

Representing Ozone-Vegetation Interactions in GEOS-Chem: Implications for Air Quality and Ecosystems

Tai Group for Atmosphere-Biosphere Interactions



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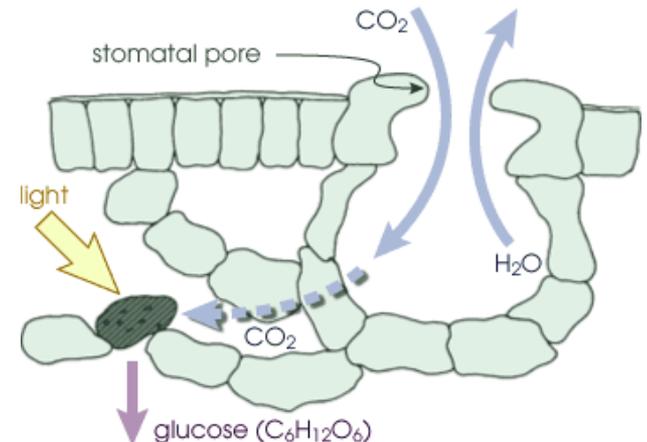
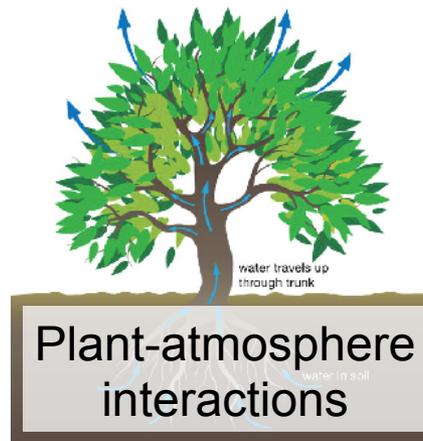
Earth System Science Programme

