EESM PI MEETING 2024

Large Revision of Global Net Photosynthesis with Learning Acclimation from a Multi Source Dataset

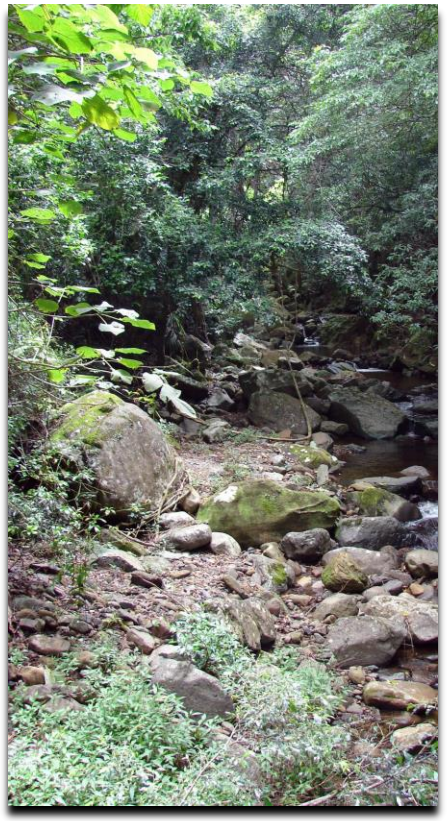
Doaa Aboelyazeed

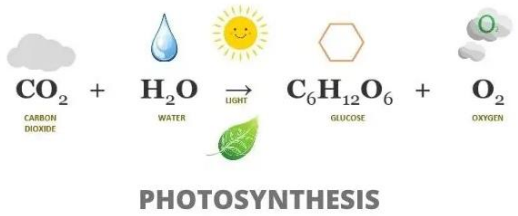
PhD student in Civil and Environmental Engineering
Penn State University

Chaopeng Shen, Chonggang Xu, Forrest M. Hoffman, Lianhong Gu, Jiangtao Liu, Kathryn Lawson

