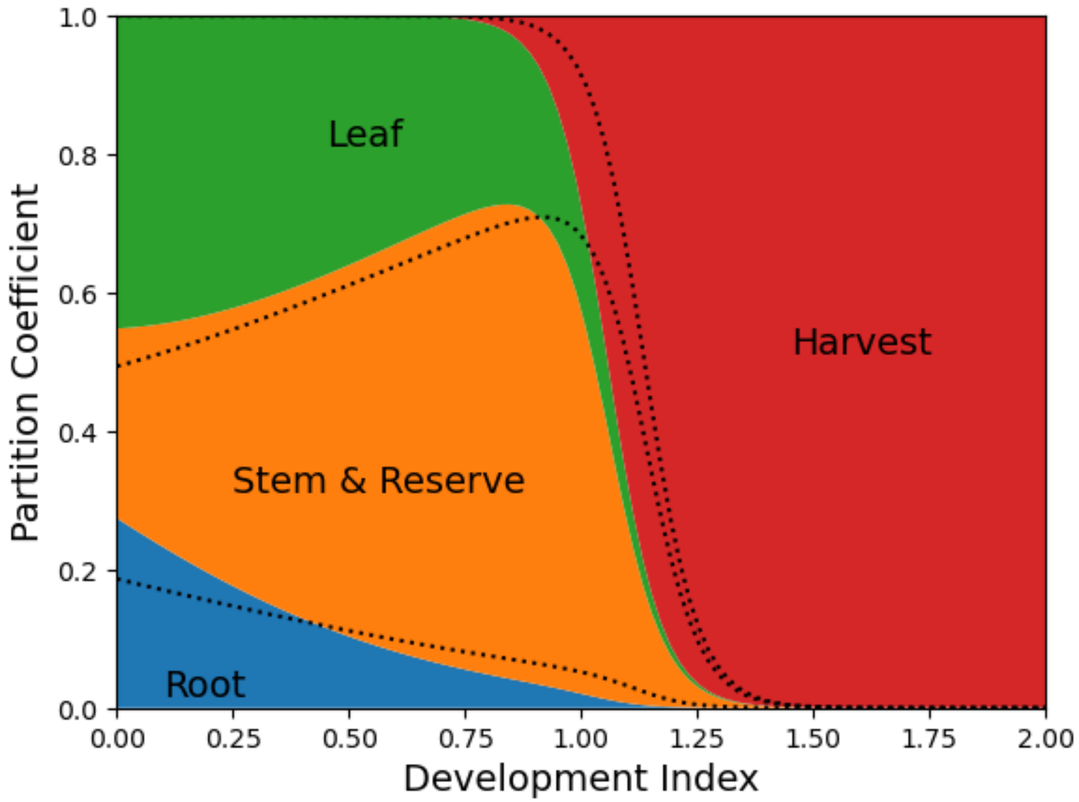

Calibration of carbon partition and crop height

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