Ozone(O_3) risks to rice yields under warming climate using O_3-FACE observations

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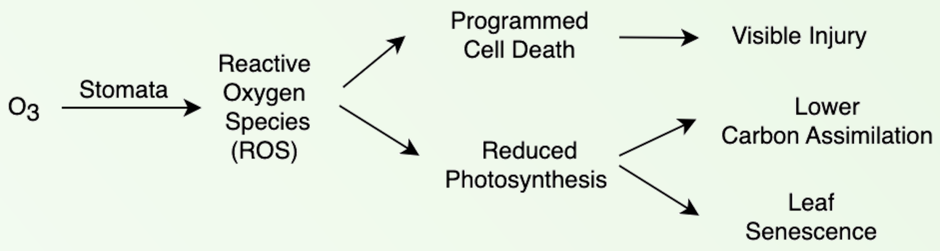
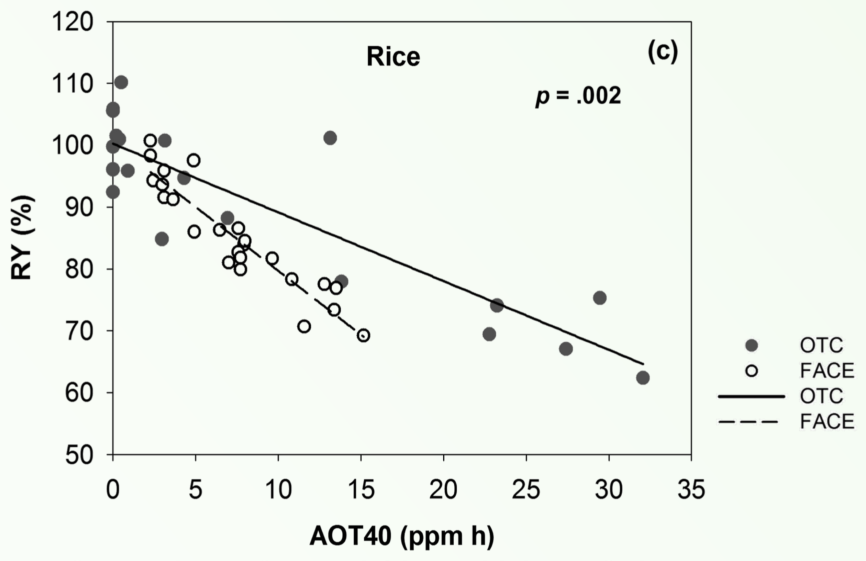
Introduction

Ozone (O_3) pollution is a growing threat to rice production and food security.



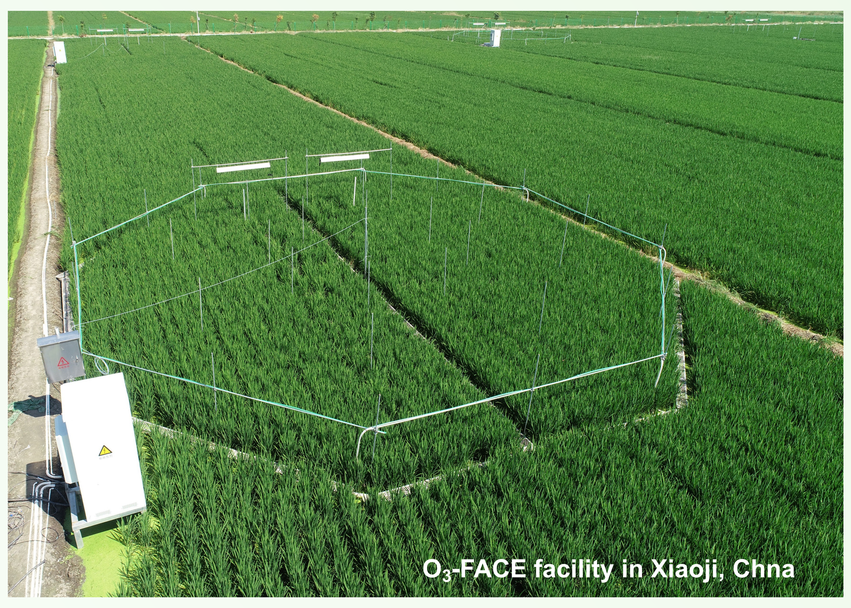
Tian et al., 2016

Open-top chambers (OTC) and free air concentration enrichment (FACE) experiments are two major methods to study O_3 effects on crops.