PennState

U.S. DEPARTMENT OF ENERGY
Office of Science

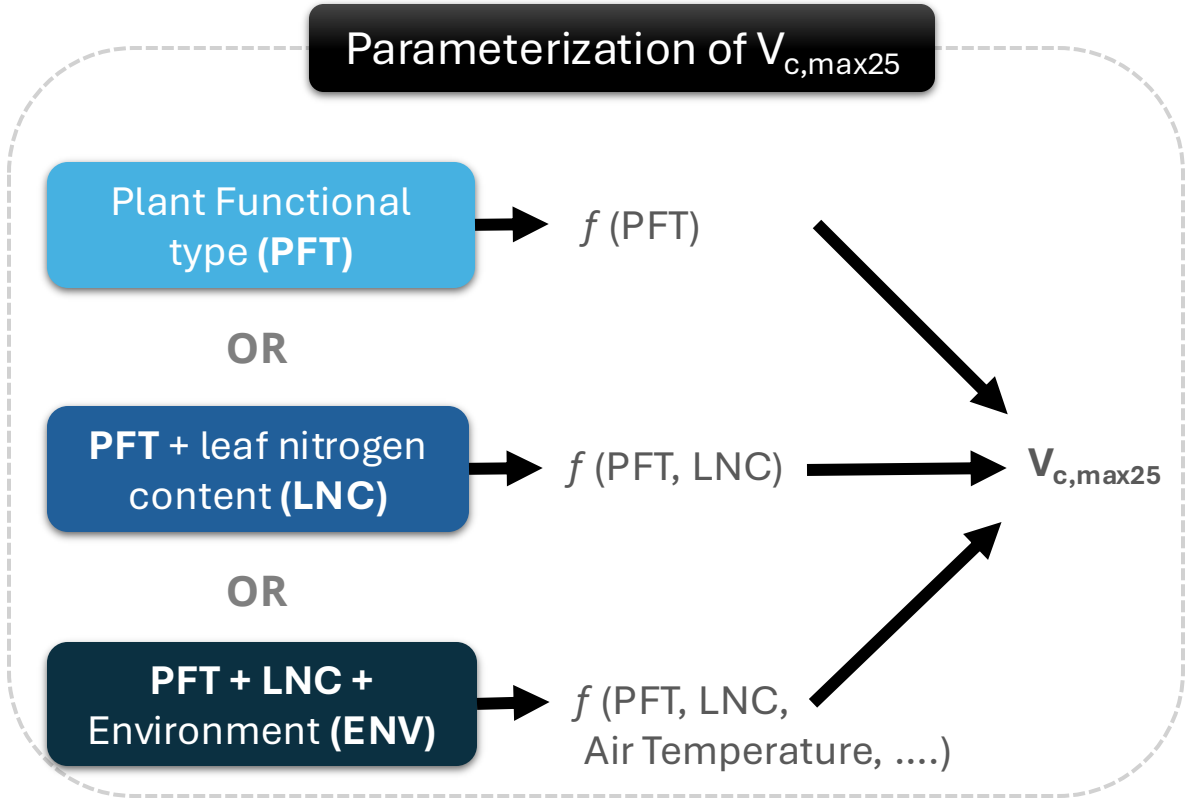


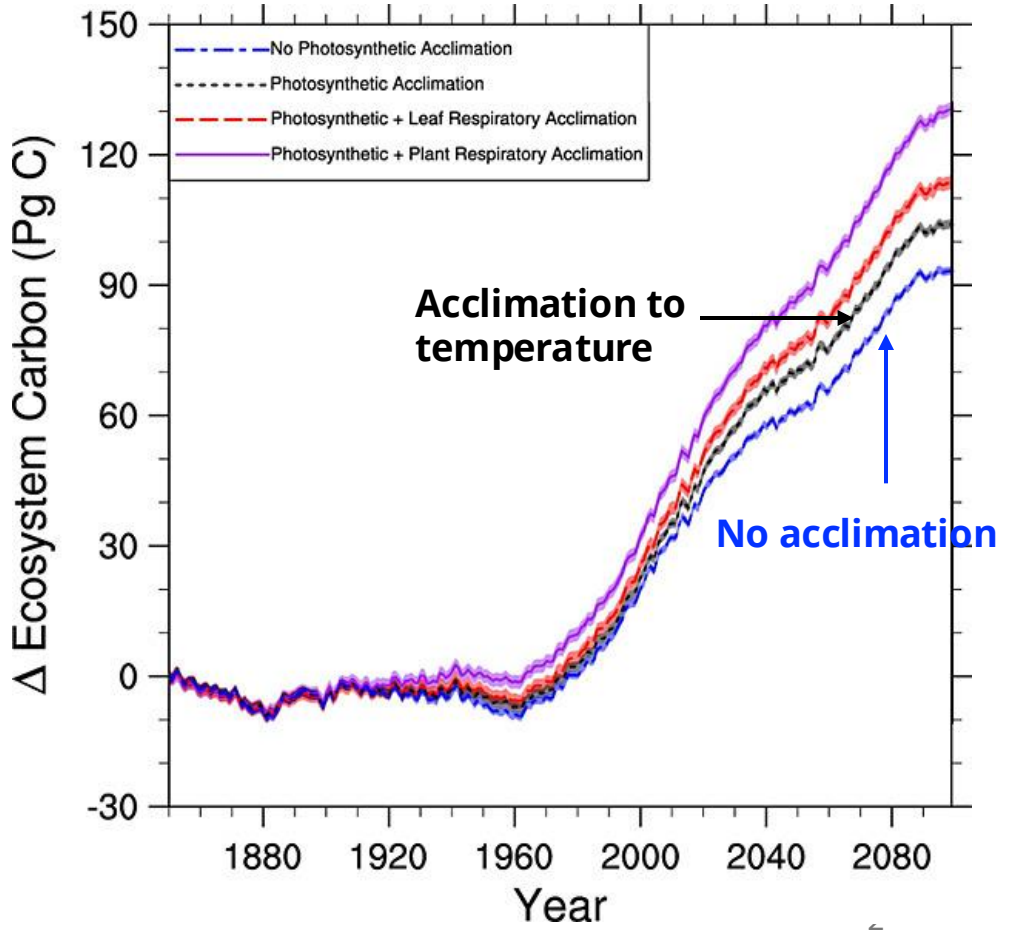


Background: Photosynthesis simulations in Earth System Models (ESMs)