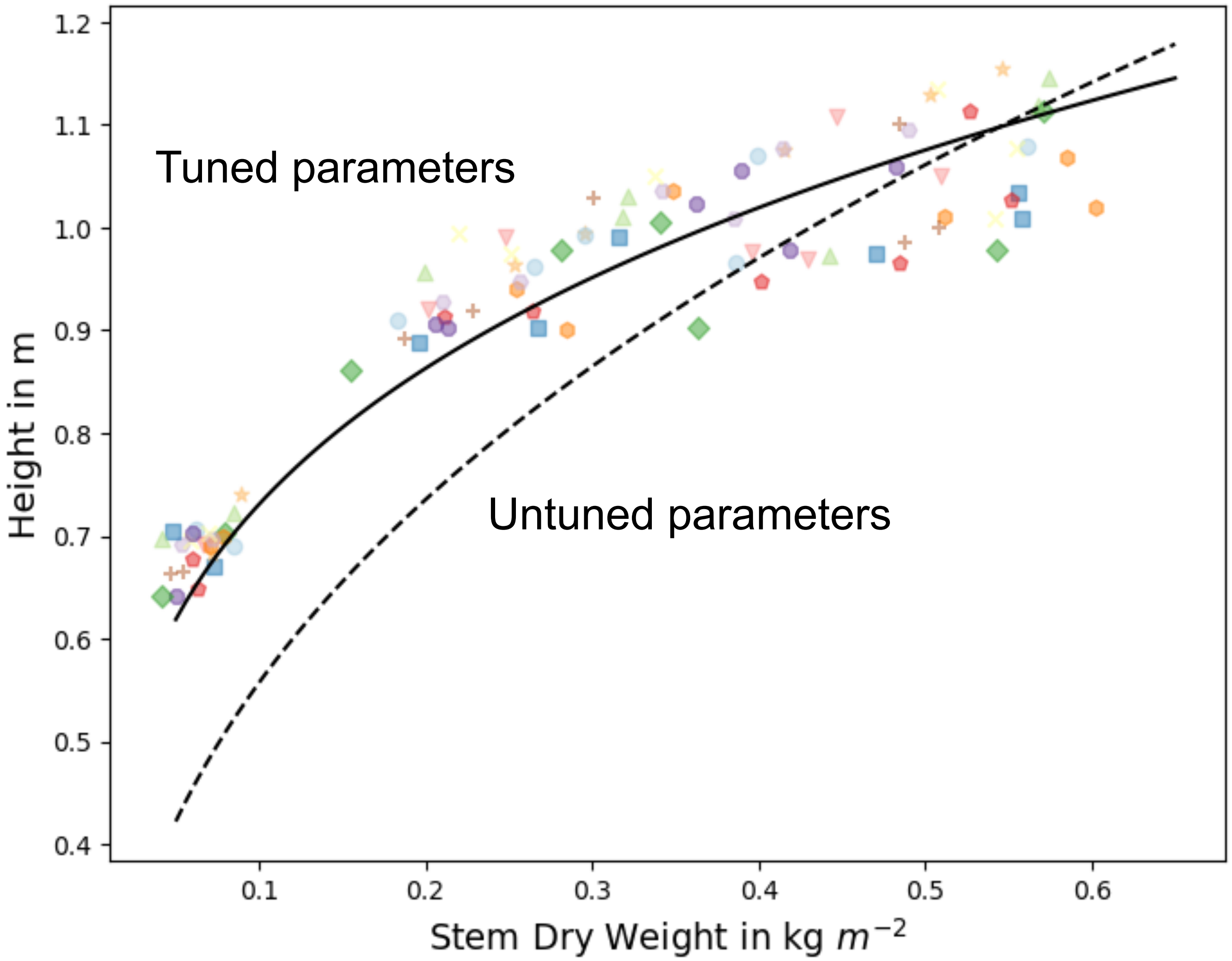
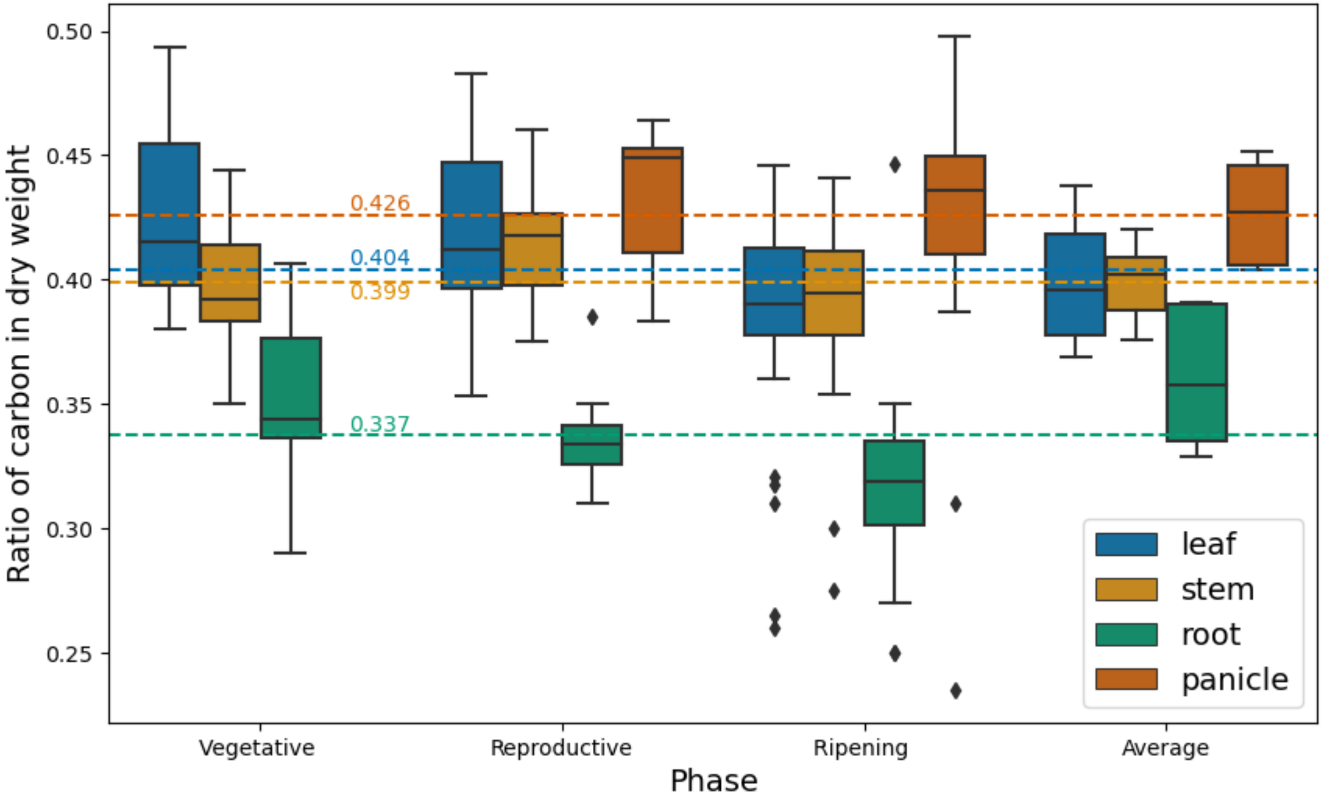
The calculation of crop height (h) depends on the amount of carbon in the stem (C_{stem}):