Chinese University of Hong Kong



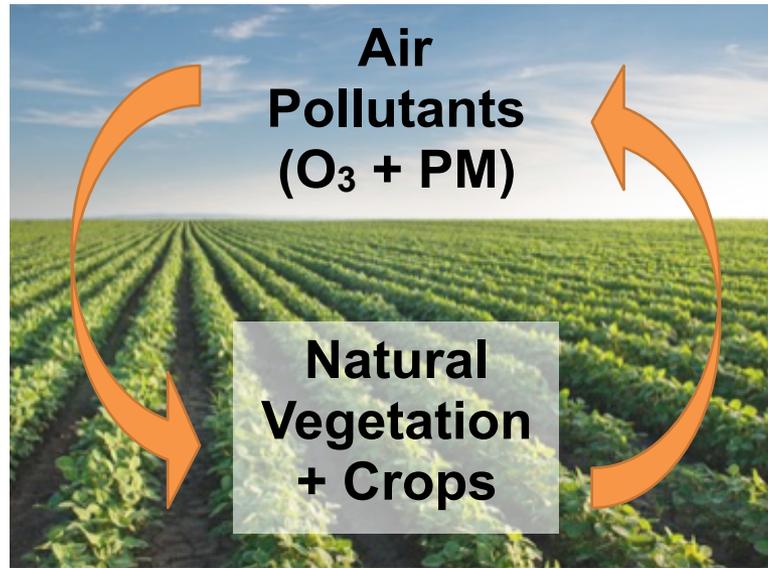
EARTH SYSTEM
SCIENCE PROGRAMME

7 May 2019 @ 9th International GEOS-Chem Meeting

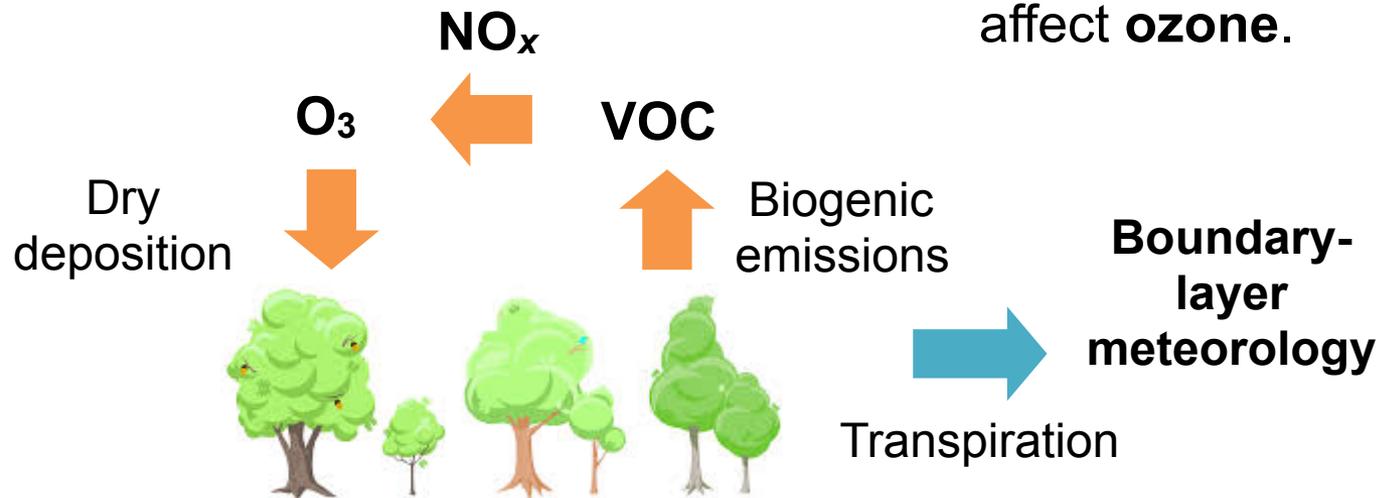


Ozone-Vegetation Interactions: Air Quality and Ecosystems

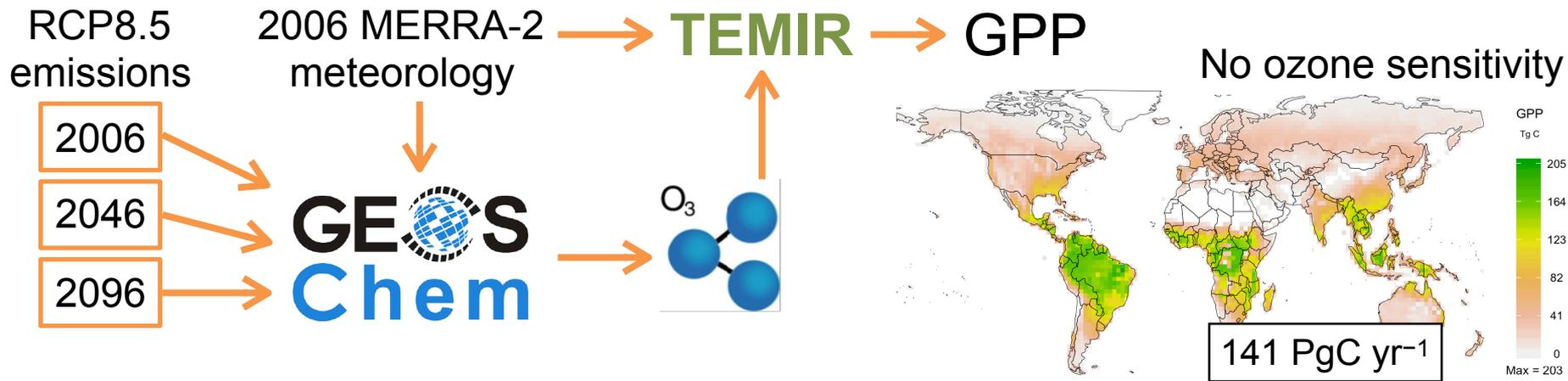
Ozone severely damages crops and vegetation, affecting **ecosystem productivity and services**



Via dry deposition, biogenic VOC emissions and transpiration, **plant ecophysiology, structure and distribution** strongly affect **ozone**.