EESM PI MEETING 2024

- **Static or empirically derived parameters**



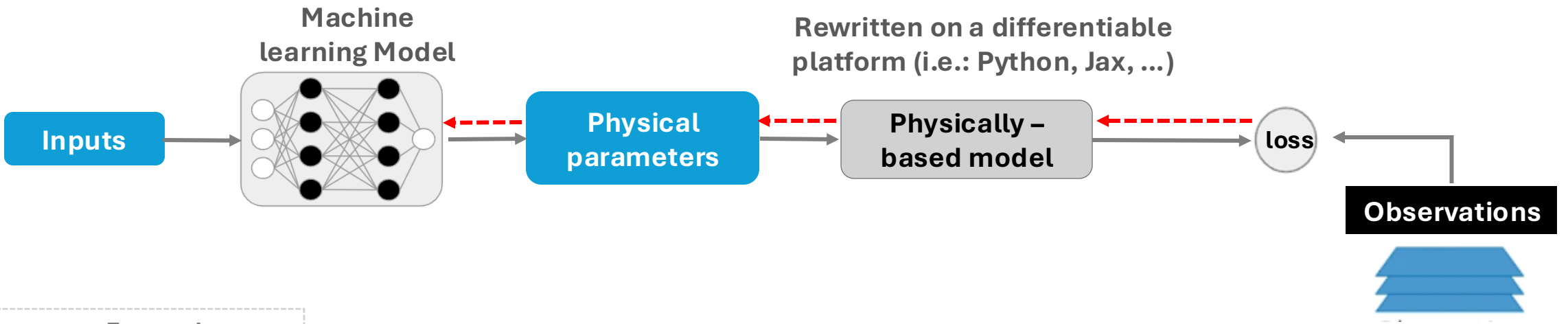


Lombardozzi et al. 2015

Research questions & Methodology

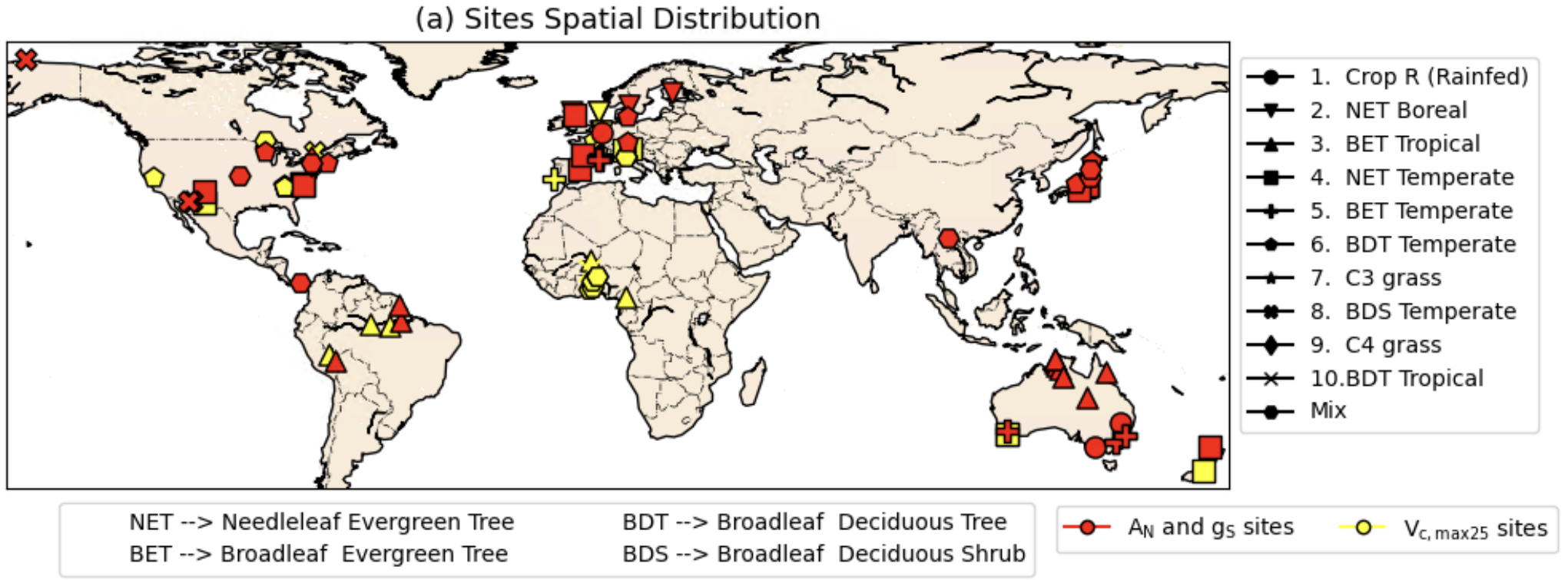
Impact of calibrating different photosynthetic parameters using various acclimation approaches while learning from a multi-source dataset