$$h = \kappa(\frac{C_{stem}}{f_{C,stem}})^{\lambda}$$

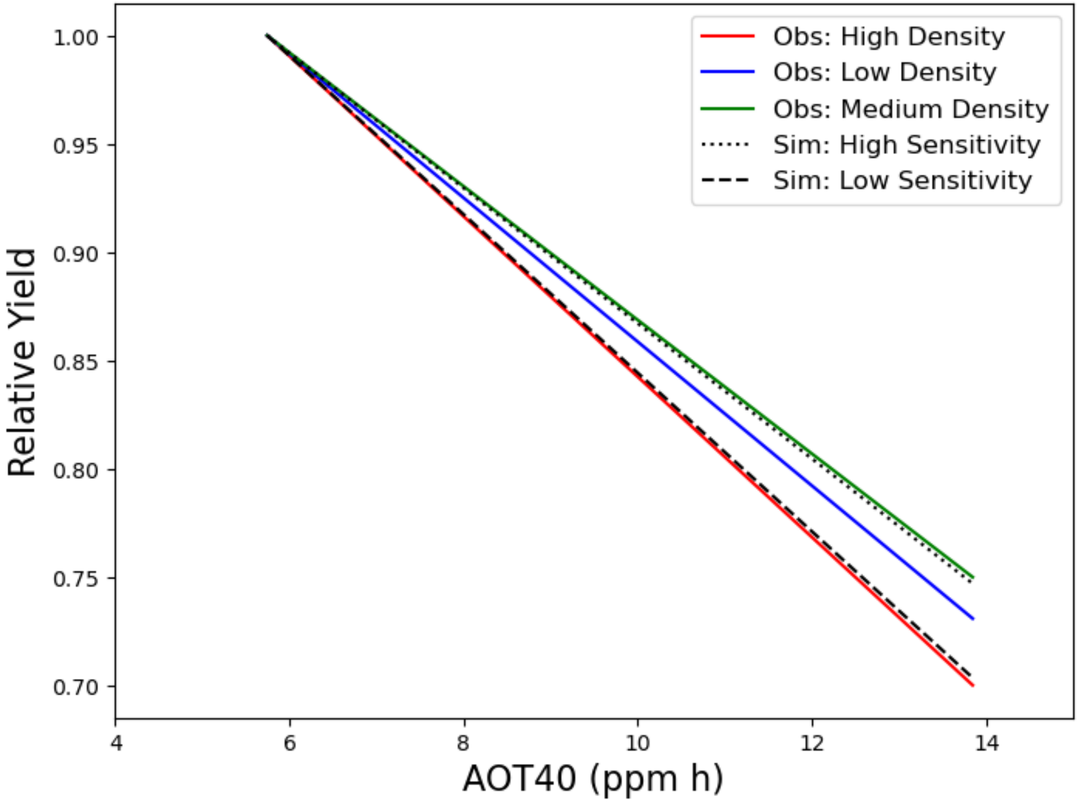
where $f_{c,leaf}$ represents the carbon fraction of dry matter in the stem, and κ and λ were determined by fitting the relationship between h and dry matter of stems which is equal to $\frac{C_{stem}}{f_{C,stem}}$.



Calibration of carbon fractions and O_3 paramerters



Ratio of carbon in dry weight of the leaf, stem, root, and panicle during different crop development phases where the average means the value collected from the literature which only provided an average value for all stages during the rice growth.



Summary

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- Rice is one of the most important cereal crops and is crucial for food security under the threat of increasing ozone.
- JULES-crop is a crop model using the flux-based ozone scheme and has not been calibrated for rice parameters.
- Rice parameters were tuned based on unique O_3-FACE experimental datasets which have not been applied to calibrate crop models.
- The simulations of rice using JULES-crop were significantly improved by tuning parameters relating to rice physiology, phenology, and yields.

Beiyao Xu, Steven Dobbie, Huiyi Yang, Lianxin Yang, Yu Jiang, Andrew Challinor, Yunxia Wang, Karina Williams, Tijian Wang. **Calibration of rice parameters in JULES 7.4 based on O_3-FACE experiment in China**. 2024 (To be submitted)