Comparison of crop yield sensitivity to O_3 between open-top chamber (OTC) and free-air (FACE) experiments.

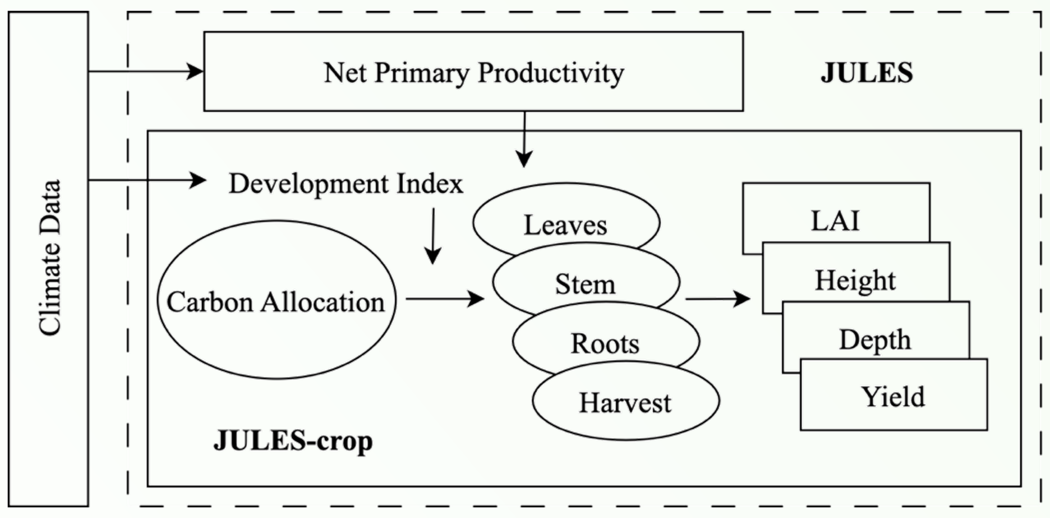
Feng et al., 2018



Several environmental variables are altered inside the OTCs: air turbulence, light intensity, air temperature, and humidity. State-of-the-art FACE experiments, which provide more natural environments for crops, are ideal for establishing O_3 exposure metrics and investigating the impacts of O_3 on crops

Method

JULES-crop is an extension of JULES, a land surface model designed to simulate the fluxes of carbon, water, energy, and momentum between the land surface and the atmosphere (Best et al., 2011; Clark et al., 2011). JULES uses a flux-gradient approach to model ozone damage, following Sitch et al. (2007).



