A Systems Approach to Understanding How Plants Transformed Earth's Environment in Deep Time

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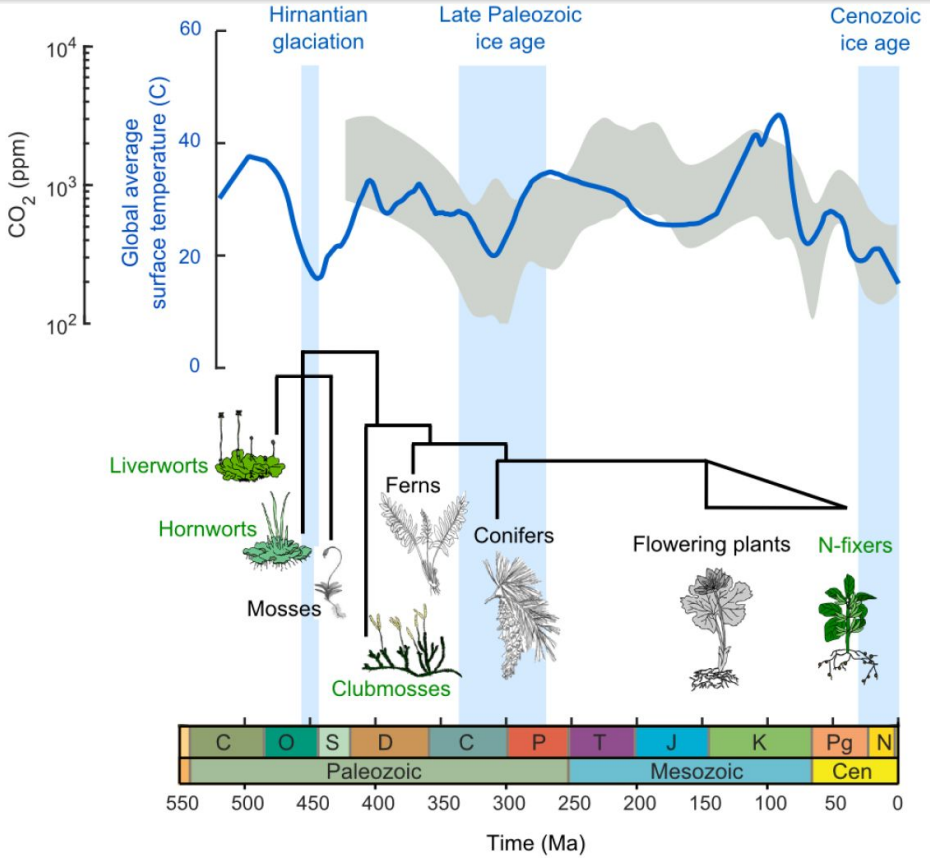
JUNE 14, 2023

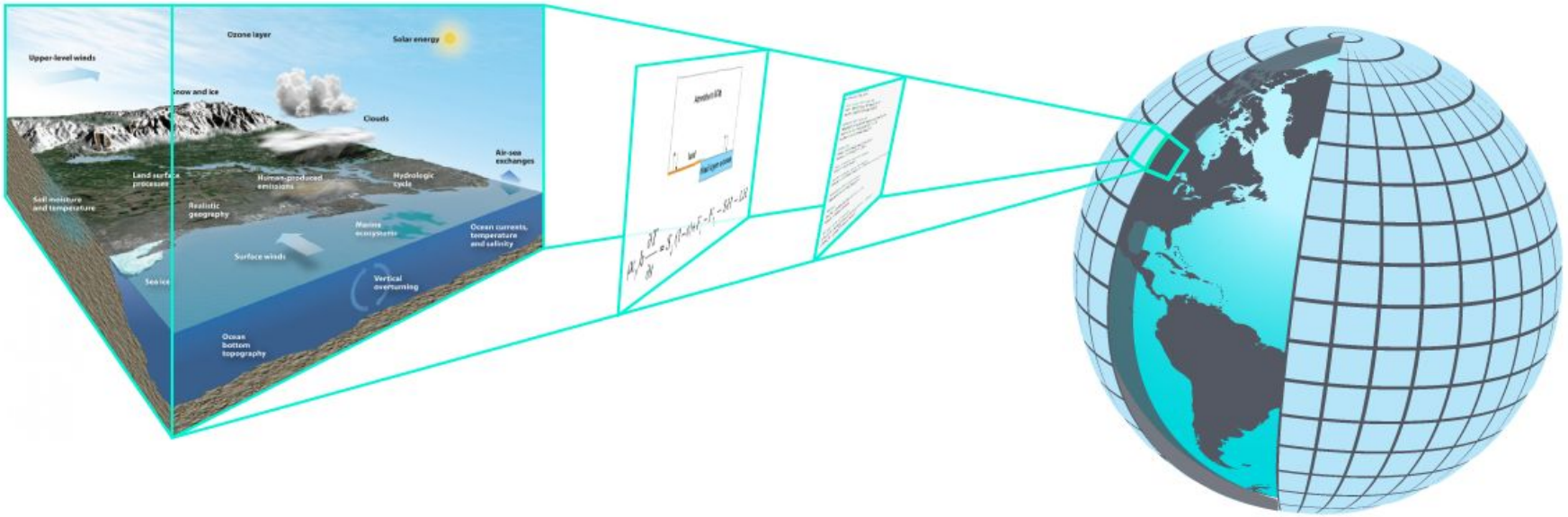
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Linkages between climate change and plant evolution are unclear



Source: Benjamin Mills

Best tool to study the role of plants in the coupled Earth system



Source: Climate Research Division, Environment and Climate Change Canada.

