How stomatal function shapes evapotranspiration in an elevated CO_2 world

CESM Land Model + BGC Working Group Meeting | 2026.02.24

Amy Liu[1], Abigail Swann[1], and Gabe Kooperman[2]

Funding from NSF

[1]UW [2]UGA

Photo Credit: Douglas Clark

Predicting and understanding drivers of ET is challenging

Article | Open access | Published: 12 February 2025

Emergent constraints indicate slower increases in future global evapotranspiration

Yuanfang Chai, Yao Yue, Louise Slater & Chiyuan Miao

npj Climate and Atmospheric Science **8**, Article number: 46 (2025) | Cite this article

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When Does Vapor Pressure Deficit Drive or Reduce Evapotranspiration?

Adam Massmann[1], Pierre Gentine[1], and Changjie Lir

[1]Department of Earth and Environmental Engineering, Columbia Univers

Research article |

Attribution of global evapotranspiration

mework

heed Ullah, Daniel Fiifi Tawia

SCIENCE ADVANCES | RESEARCH ARTICLE

CLIMATOLOGY

A drier than expected future, supported by near-surface relative humidity observations

Hervé Douville[1]* and Katharine M. Willett[2]

Despite continuous progress in climate modeling, global projections of the terrestrial water cycle remain highly model dependent. Here, we use quality-controlled gridded observations of temperature and humidity to constrain projected changes in continental near-surface relative humidity across the 21st century. Results show that the projections are poorly constrained when using surface temperature observations only and argue for mitigation policies that are not only rooted in global warming levels. Projections constrained with both near-surface temperature and relative humidity observations show an inevitable continental drying, especially in the northern midlatitudes where anthropogenic aerosols have, however, countered this long-term response until the late 1980s. A "strong drying" storyline is then used to highlight the urgent need for careful adaptation strategies and to suggest a possible contribution of land surface processes to model uncertainties.

availability reduced by
ponses to climate change

Smerdon, Benjamin I. Cook & A. Park Williams

e this article

LETTER • OPEN ACCESS

Stomatal response to decreased relative humidity constrains the acceleration of terrestrial evapotranspiration

Mingzhong Xiao, Zhongbo Yu, Dongdong Kong, Xihui Gu, Ivan Mammarella, Leonardo Montagnani, M Altaf Arain, Lutz Merbold, Vincenzo Magliulo, Annalea Lohila Show full author list

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Environmental Research Letters, Volume 15, Number 9

Citation Mingzhong Xiao *et*

DOI 10.1088/1748-9326/ab9

Article | Published: 16 March 2020

Increased control of vegetation on global terrestria energy fluxes

Philippe Ciais, Ramdane Alkama, Youngryel Ryu, Gregory
Markus Kautz, Brecht Martens, Chongya Jiang, Almut Arne
herini, Peter Anthoni, Peter Lawrence, Andy Wiltshire, Juli
Daniel S. Goll, Vivek K. Arora, Sebastian Lienert, ... Alessa

2020) | Cite this article

Article | Open access | Published: 30 October 2015

Vegetation Greening and Climate Change Promote Multidecadal Rises of Global Land Evapotranspiration

Ke Zhang, John S. Kimball, Ramakrishna R. Nemani, Steven W. Running, Yang Hong, Jonathan J. Gourley & Zhongbo Yu

Scientific Reports **5**, Article number: 15956 (2015) | Cite this article

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PNAS

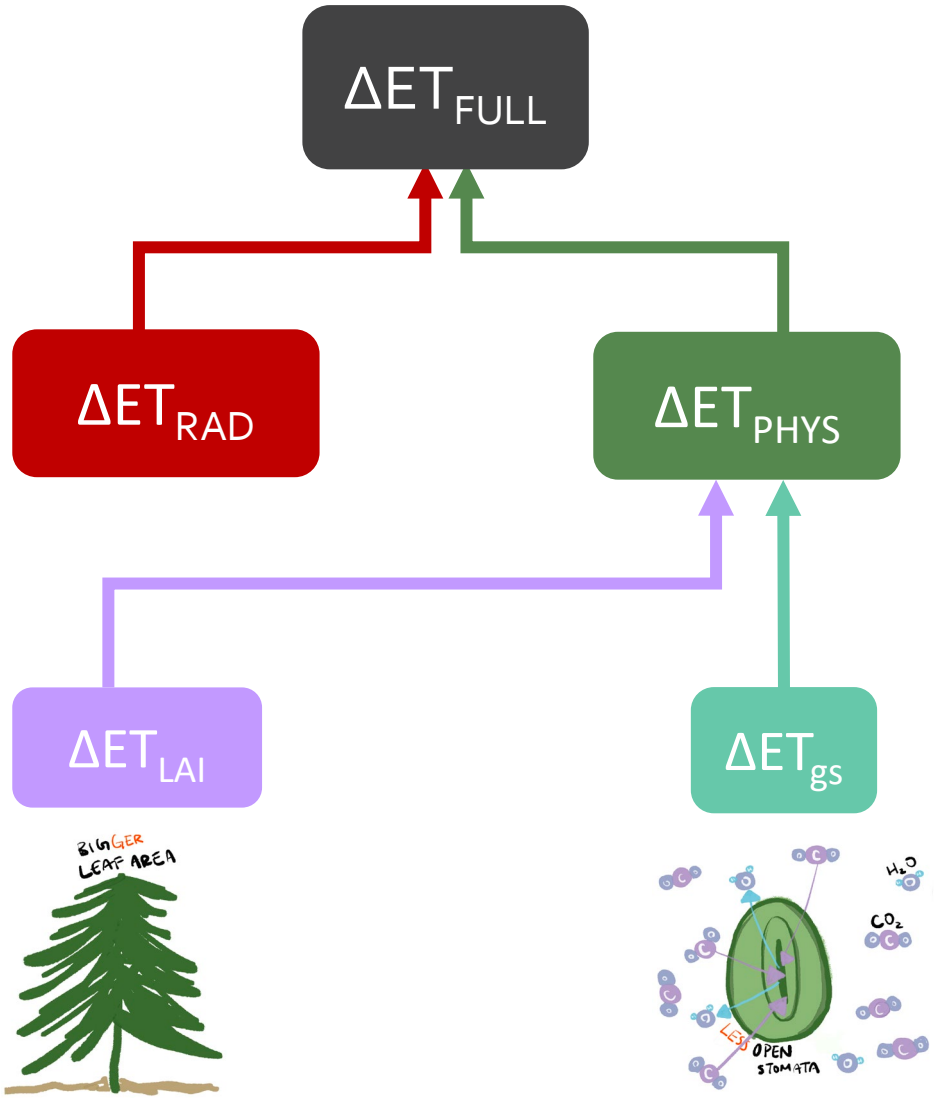
RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES

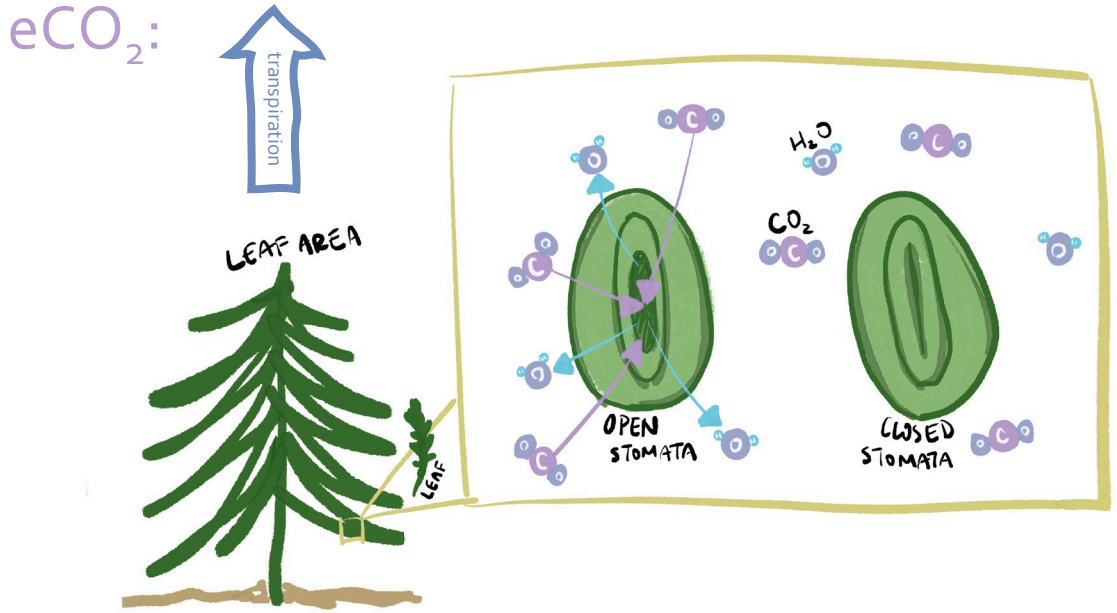
Check for updates

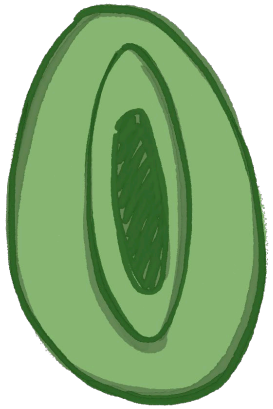
Observed humidity trends in dry regions contradict climate models

Isla R. Simpson[a,1], Karen A. McKinnon[b,c,d], Daniel Kennedy[a,e], David M. Lawrence[a], Flavio Lehner[a,f,g], and Richard Seager[h]

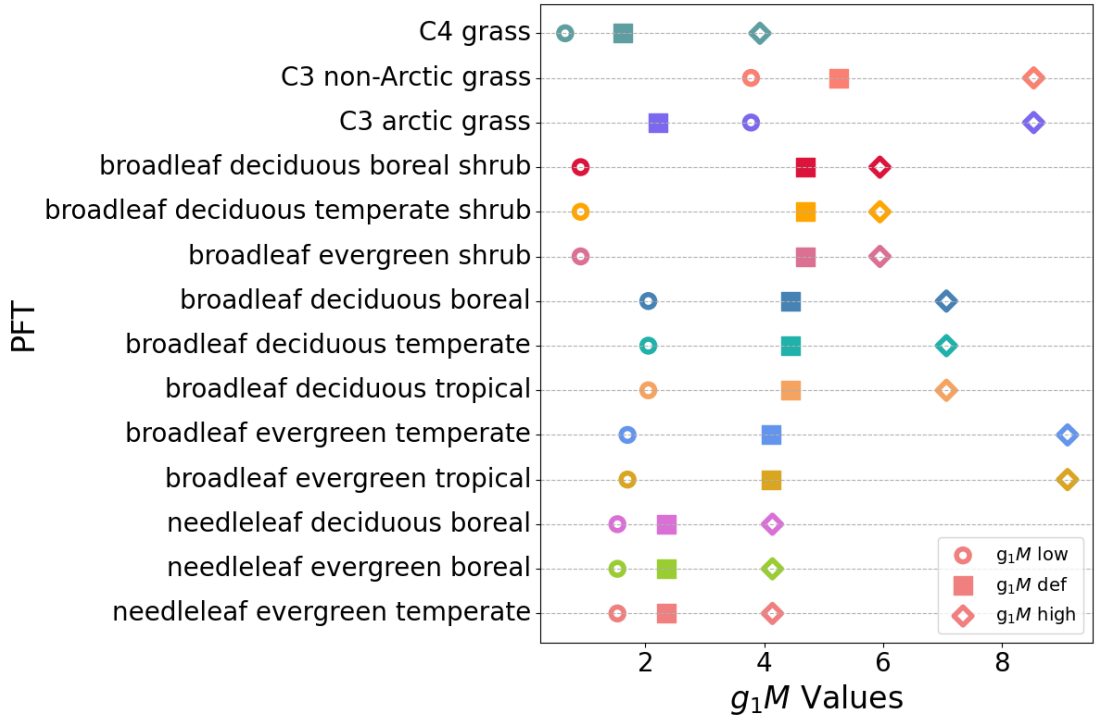
Leaf area and stomata have competing effects on ET under elevated CO_2

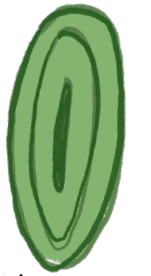






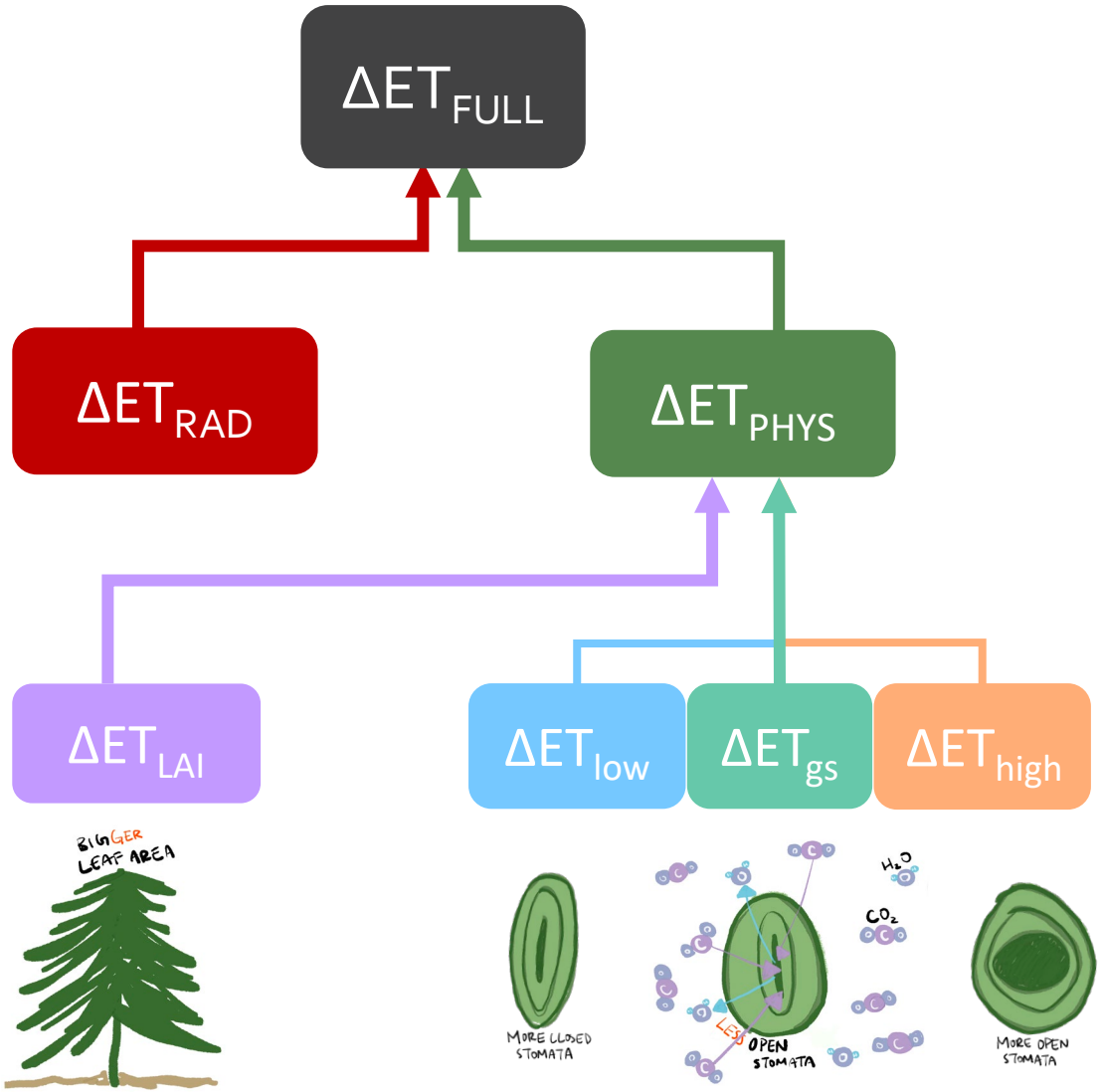
Low, Default, and High g_{1M} values for each PFT