A differentiable parameter learning framework



*FATES: Functionally Assembled Terrestrial Ecosystem Simulator

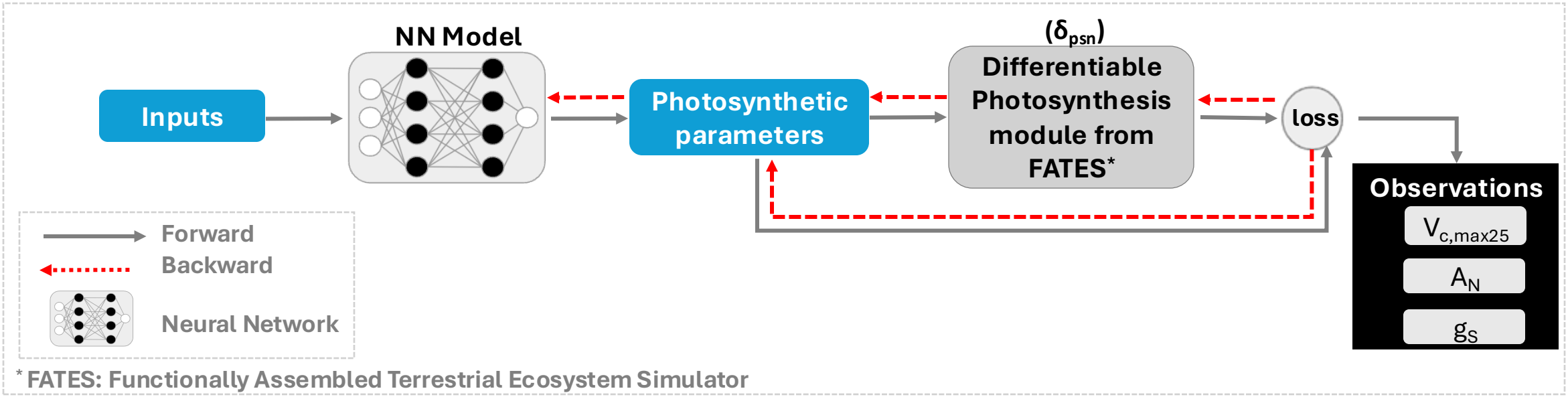
Methodology: Datasets



Leaf gas exchange databases and Literature

- Net Photosynthesis **(A_N)**
- Stomatal Conductance **(g_S)**
- Maximum carboxylation rate at 25 °C **($V_{c,max25}$)**