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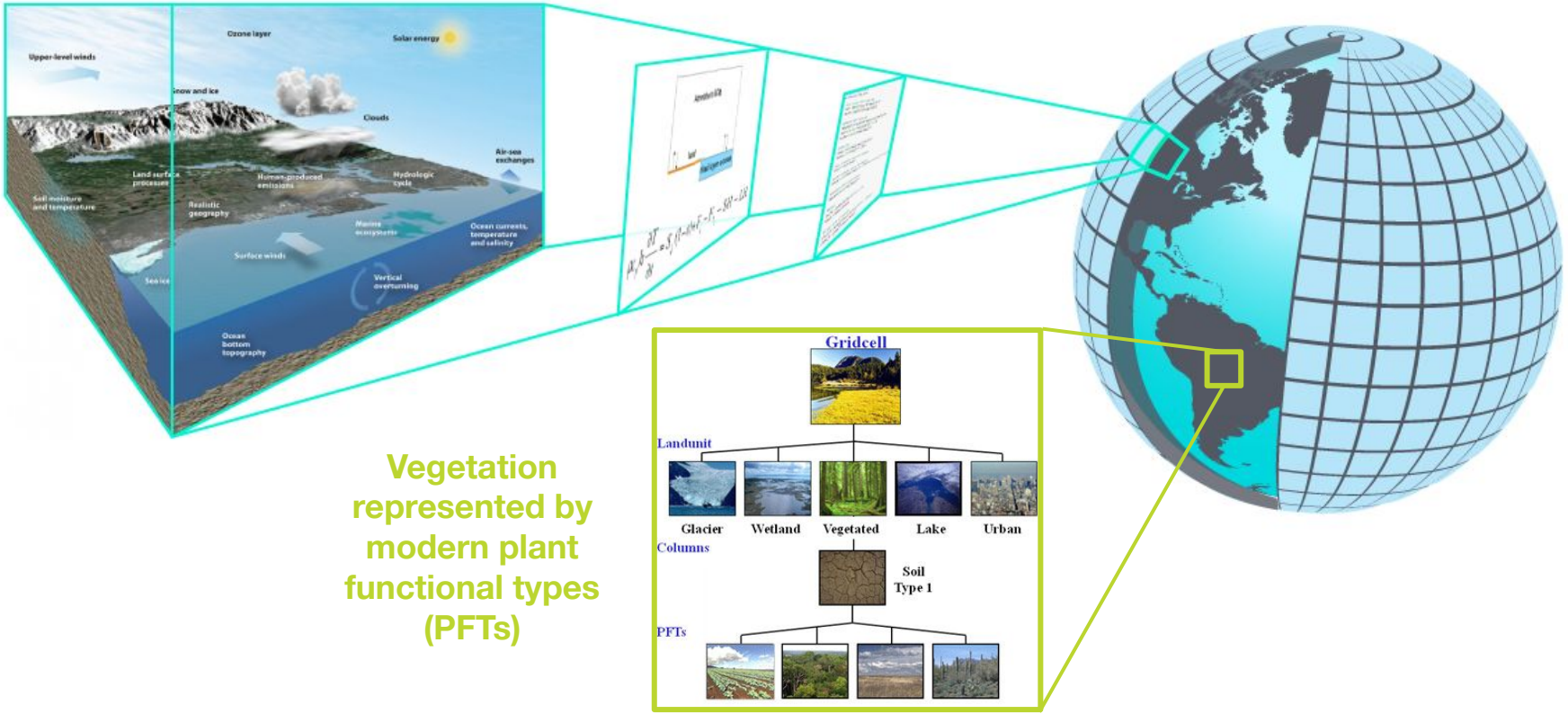
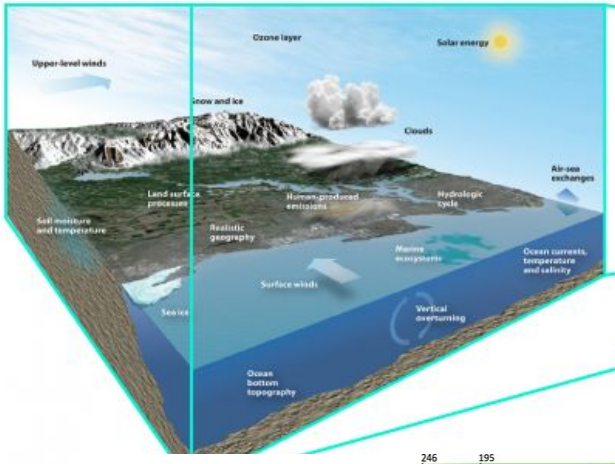
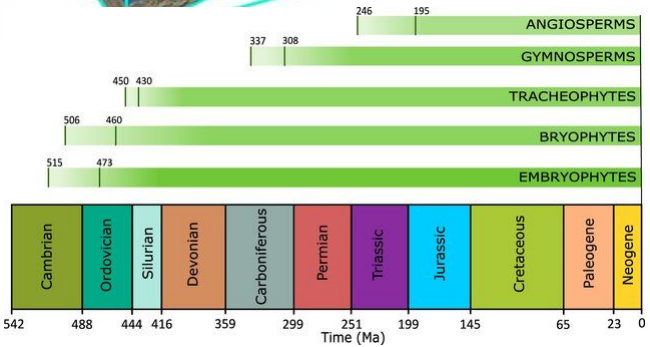
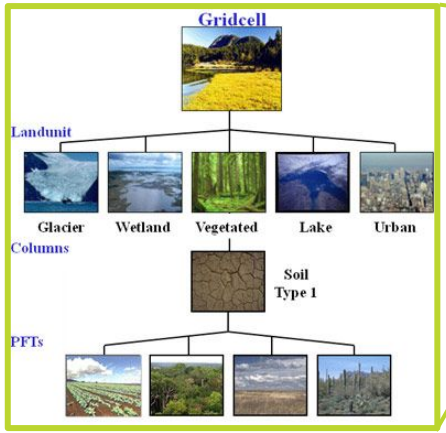


Vegetation represented by modern plant functional types (PFTs)

Best tool to study the role of plants in the coupled Earth system



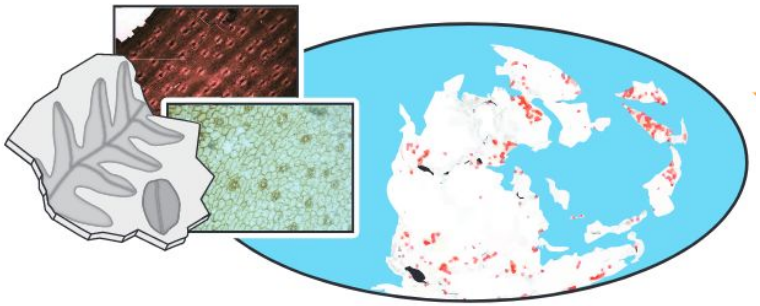




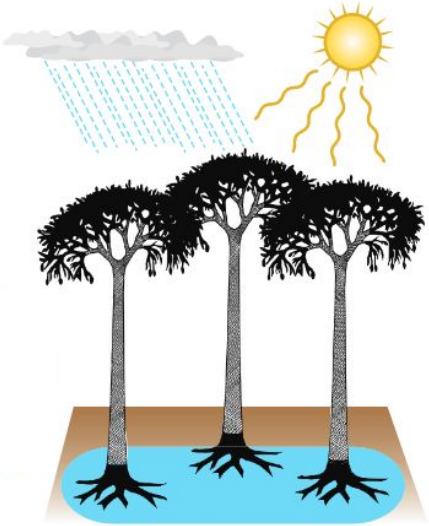
Source timeline: Gurung et al. (2022), Nature Comm.