Impacts of Future Ozone on Gross Primary Production



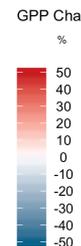
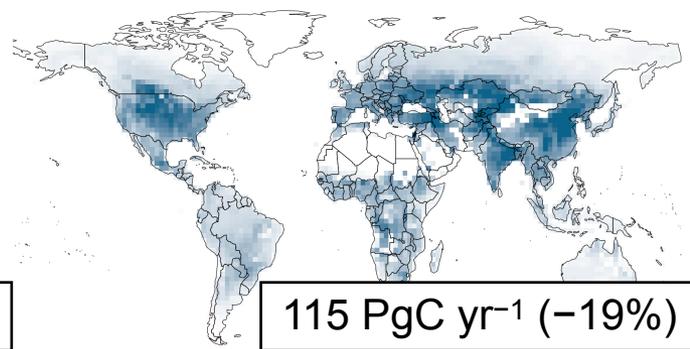
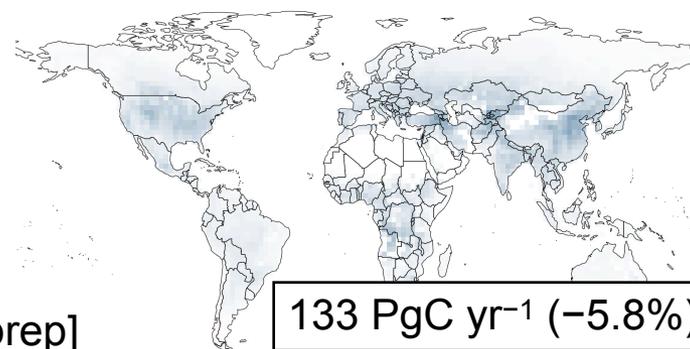
GPP and ΔGPP

Sitch - low sensitivity

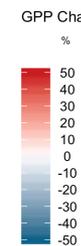
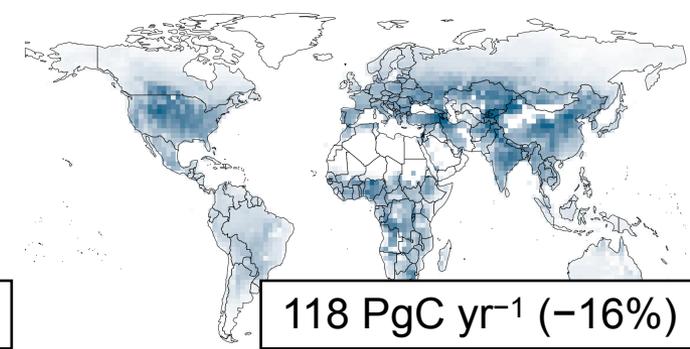
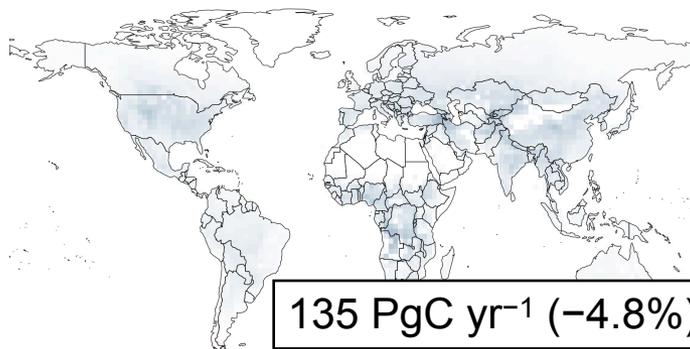
Sitch - high sensitivity

Year 2046

[Yung et al., in prep]