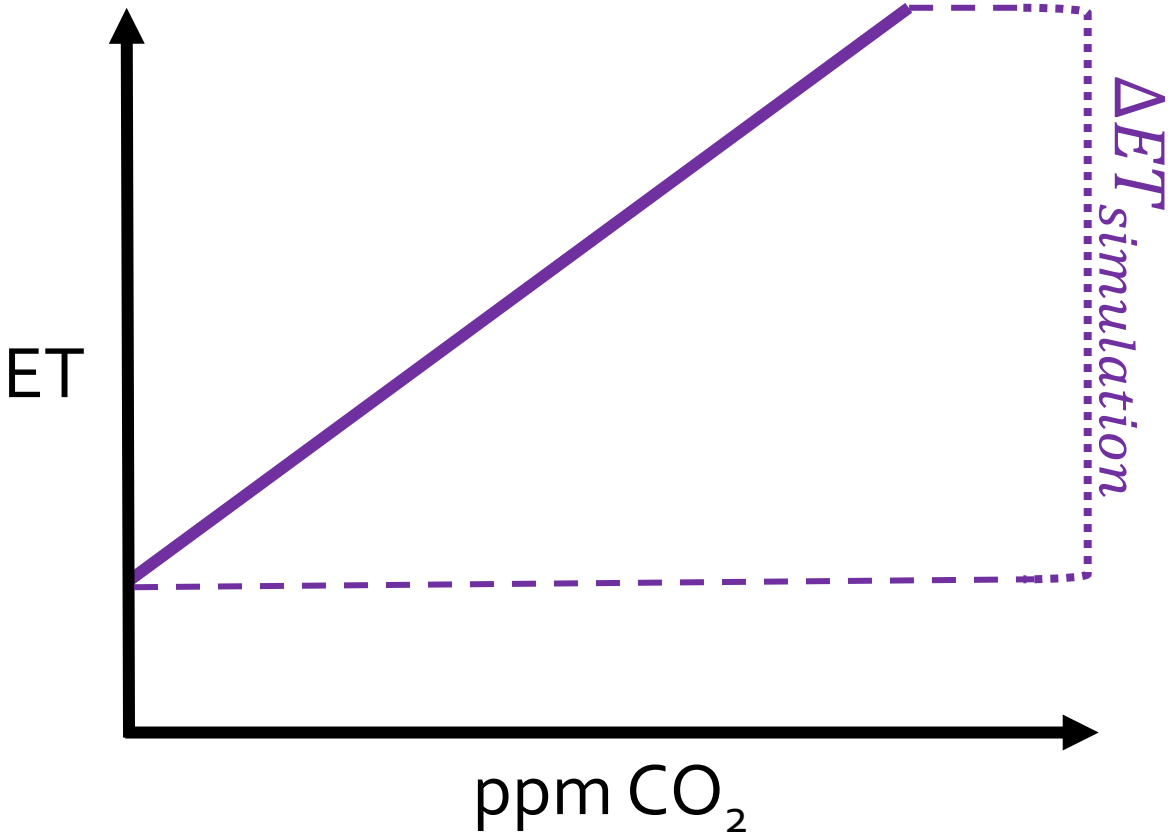


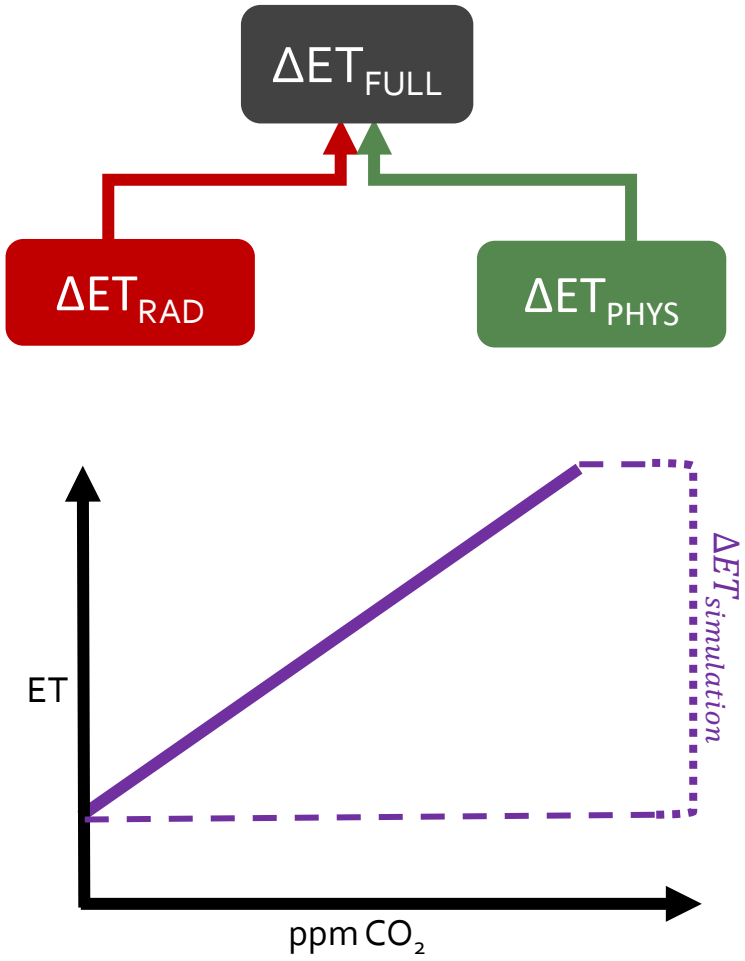


= Low g_{1M} ~ high *WUE*

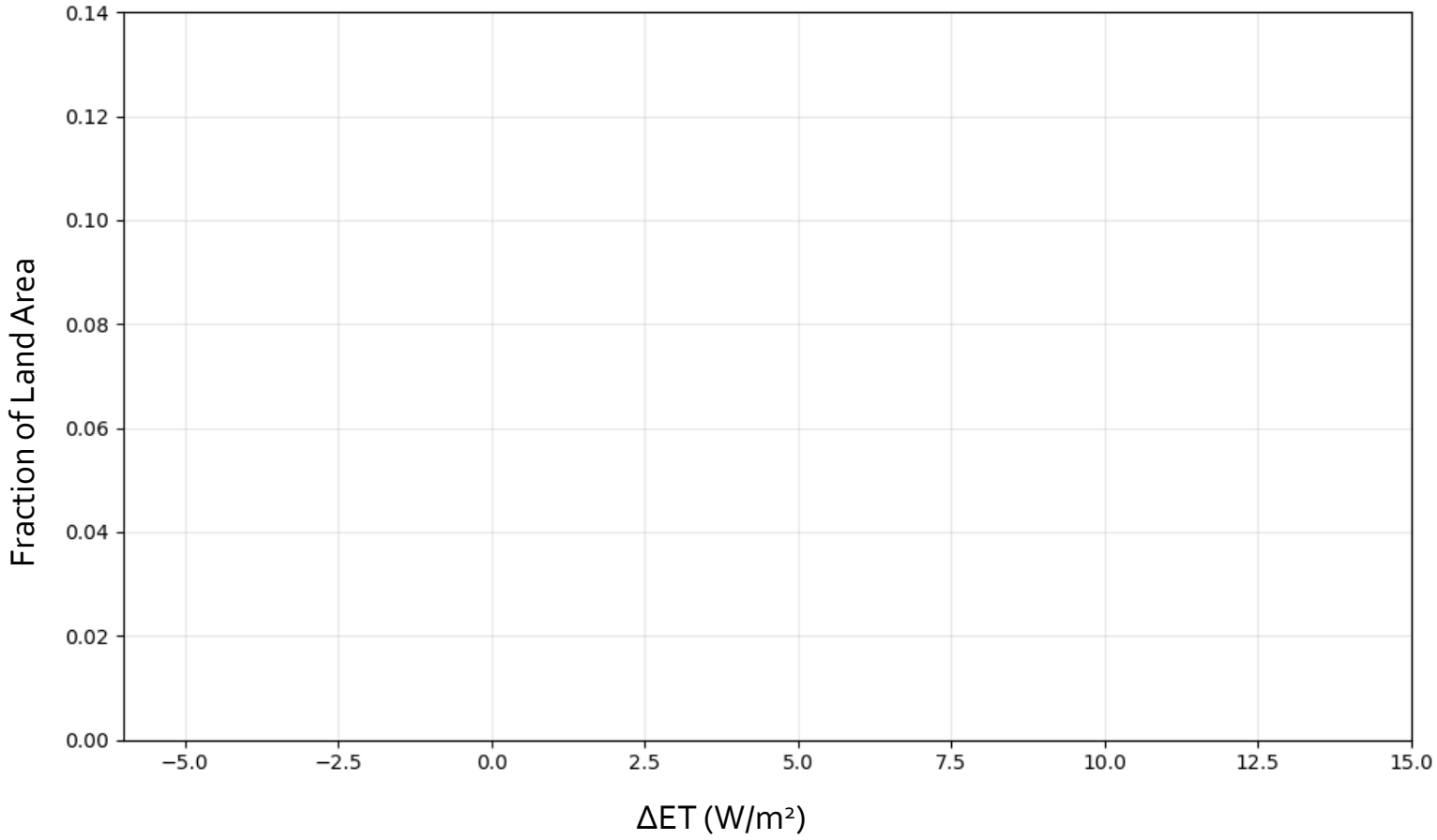
= High g_{1M} ~ low *WUE*


ΔET FULL
ΔET RAD
ΔET PHYS
ΔET LAI
ΔET low
ΔET gs
ΔET high
BIGGER LEAF AREA
MORE CLOSED STOMATA
LESS
OPEN STOMATA
MORE OPEN STOMATA
H2O
CO2