Reconstructing time-appropriate vegetation-climate interactions

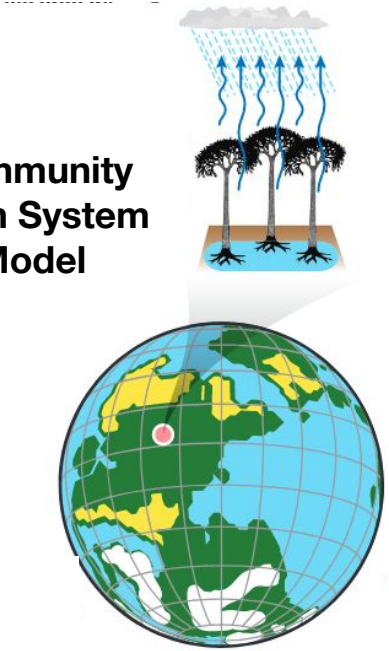
Fossil record



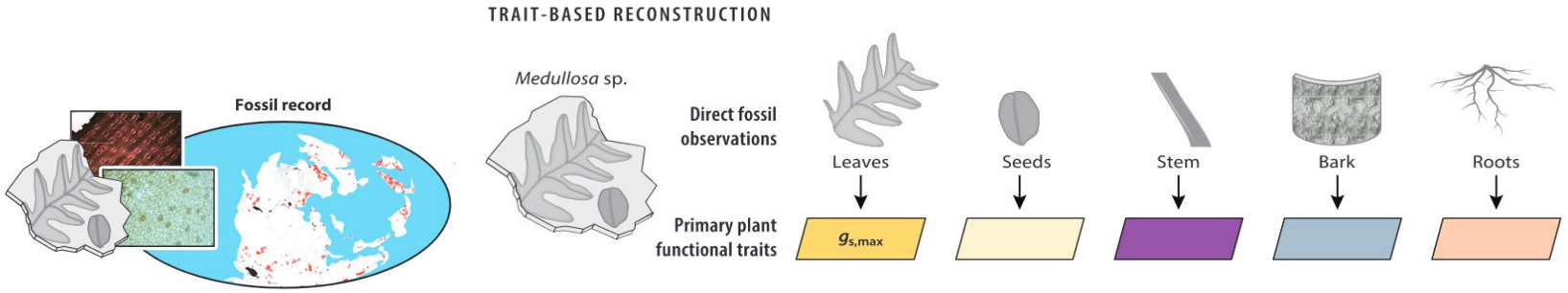
Ecosystem process model *Paleo*-BGC

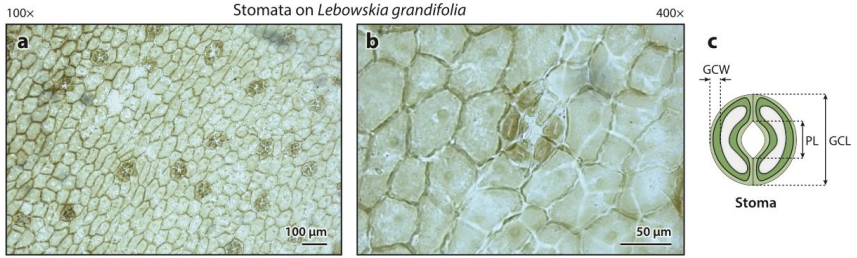


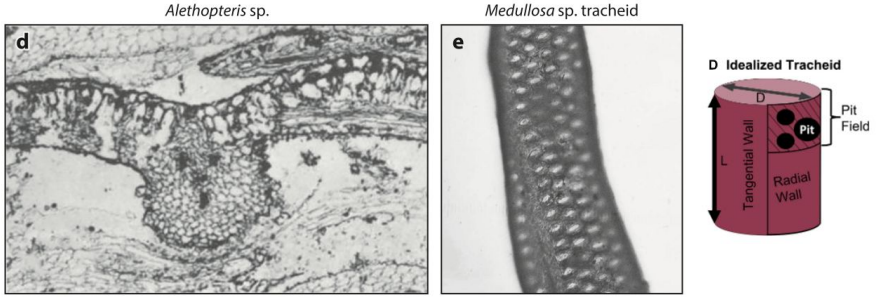
Community Earth System Model



Trait-Based Whole Plant Functional Strategy







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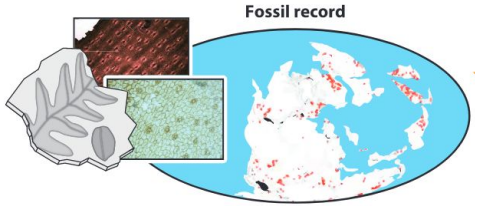