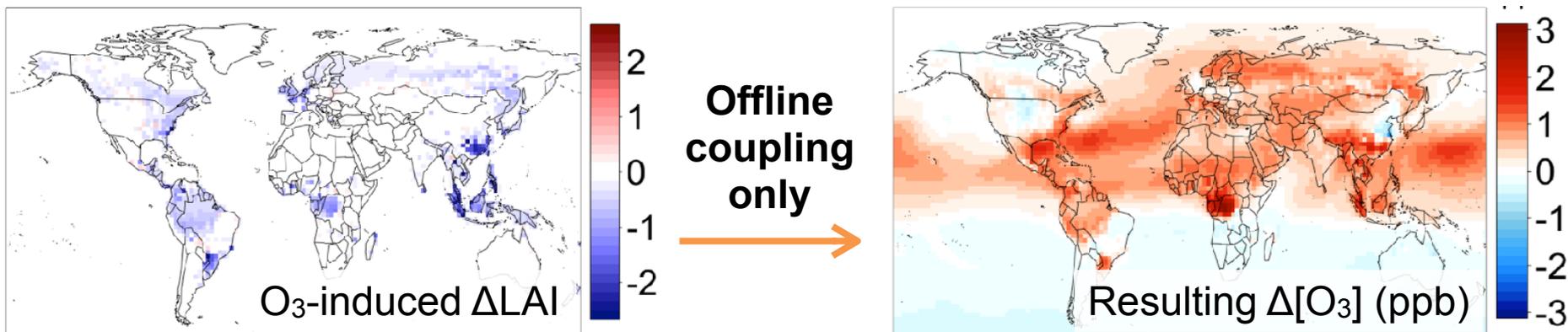
Year 2096



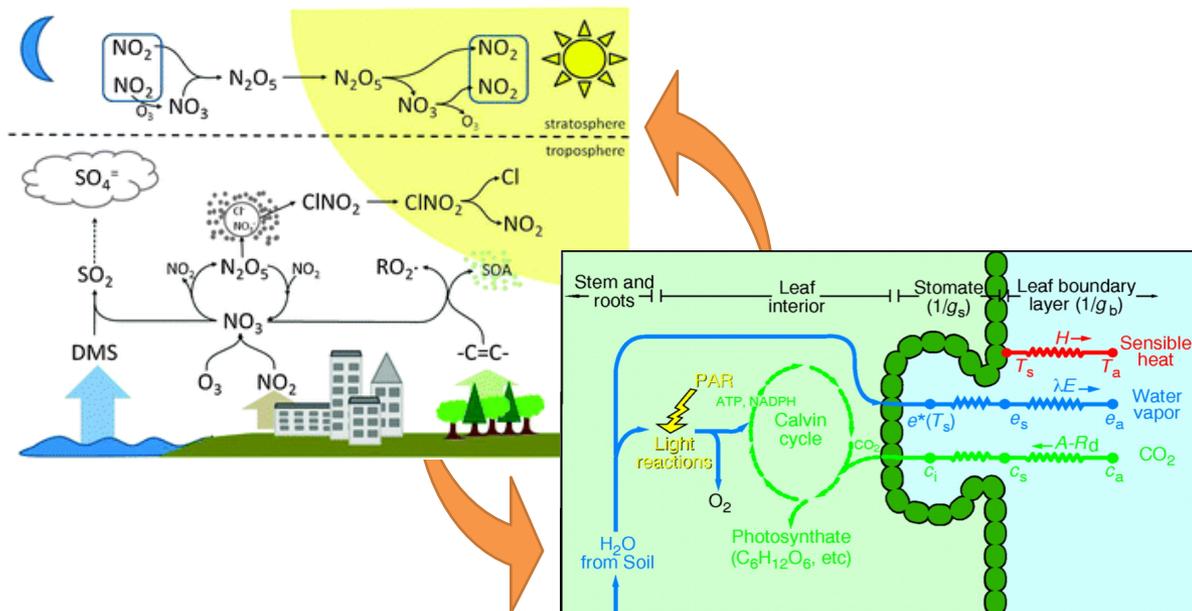
Motivations for Plant Ecophysiology in GEOS-Chem

- ▶ Ozone damage reduces LAI, which enhances ozone via positive feedbacks (mostly via reduced dry deposition)

[Zhou et al., *Atmos. Chem. Phys.*, 2018]



- ▶ Proposal: Synchronous **“online” coupling between ozone and plants** in GEOS-Chem to simultaneously obtain “better” ozone air quality and ecosystem damage