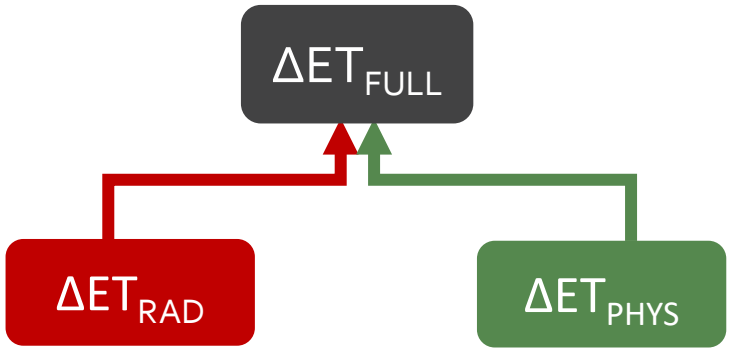

ET
ppm CO2
ΔET simulation



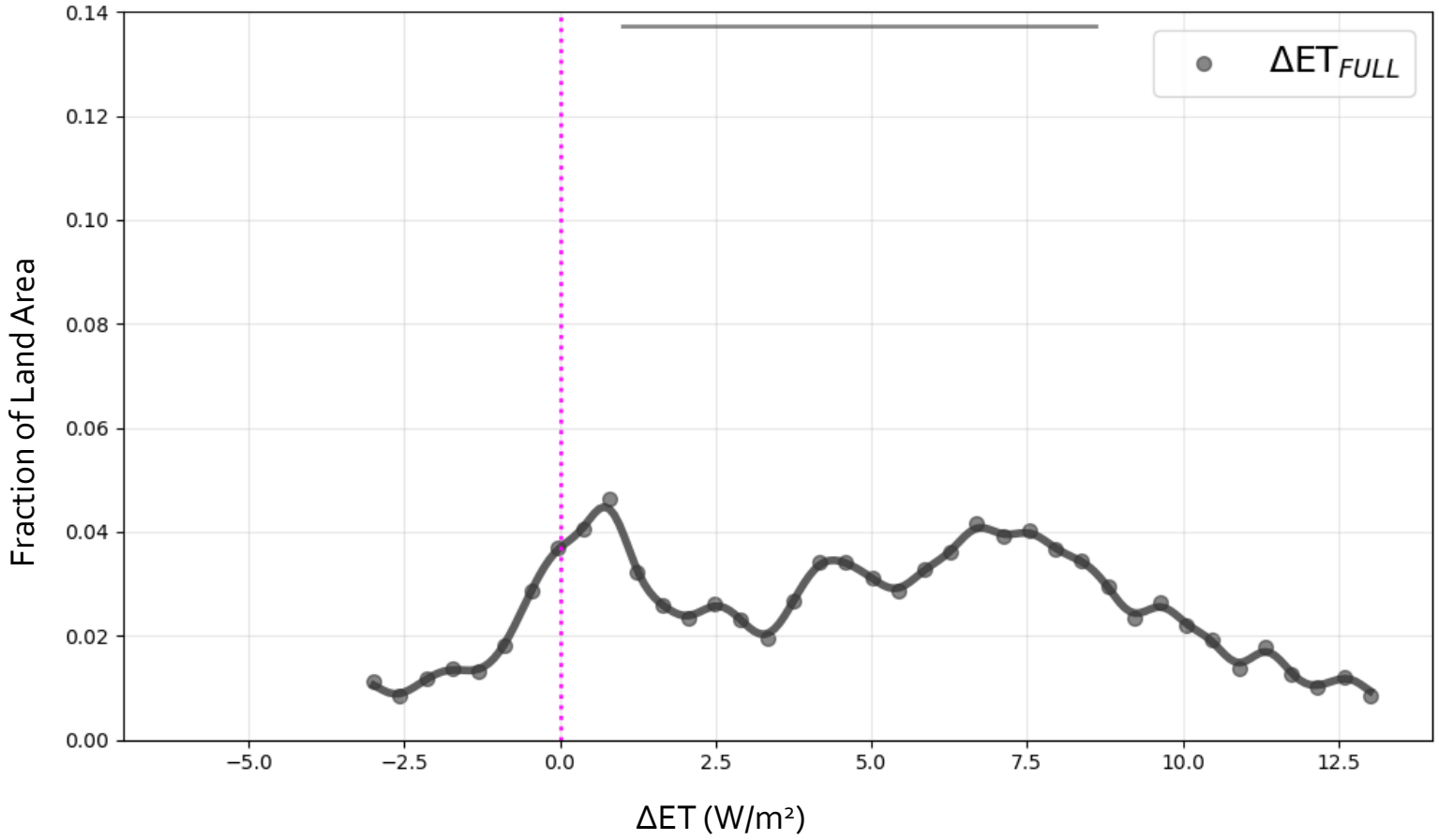
Land fraction distribution: Full, radiatively- and physiologically- driven ET response to eCO_2



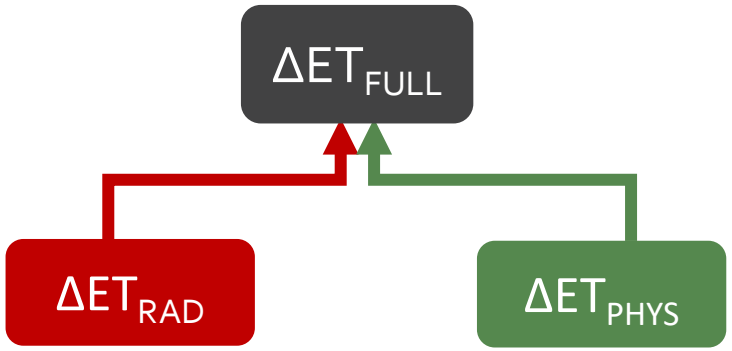
ET is expected to increase under eCO_2



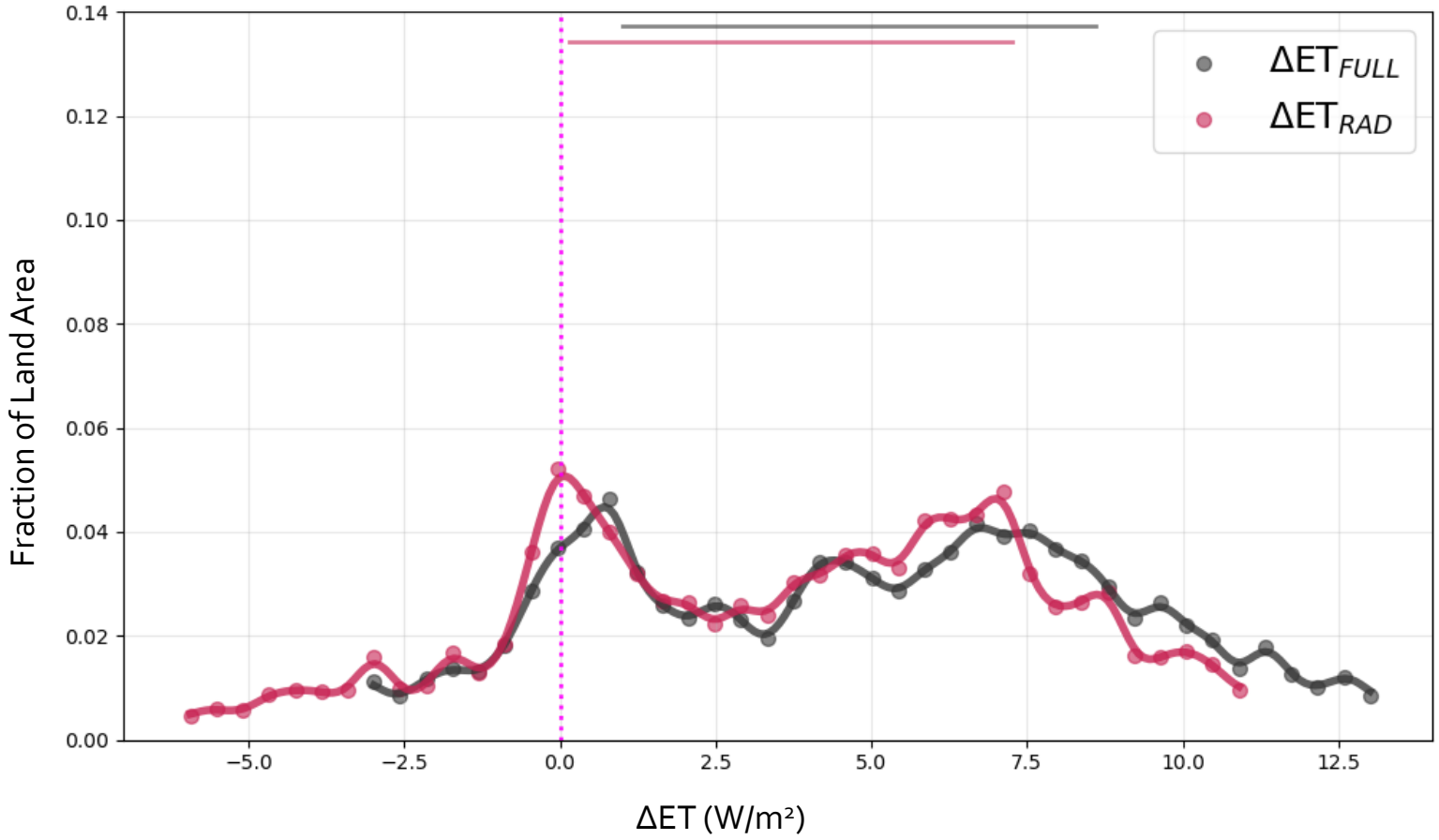
Land fraction distribution: Full, radiatively- and physiologically- driven ET response to eCO_2