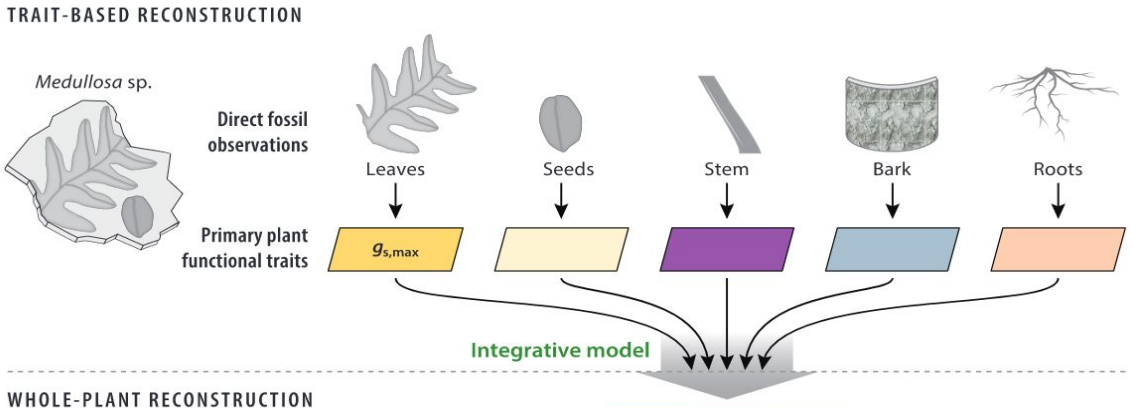

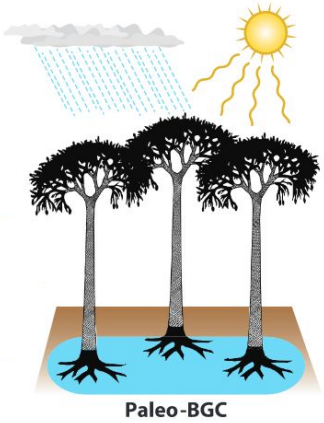

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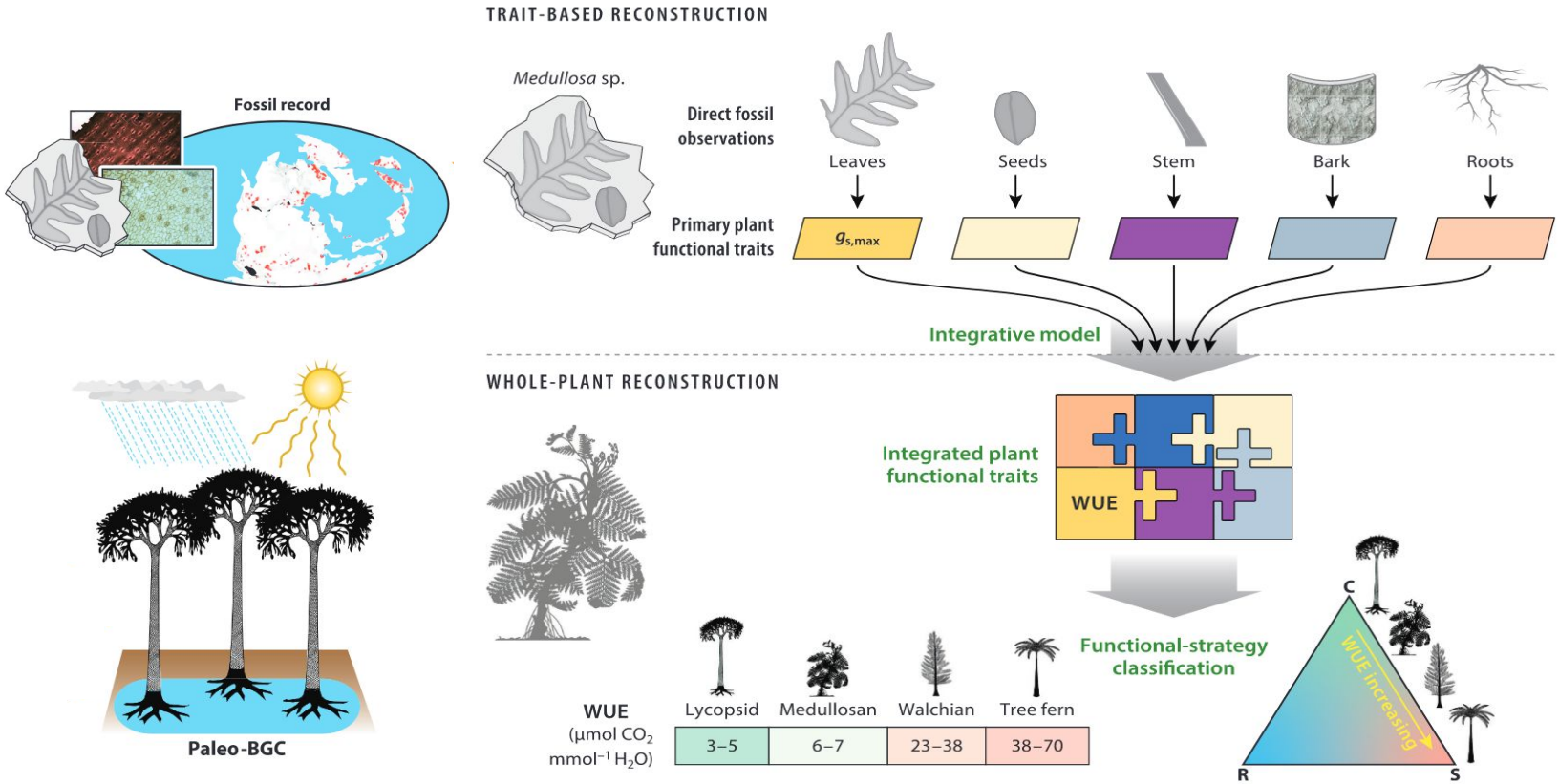

Case Study: The First Tropical Forests ~300 Mya

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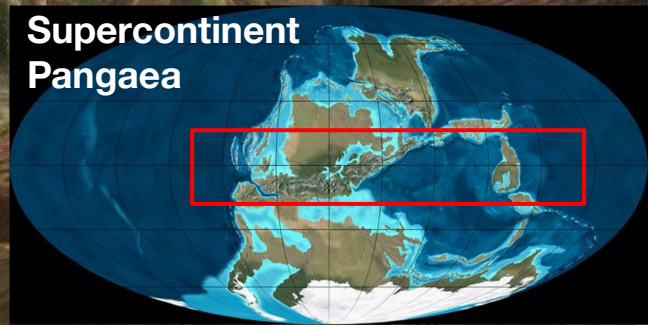
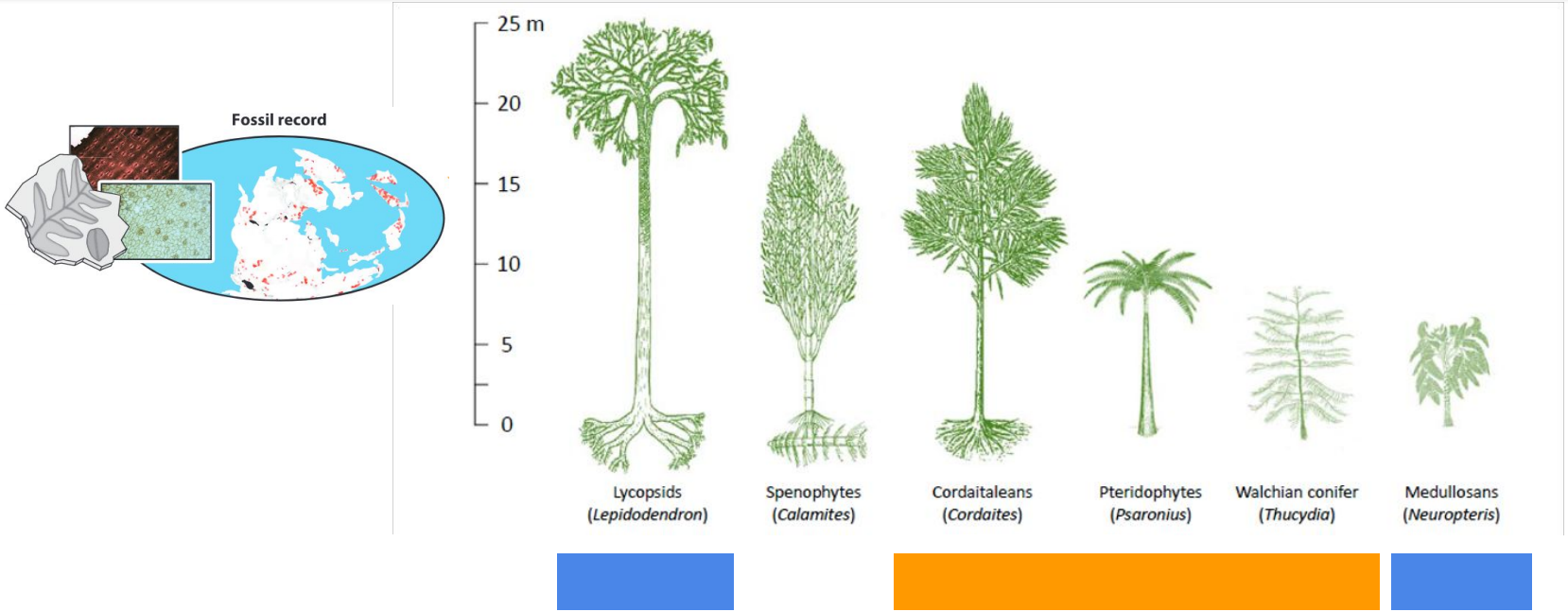
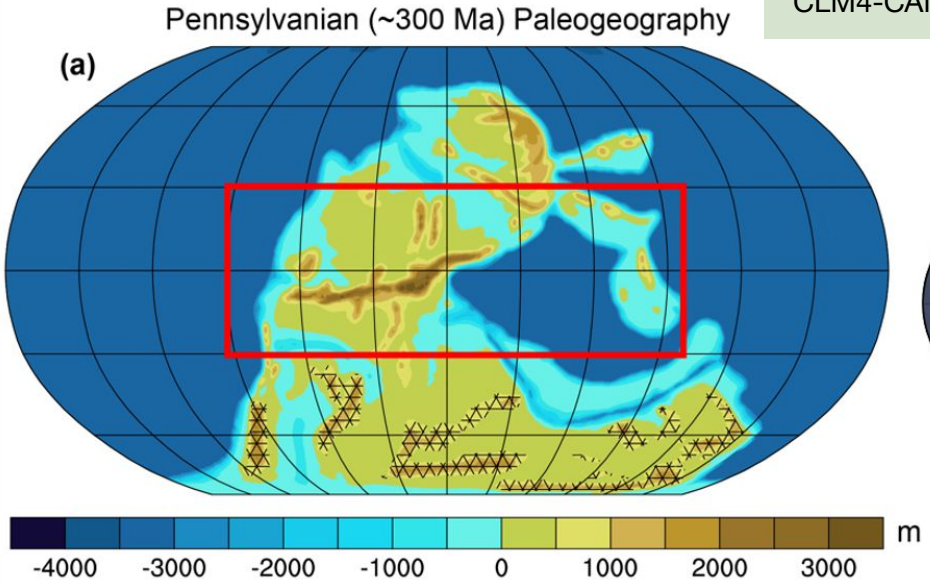