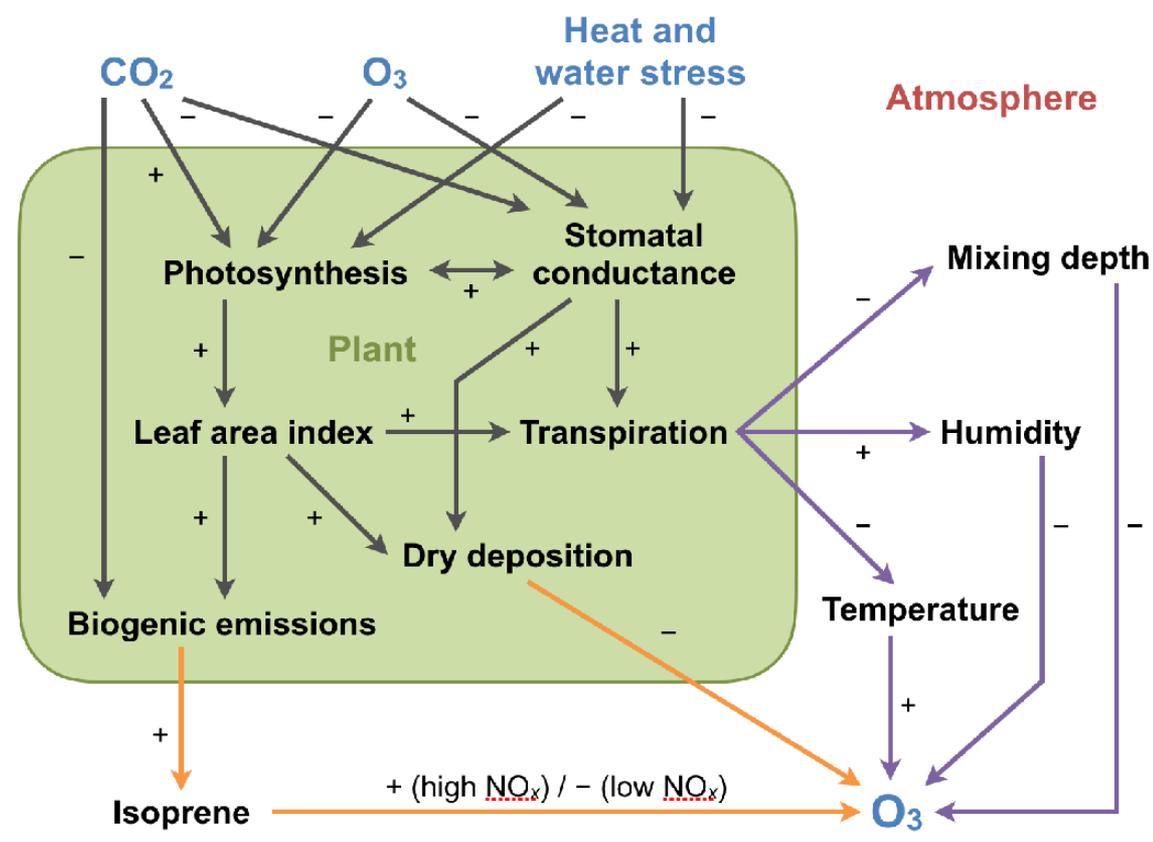
Motivations for Plant Ecophysiology in GEOS-Chem

- ▶ **Plant ecophysiological responses to environmental and climatic stress** can substantially modify atmospheric chemistry.