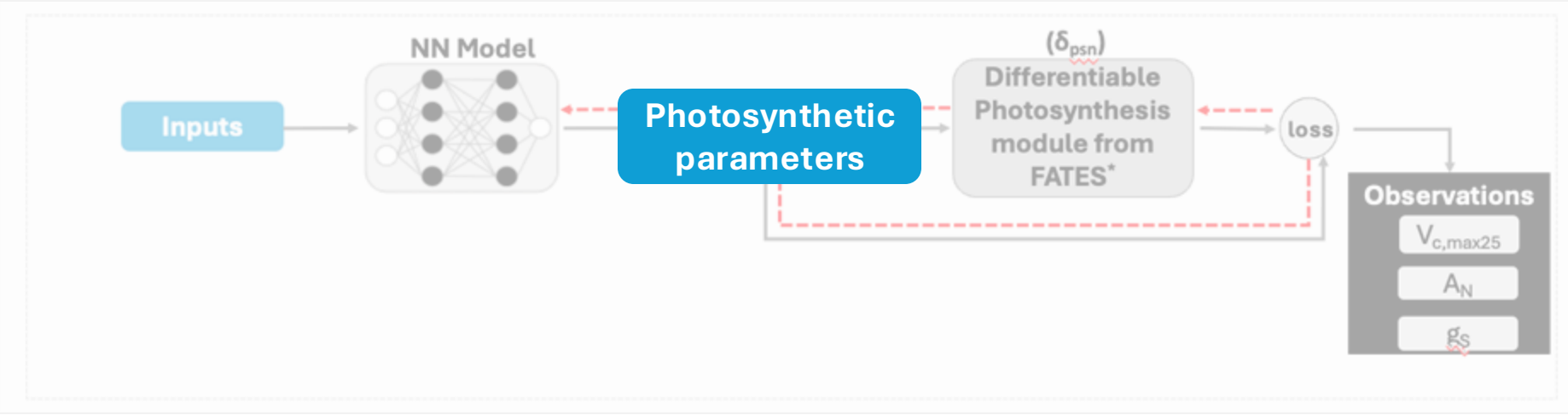
Methodology: Experiments



Inputs

- **Case I: PFT** (Plant functional type)
- **Case II: PFT +LNC** (Leaf nitrogen content)
- **Case III: PFT +LNC + ENV** (Environment)