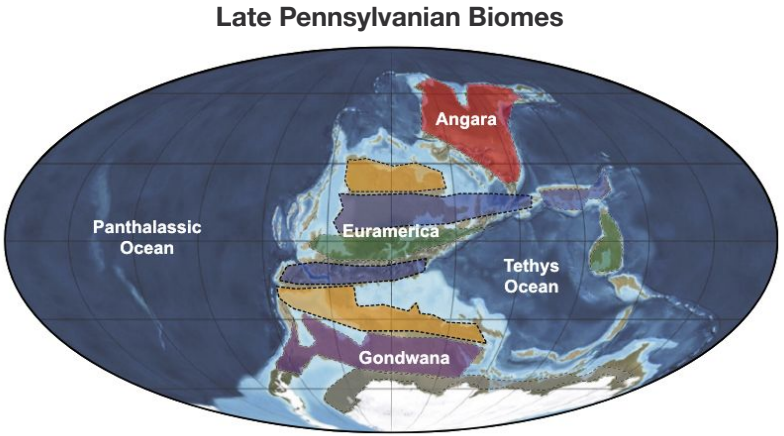
Some of the most well-studied plant fossil assemblages



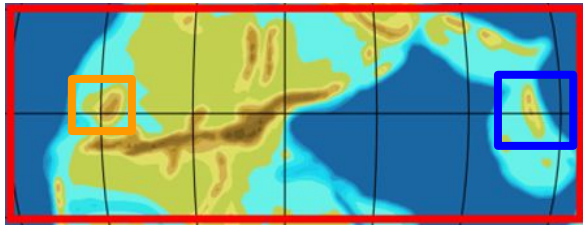
CESM simulations of the late Pennsylvanian (~300 Ma)

Simulations	Type of plants
CLM4-CAM5–modern	Closest living plant analogs (“Modern”)

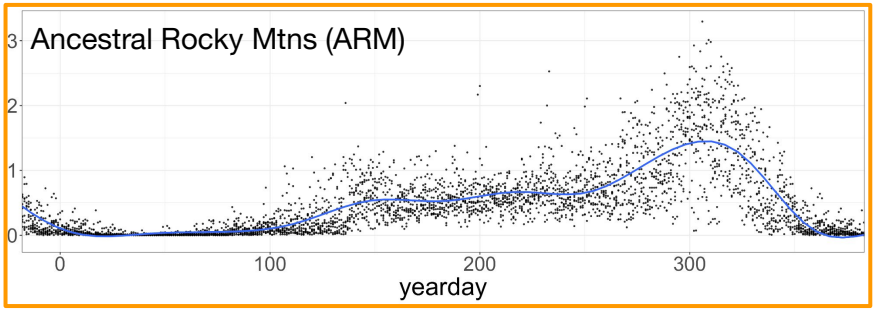


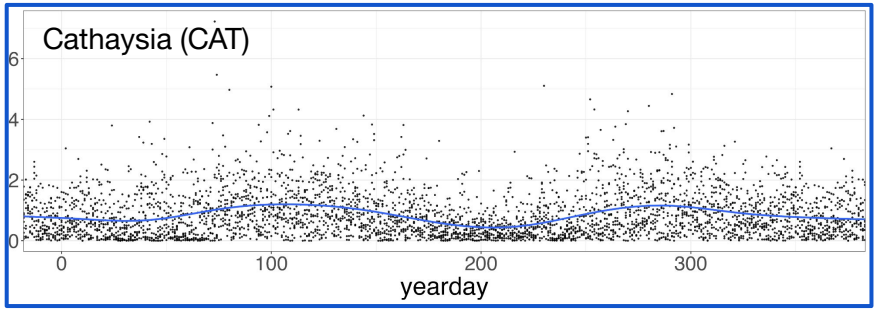


CESM produces time-appropriate atmospheric conditions



Daily Precipitation (cm/day)





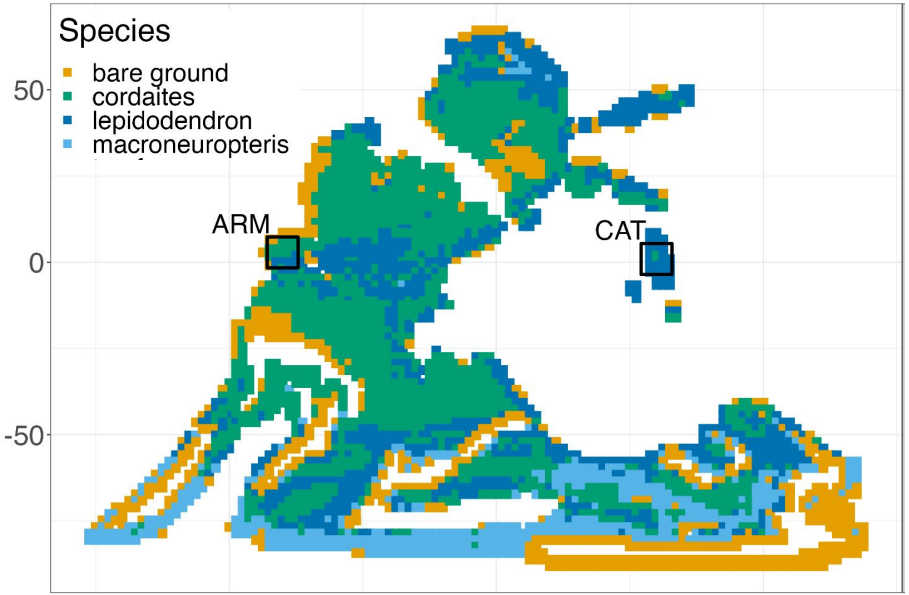
High seasonality

Low seasonality

Matthaeus et al. (2022), Frontiers Ecol. & Evol.
White et al. (2021), American Journal of Science

Abundance of tropical paleo-PFTs reflects precipitation seasonality

- Relative abundances of cordaites and lepidodendron reflect their distinct leaf-stem adaptations due to moisture availability