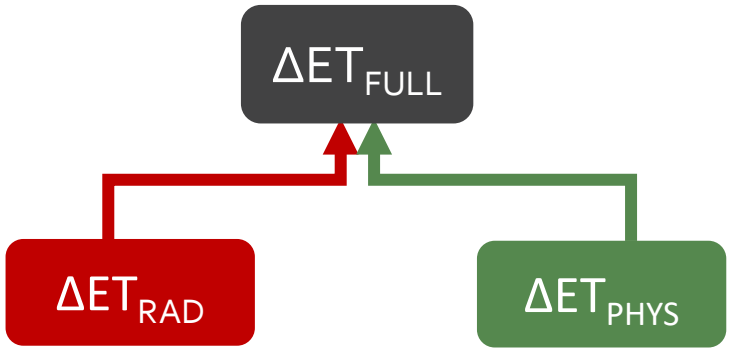
RAD increase ET and is the major contributor to the FULL response



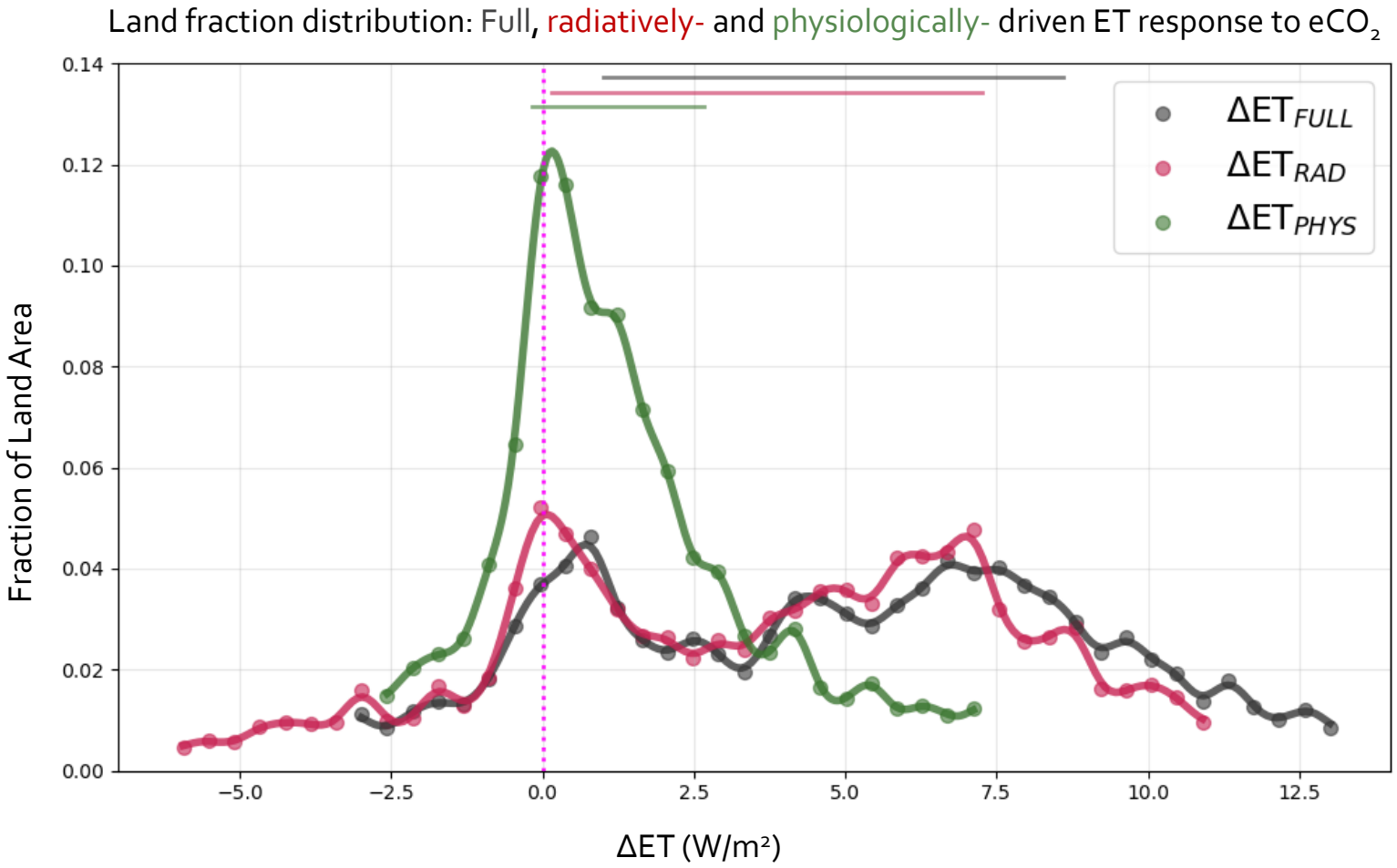
Land fraction distribution: Full, radiatively- and physiologically- driven ET response to eCO_2



PHYS also increases ET, but to a smaller magnitude



~25% of the FULL response is from PHYS



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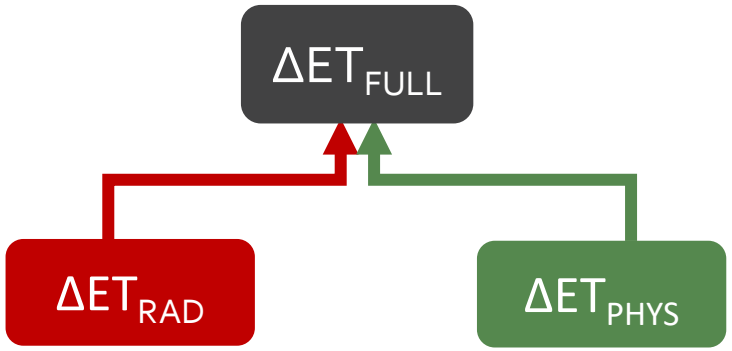