Methodology: Experiments



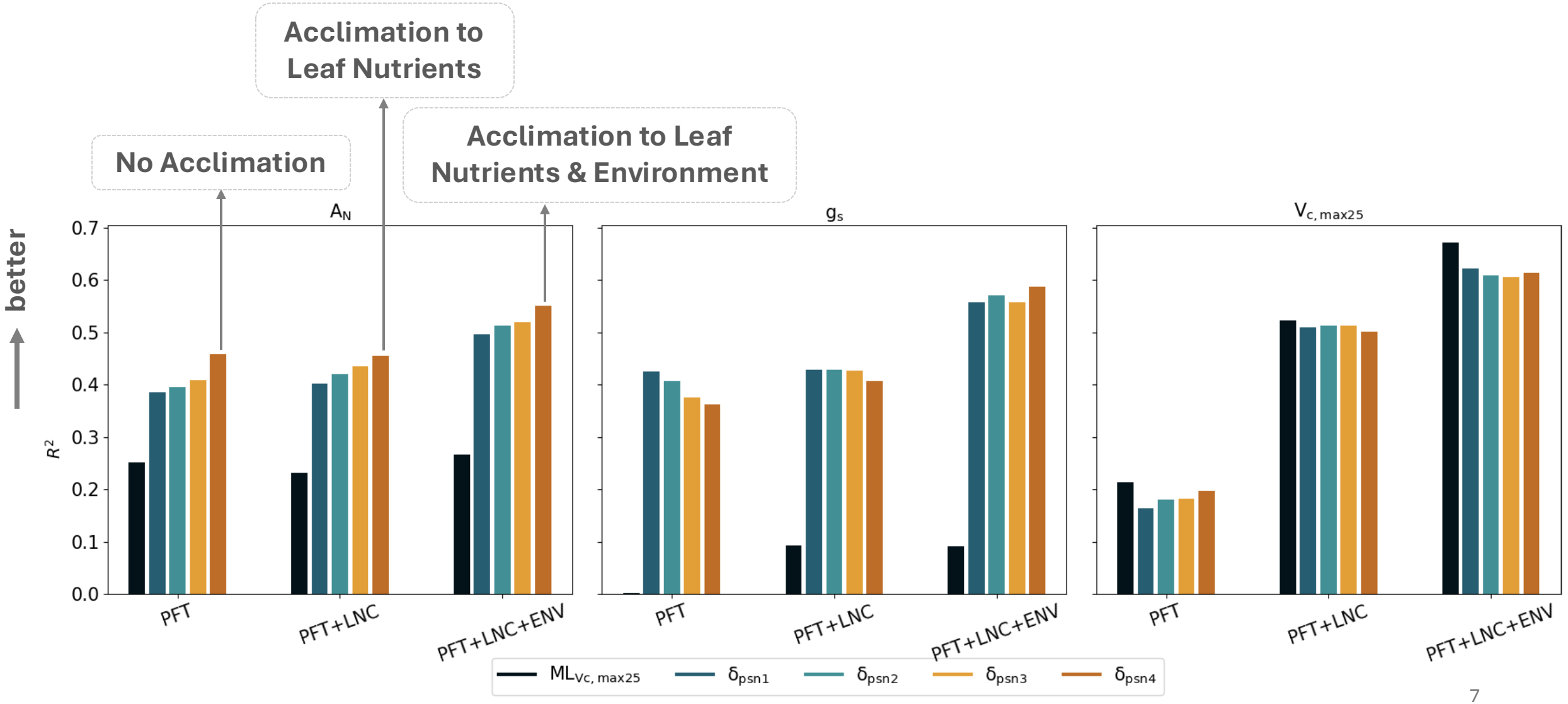
Parameters

- Photosynthetic capacity: ($V_{c,max25}$)
- Stomatal conductance parameters (Slope: g_1 & intercept: g_0)
- Temperature response function parameters (activation energy H_a)

8 Differentiable models (δ_{psn})

δ_{psn1}	$V_{c,max25}$		
δ_{psn2}	$V_{c,max25} + g_0$	$V_{c,max25} + g_1$	$V_{c,max25} + H_a$
δ_{psn3}	$V_{c,max25} + g_0 + g_1$	$V_{c,max25} + g_0 + H_a$	$V_{c,max25} + g_1 + H_a$
δ_{psn4}	$V_{c,max25} + g_0 + g_1 + H_a$		