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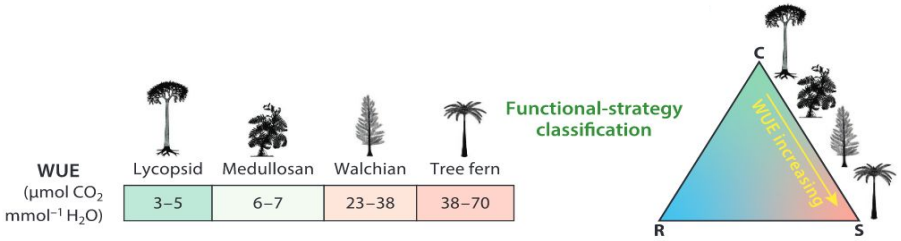
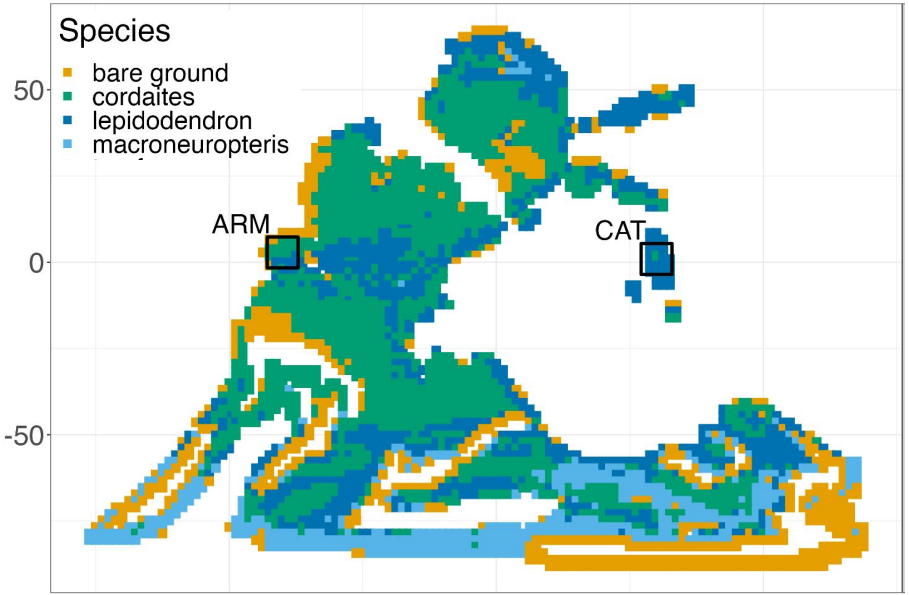
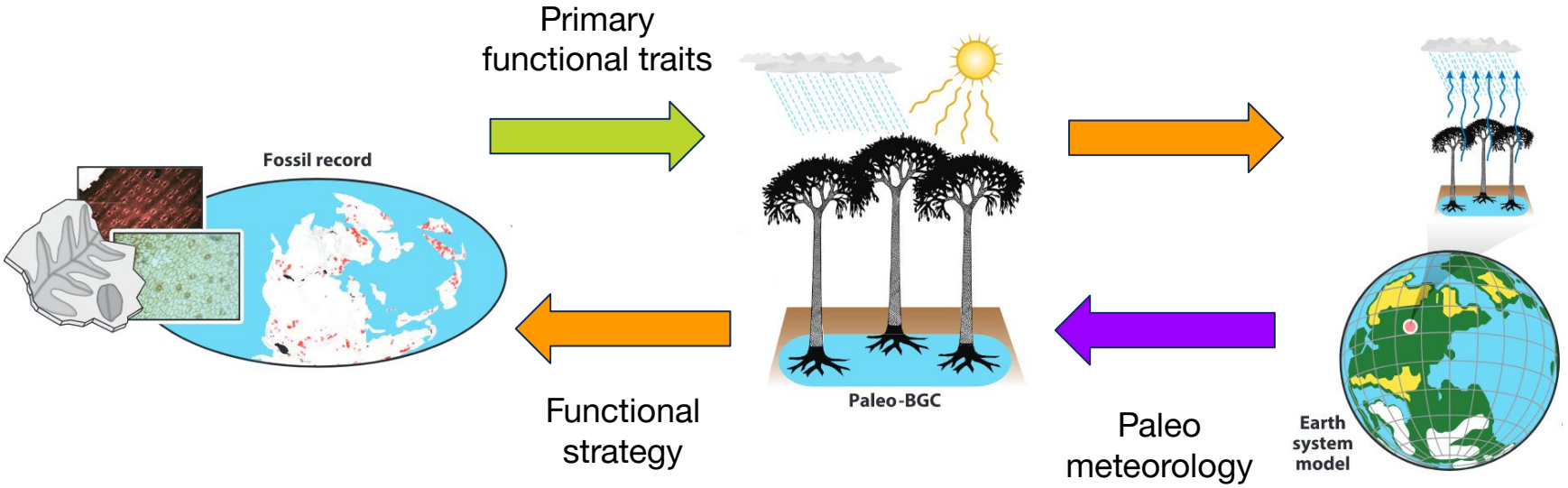




Reconstructing time-appropriate vegetation-climate interactions



CESM simulations of the late Pennsylvanian (~300 Ma)