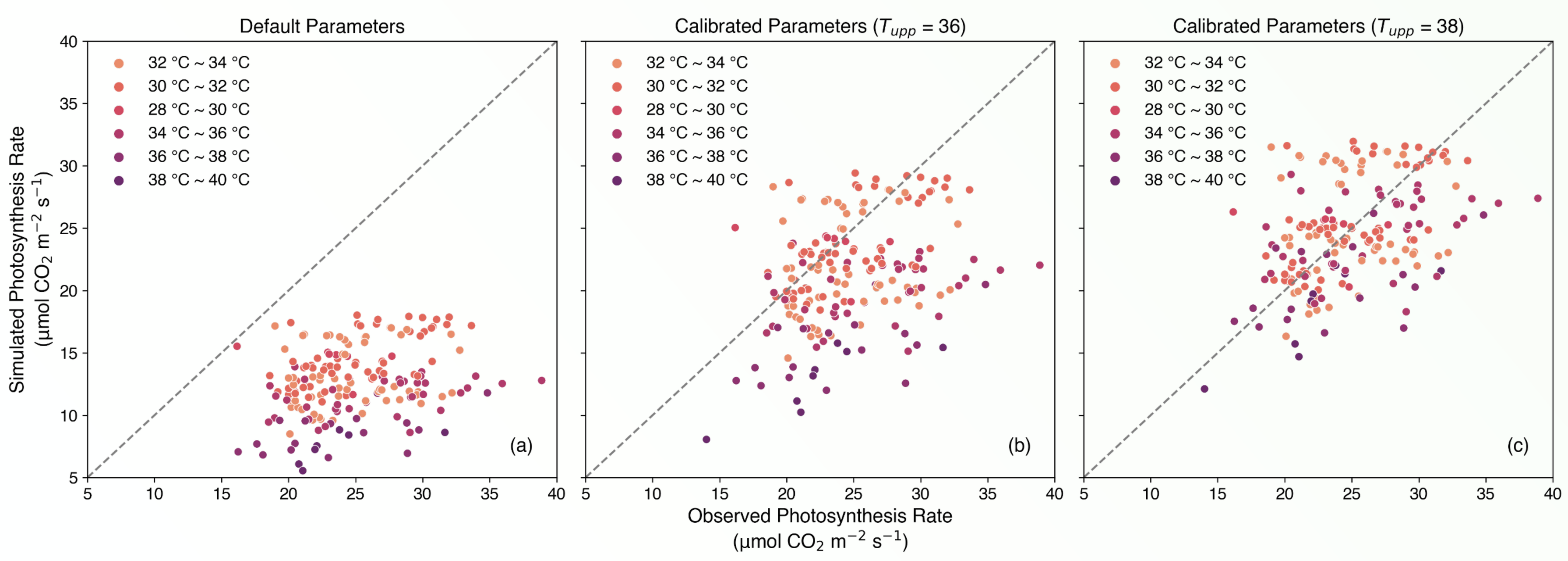
Schematic of JULES-crop

JULES-crop was developed to simulate the growth and development of major crops under a range of environmental influences such as temperature, precipitation, radiation, and soil moisture (Osborne et al., 2015).

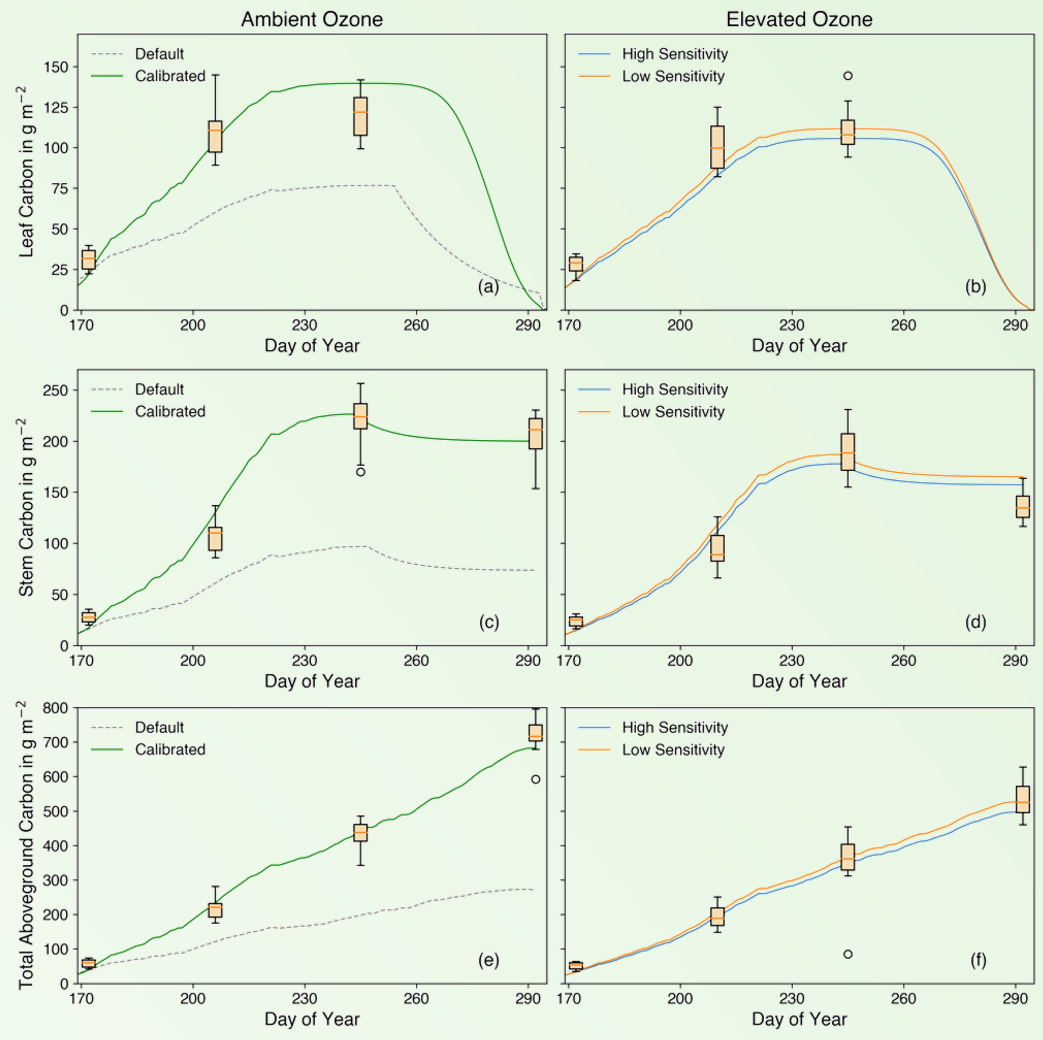
In this research, we calibrated the rice parameters in JULES-crop using novel O_3-FACE data, enabling leading-edge future assessments of O_3 damage to rice.