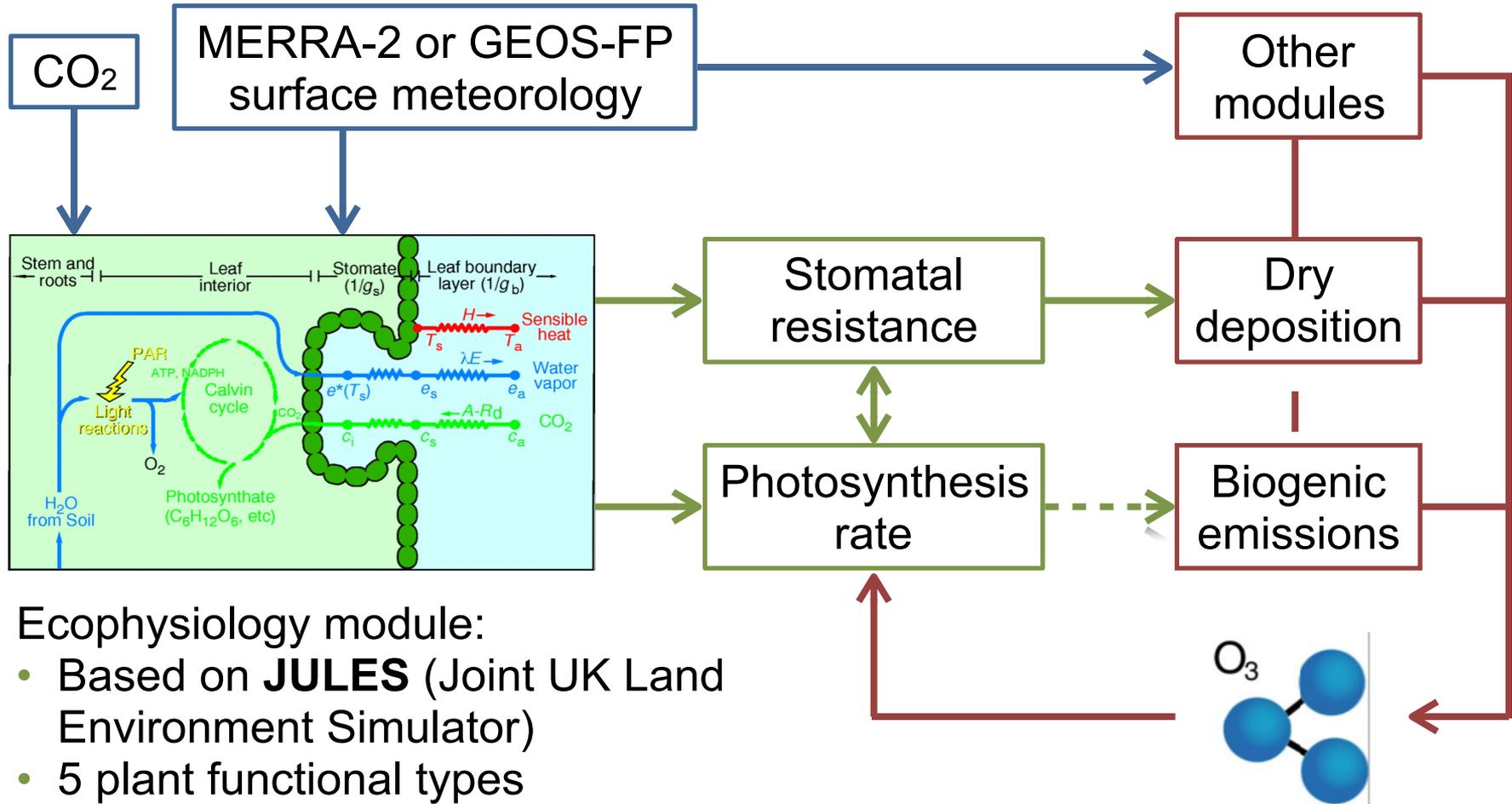
- ▶ Current Wesely [1989] stomatal resistance scheme may capture monthly averages, but fails in:

- Diurnal cycle
- Responses to water stress (via VPD, soil moisture)
- Day-to-day ozone-meteorology covariation

- ▶ Why not fully coupled weather/climate models with chemistry (WRF-Chem, CESM, etc.)? Poor hydrometeorology, non-reality...