Simulations	Type of plants
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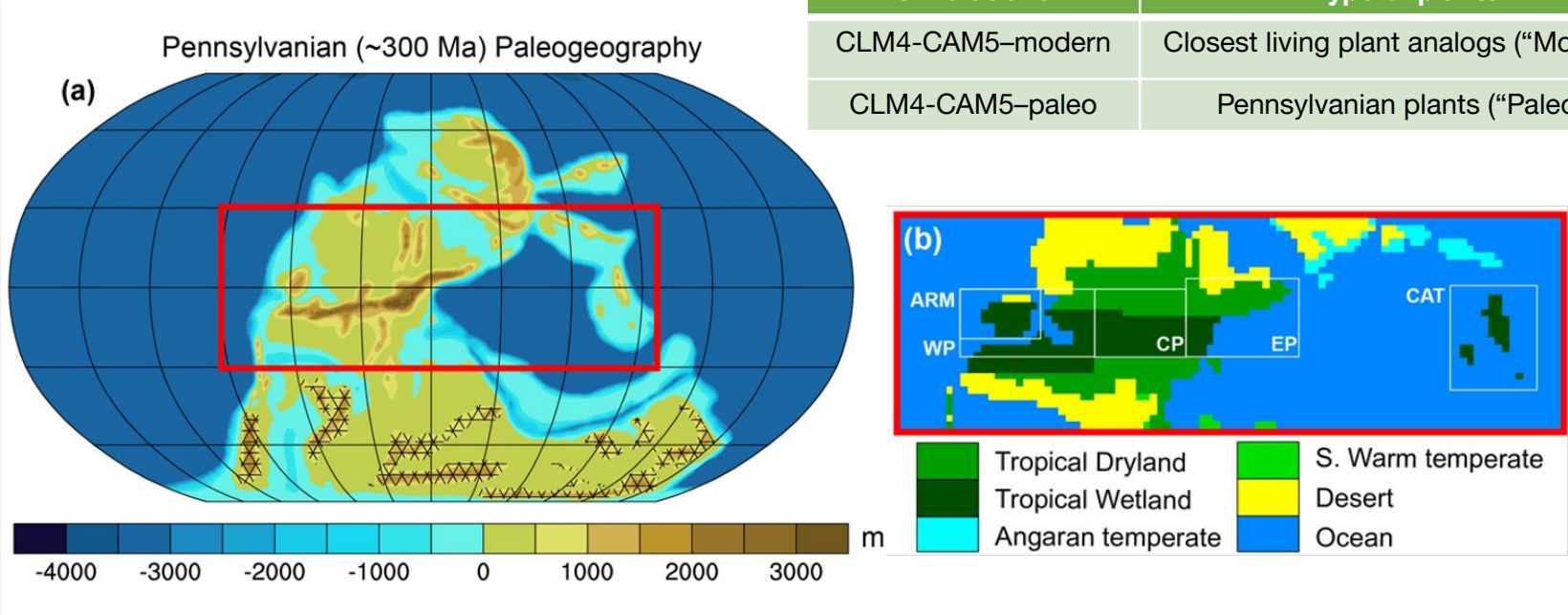
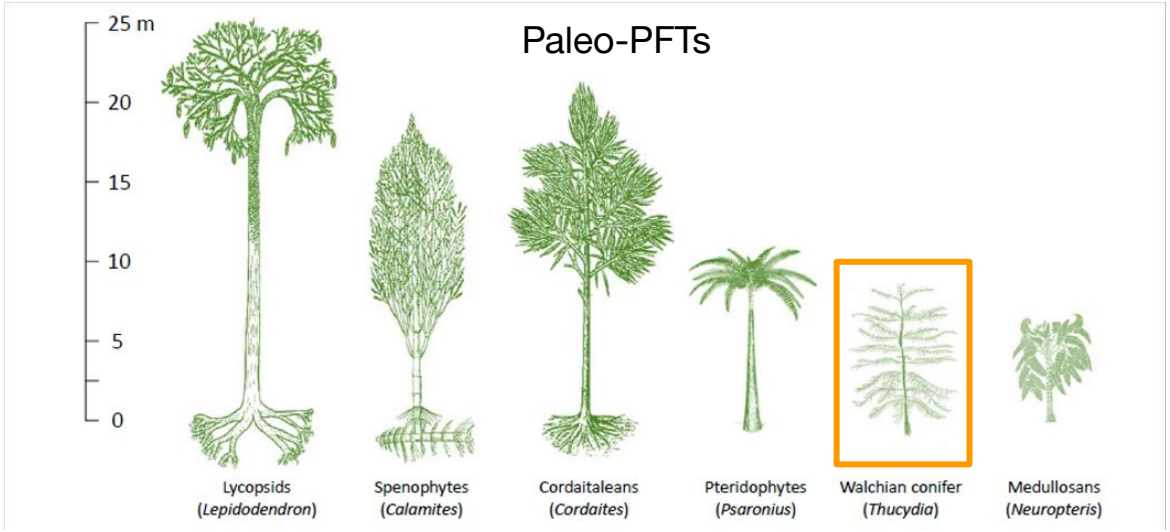
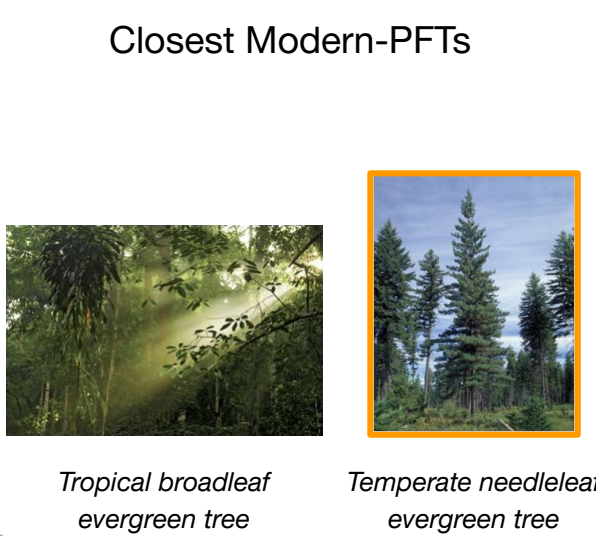
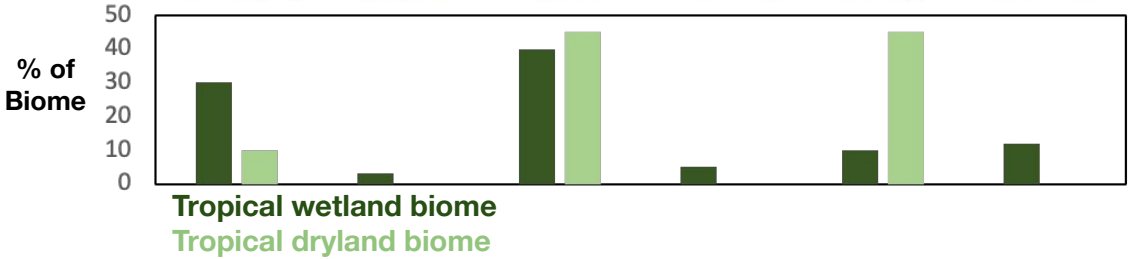
CLM4-CAM5–paleo	Pennsylvanian plants (“Paleo”)