Calibration

The calibration process for rice follows four main steps: The first step involves calibrating leaf-level simulations by fitting simulated photosynthesis rates with observations.



Simulated photosynthesis rate ($\mu mol\ CO_2\ m^{-2}\ s^{-1}$) using parameters before (a) calibration and after calibration without (b) or with (c) changing the upper temperature limitation parameter (T_{upp}). The dashed line is the 1:1 line.



Leaf, stem, and total aboveground carbon against day of year under ambient and elevated ozone conditions.

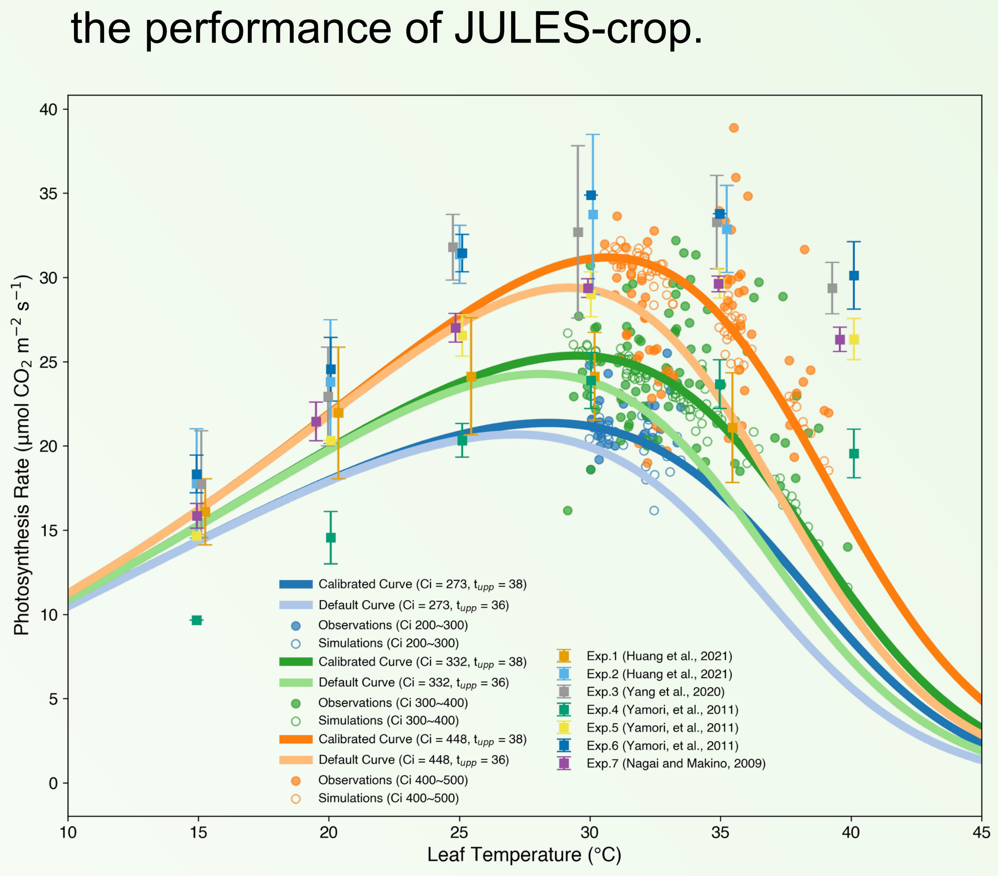
Secondly, the canopy-level simulations were calibrated by determining the rice growth rate and partitioning of assimilated carbon.

Third, model simulations were evaluated against observed LAI and crop height following the calibration of crop physiology parameters.