Results: Spatial Test Performance



Results: Global Net Photosynthesis

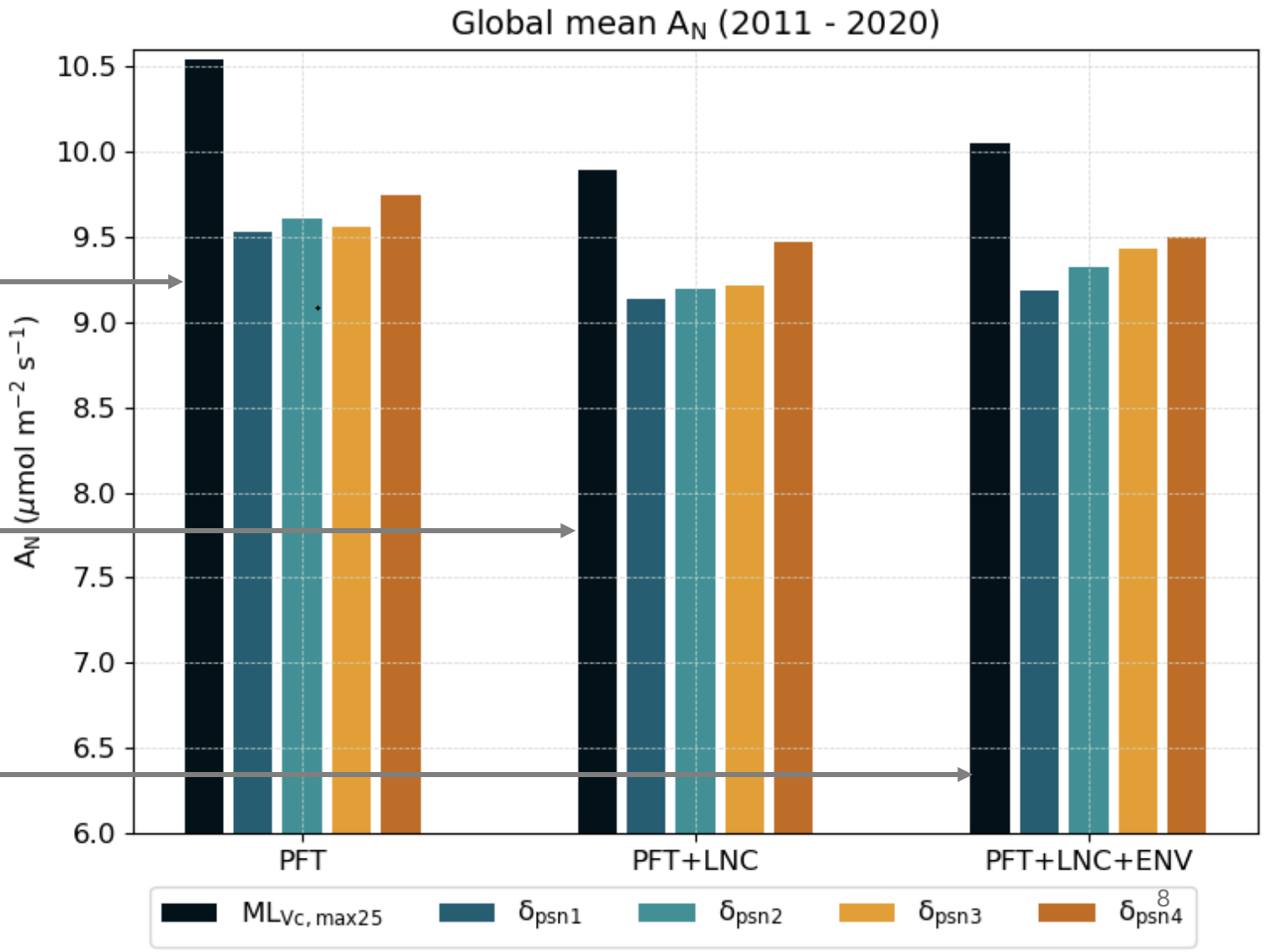
EESM PI MEETING 2024

- Top canopy leaf-layer global A_N

No Acclimation

Acclimation to Leaf Nutrients

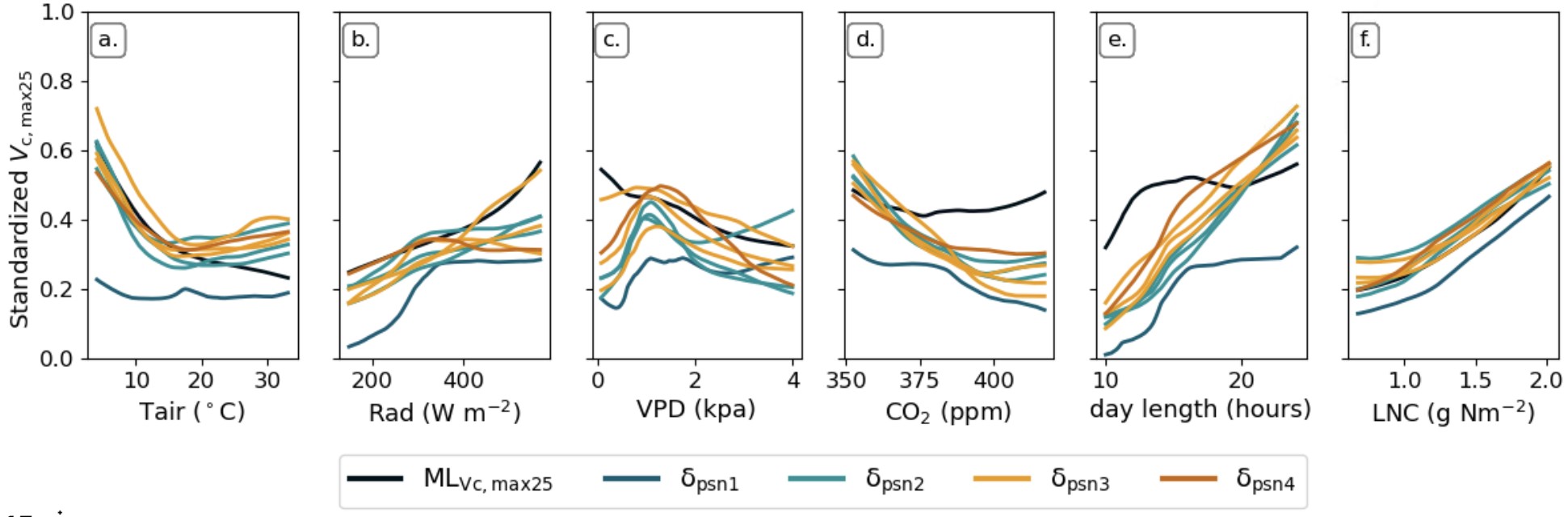
Acclimation to Leaf Nutrients & Environment



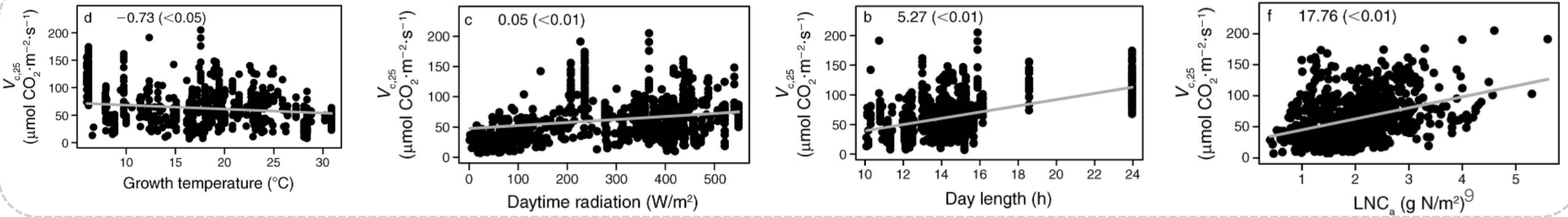
Results: Learning Physics

EESM PI MEETING 2024

Relationships learnt by neural networks in δ models



Ali et al. 2015



Conclusion

- Learning the environment dependencies of some photosynthetic parameters from a multi-source dataset can greatly improve model generalizability
- Acclimation to the environment can potentially revise photosynthesis estimates
- Remarkable adaptability of the differentiable programming paradigm to address various challenges in ecosystem modeling