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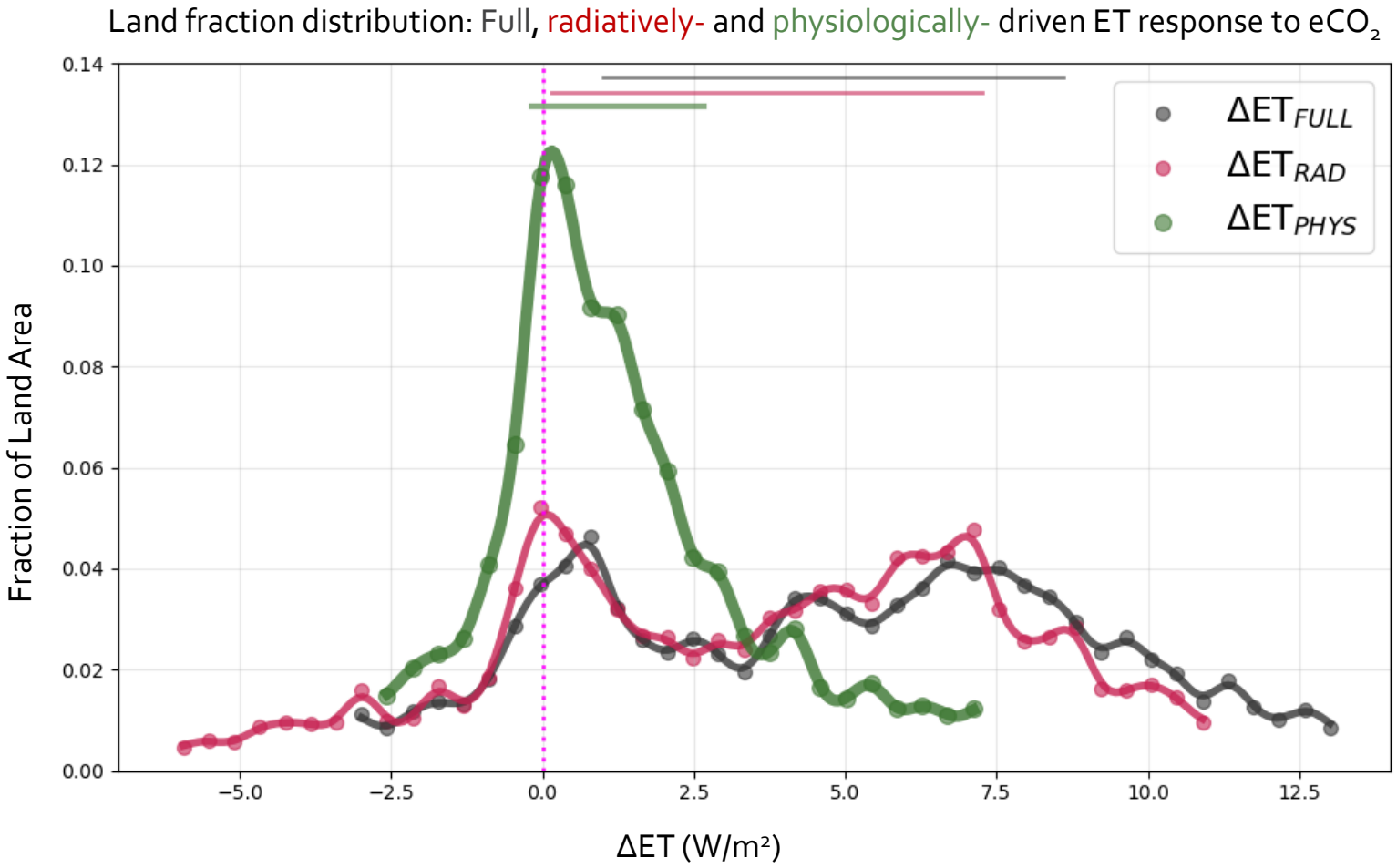