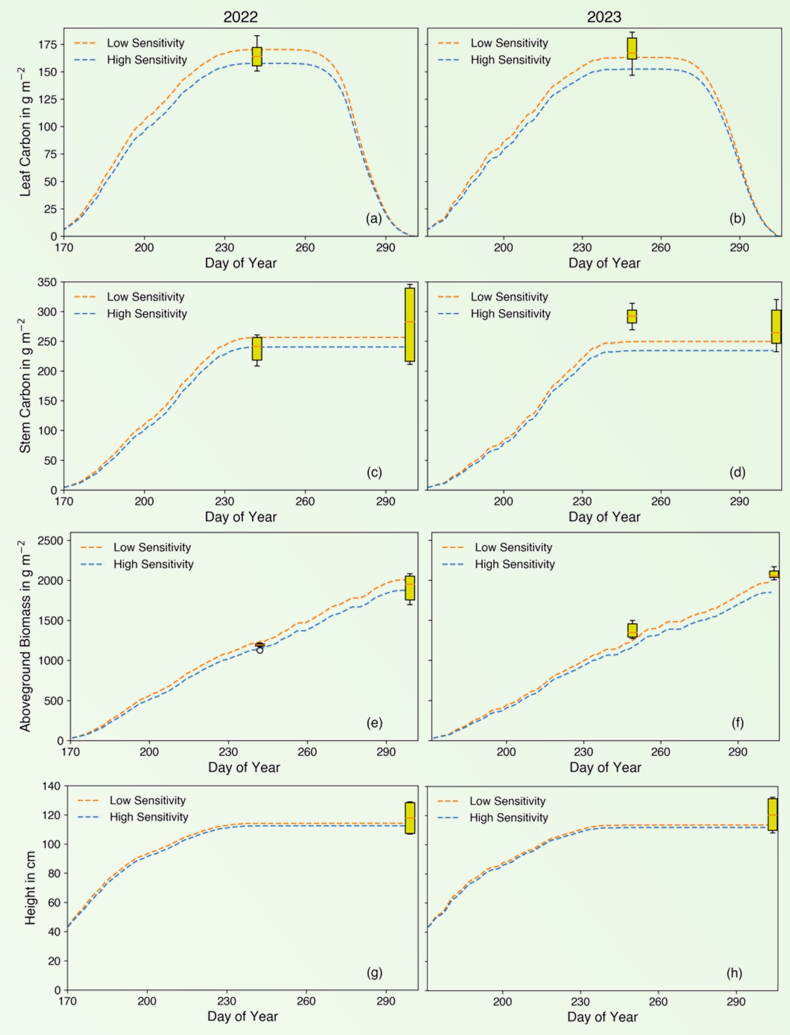
Lastly, rice yields were compared with observations under both ambient and elevated O_3 concentrations.

Evaluation

Following calibration, observations of rice yields, height, and the dry weight of leaves, stems, and panicles from an independent FACE experiment were then used to evaluate the performance of JULES-crop.



The coloured lines are simulated temperature responses of photosynthesis rate using the mean value of the observed intercellular CO_2 concentration of leaves (Ci) and calibrated (38 °C) or default (36 °C) T_{upp}.



Leaf, stem, total aboveground biomass, and crop height against day of year for 2022 and 2023.

Evaluation against independent field experiments demonstrated good agreement between simulated outcomes and observed results, affirming the model's robustness.

Summary & Ongoing Work

Summary

- This study is the first to utilise FACE observations specific to rice for calibrating JULES-crop and assessing the impacts of O_3.
- The calibration significantly enhanced model capability to simulate rice growth processes and O_3-induced yield losses, surpassing the performance of simulations based on the default parameters in JULES-crop.
- JULES-crop is now equipped to assess the impacts of O_3 on agriculture, offering a valuable tool to inform mitigation strategies.

Work Ongoing

- We investigate the response of rice under various shared socio-economic pathways (SSPs) as part of CMIP6.
- By assessing the effects of O_3 on rice under these future scenarios, we gain valuable insights into pathways that could mitigate damage to food security.

For more details

Xu, B., et al. A first calibration of the JULES-crop version 7.4 for rice using the novel O_3-FACE experiment in China, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-4077, 2025.

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Acknowledgement: Beiyao Xu gratefully acknowledges financial supports from the Dual Award - Nanjing University/University of Leeds Studentship. This work used JASMIN, the UK's collaborative data analysis environment (https://www.jasmin.ac.uk).