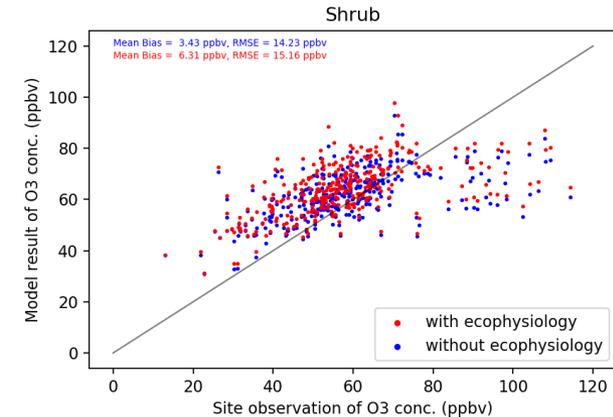
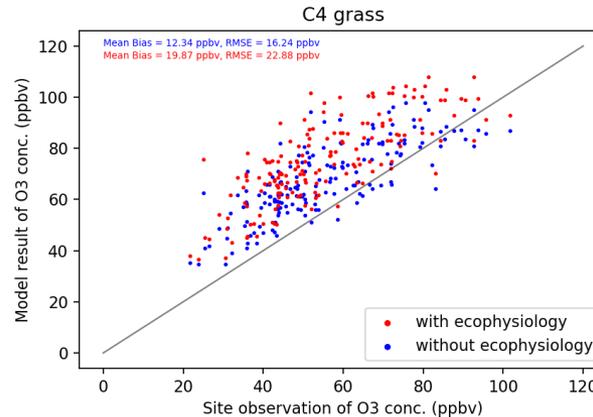
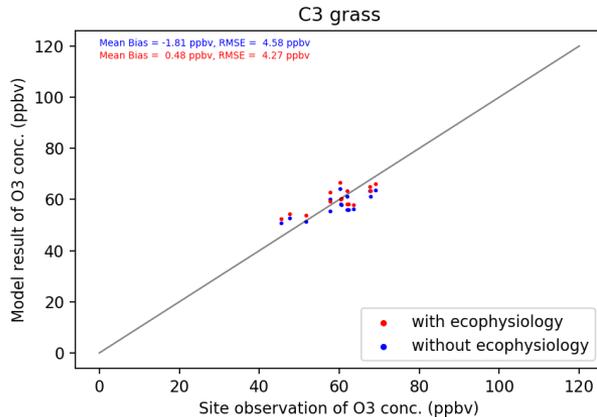
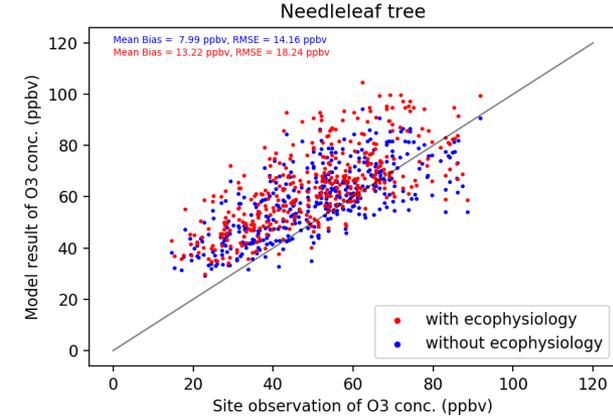
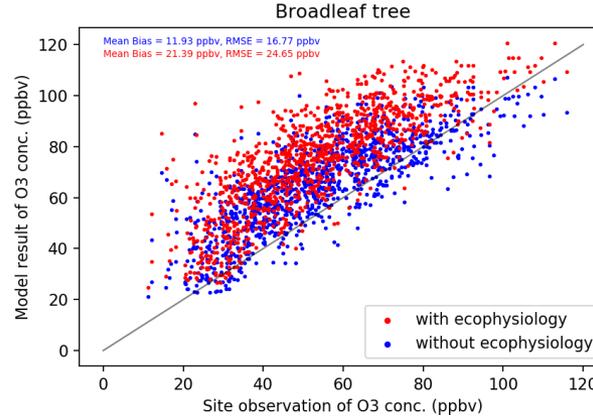
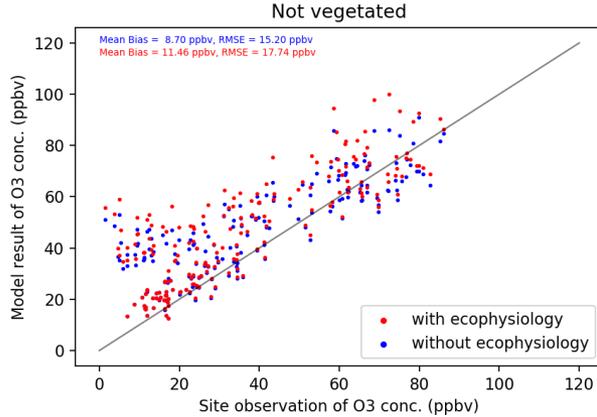
Plant Ecophysiology Module in GEOS-Chem



Ecophysiology module:

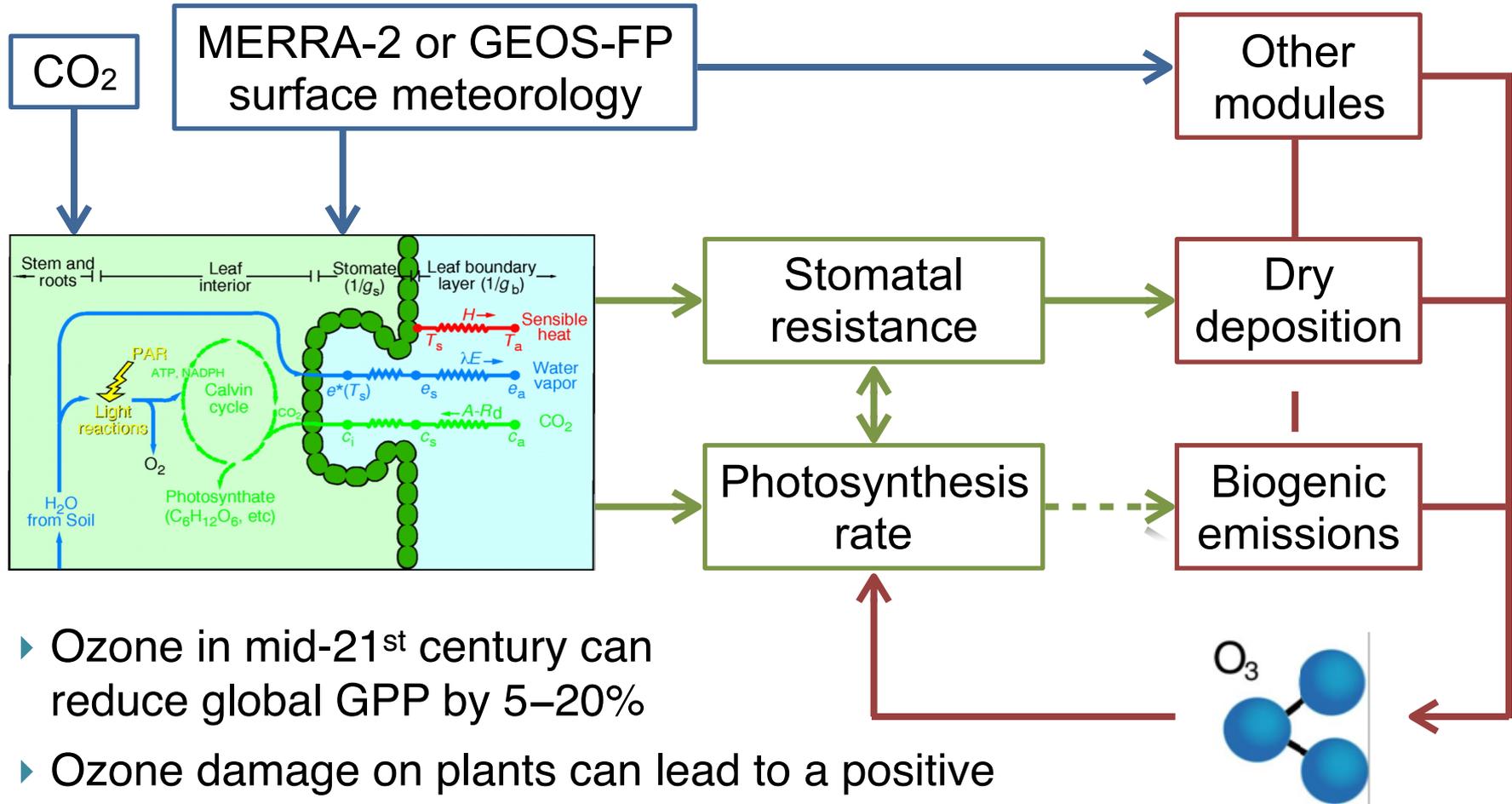
- Based on **JULES** (Joint UK Land Environment Simulator)
- 5 plant functional types
- *Farquhar* photosynthesis
- *Jacobs* stomatal conductance
- Soil water stress function linear to soil moisture

Plant Ecophysiology Module in GEOS-Chem



- ▶ With ecophysiology, stomatal resistance and thus ozone are higher, resulting in a worsening of overestimation.
- ▶ More evaluation and revision are in progress.
- ▶ Photosynthesis-based isoprene emission is under development.

Conclusions and Discussion



- ▶ Ozone in mid-21st century can reduce global GPP by 5–20%
- ▶ Ozone damage on plants can lead to a positive feedback that worsens ozone.
- ▶ Ecophysiology module can potentially improve the representation of ozone dependence on plants and meteorology, especially under changing climate, CO₂ and more frequent climatic extremes.