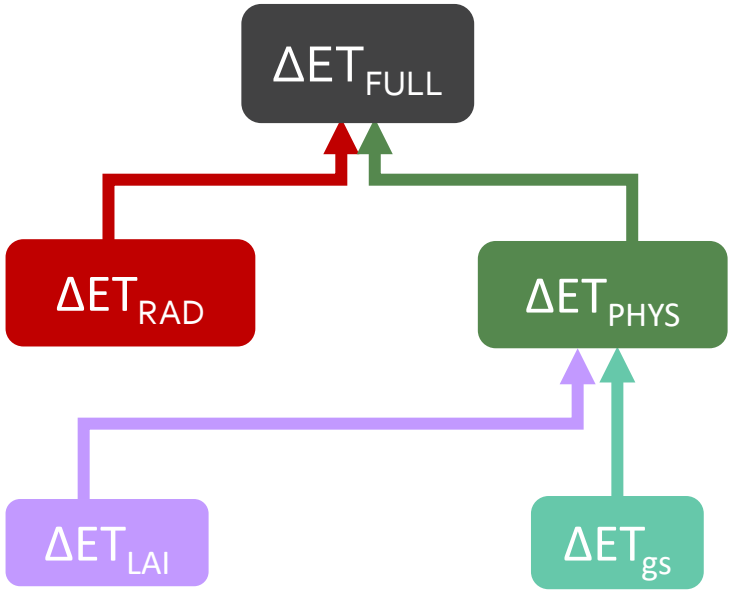
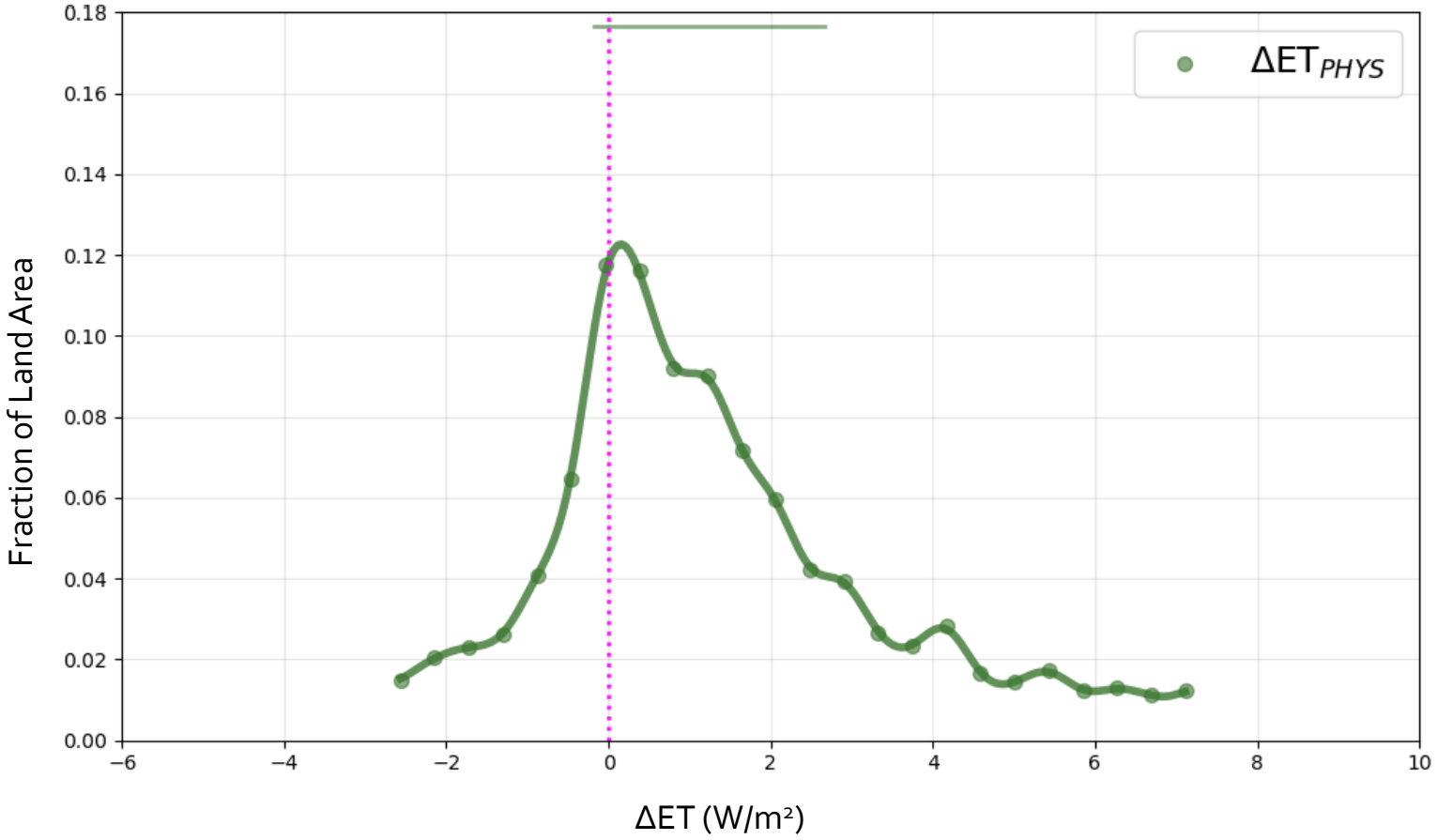
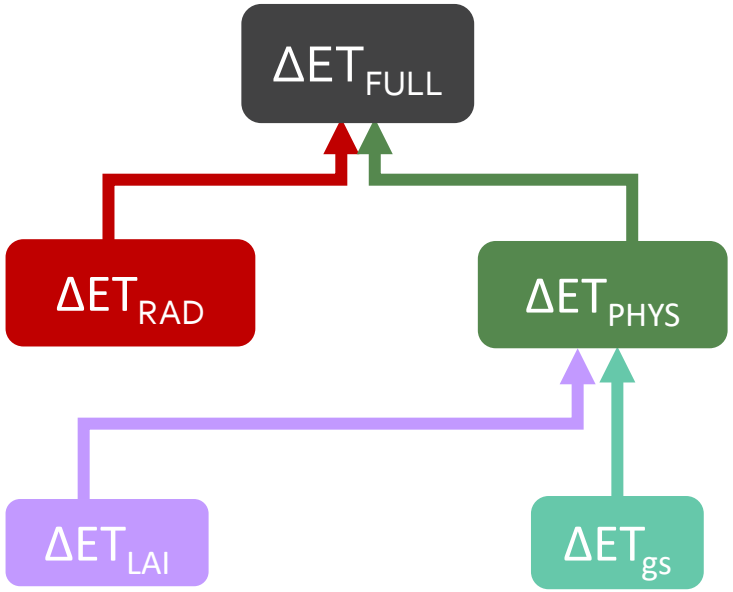