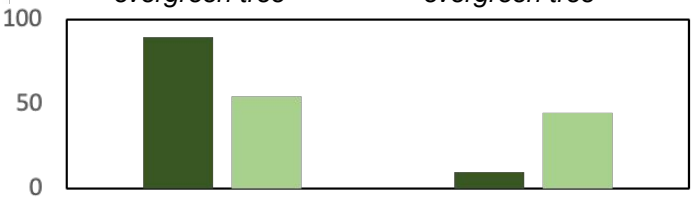


Paleo and modern PFTs in Community Land Model v4



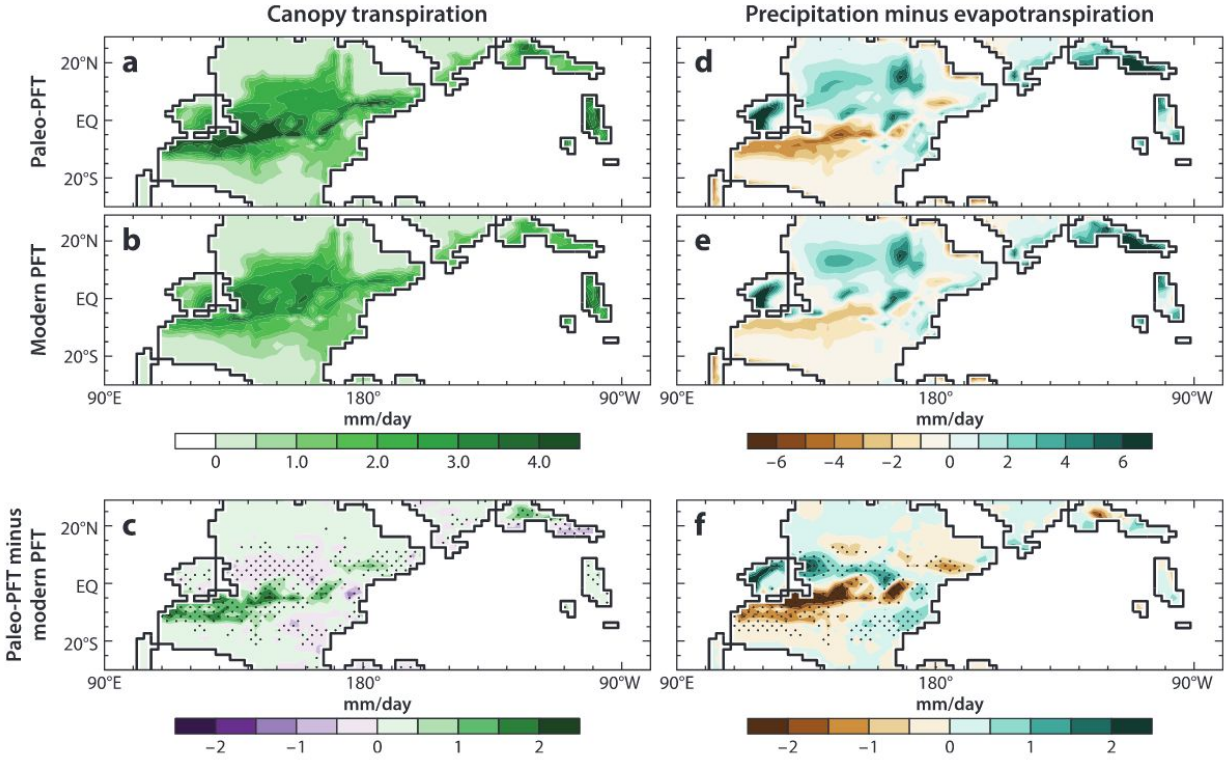




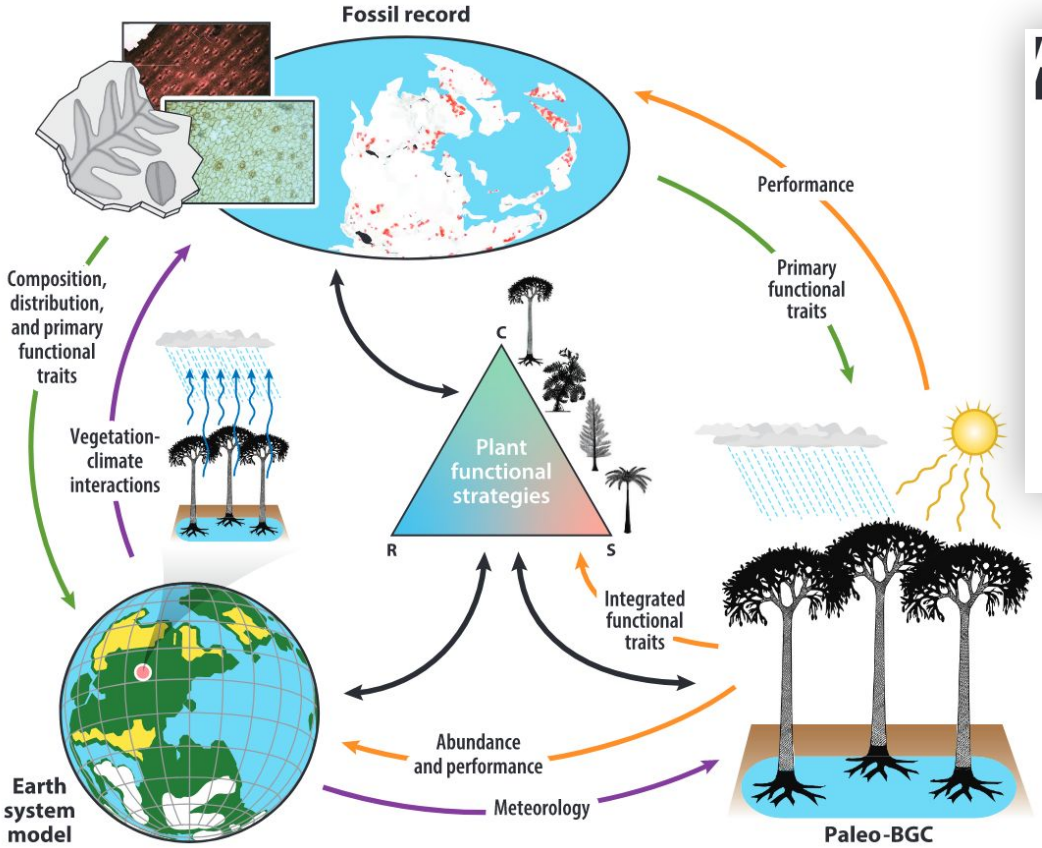


Modern and paleo-PFTs produce differences in terrestrial hydroclimate

- Overall, paleo-PFTs are more sensitive to low vapor pressure deficit due to lower stomatal resistance
- In regions where paleo-PFTs amplify dry conditions, competitor plants would likely be replaced by stress tolerant plants



Systems approach to understanding deep veg-climate interactions



ANNUAL REVIEWS

Annual Review of Earth and Planetary Sciences

A Systems Approach to Understanding How Plants Transformed Earth's Environment in Deep Time

William J. Matthaeus,[1,2] Sophia I. Macarewich,[3,4] Jon Richey,[1] Isabel P. Montañez,[1,3] Jennifer C. McElwain,[2] Joseph D. White,[5] Jonathan P. Wilson,[6] and Christopher J. Poulsen[7]

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Sophia Macarewich
macarew@ucar.edu

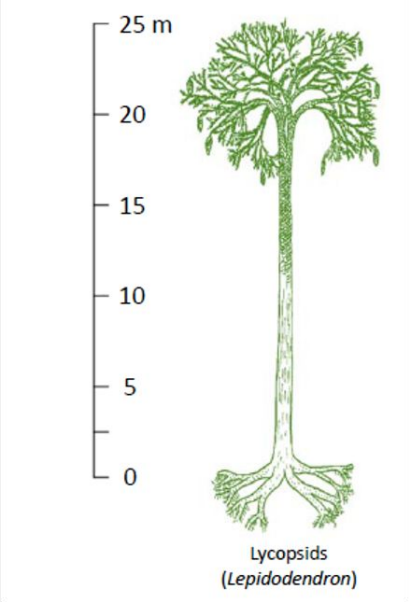
Additional Slides

Best tool to study the role of plants in the coupled Earth system

- By necessity, ancient plants are represented by closest modern plant functional types (PFTs) in Earth system models
- Functional analogy between extinct and modern plants is decreasingly valid in deep time

Source: climatearchive.org

Extinct plants may be functionally distinct from nearest living relatives



modern herbaceous
Isoetes

<u>Key Differences</u>

- Water use
- Morphology
- Nutrient uptake

Photo Source: Royal Botanic Gardens
Wilson et al. 2015; 2017; 2020

Some of the most well-studied plant fossil assemblages