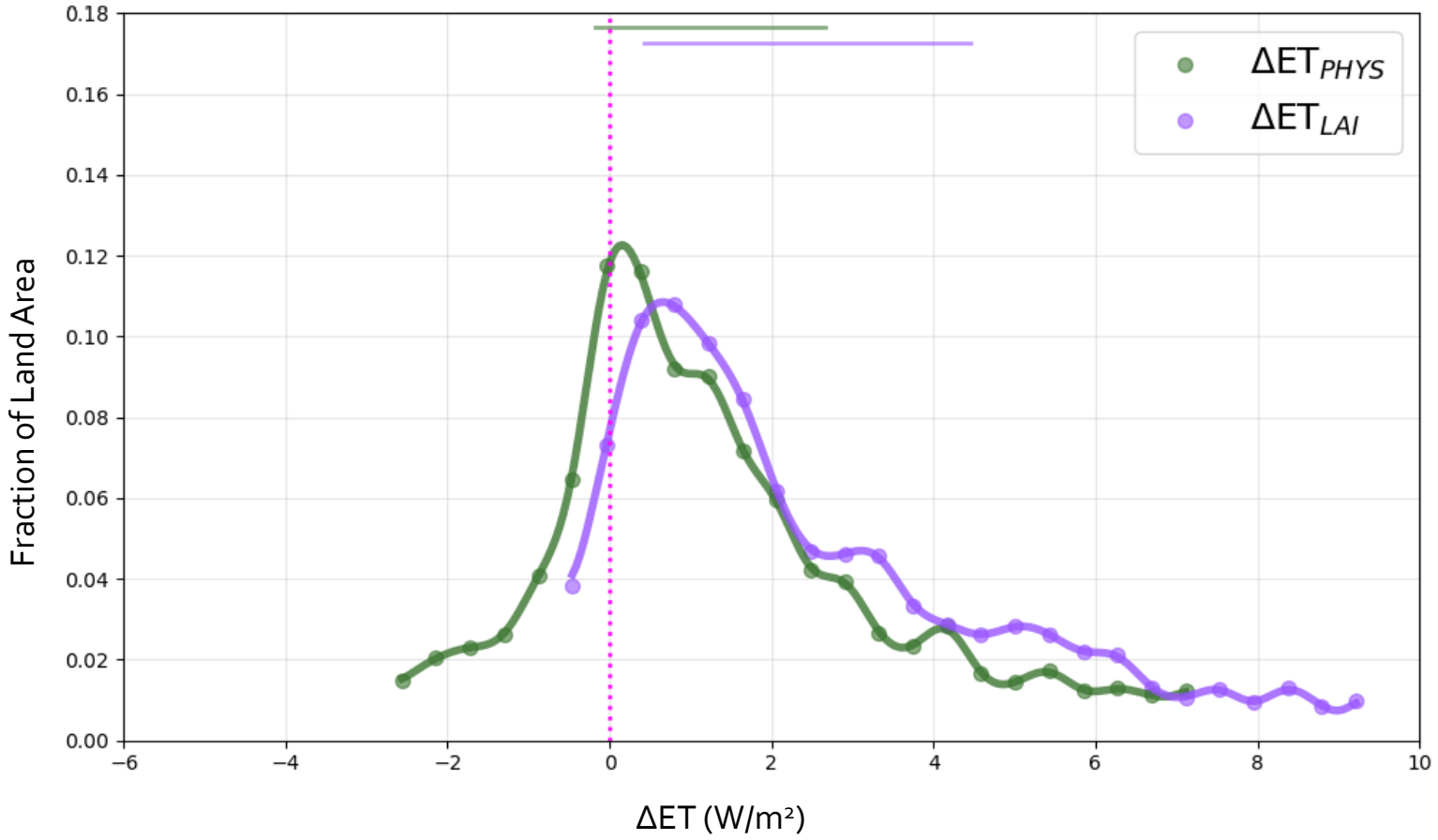
Land fraction distribution: Physiologically-, leaf area- and stomatal- driven ET response to eCO_2



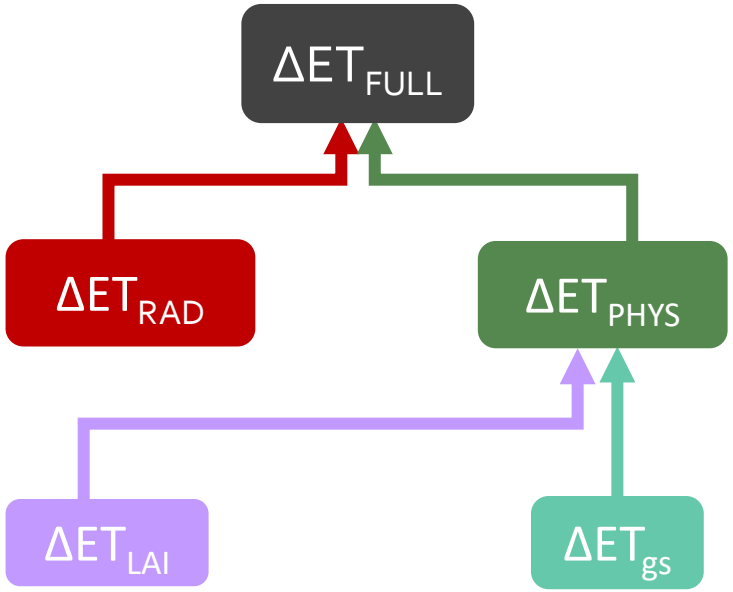
Leaf growth response to eCO_2 drives even larger increases in ET



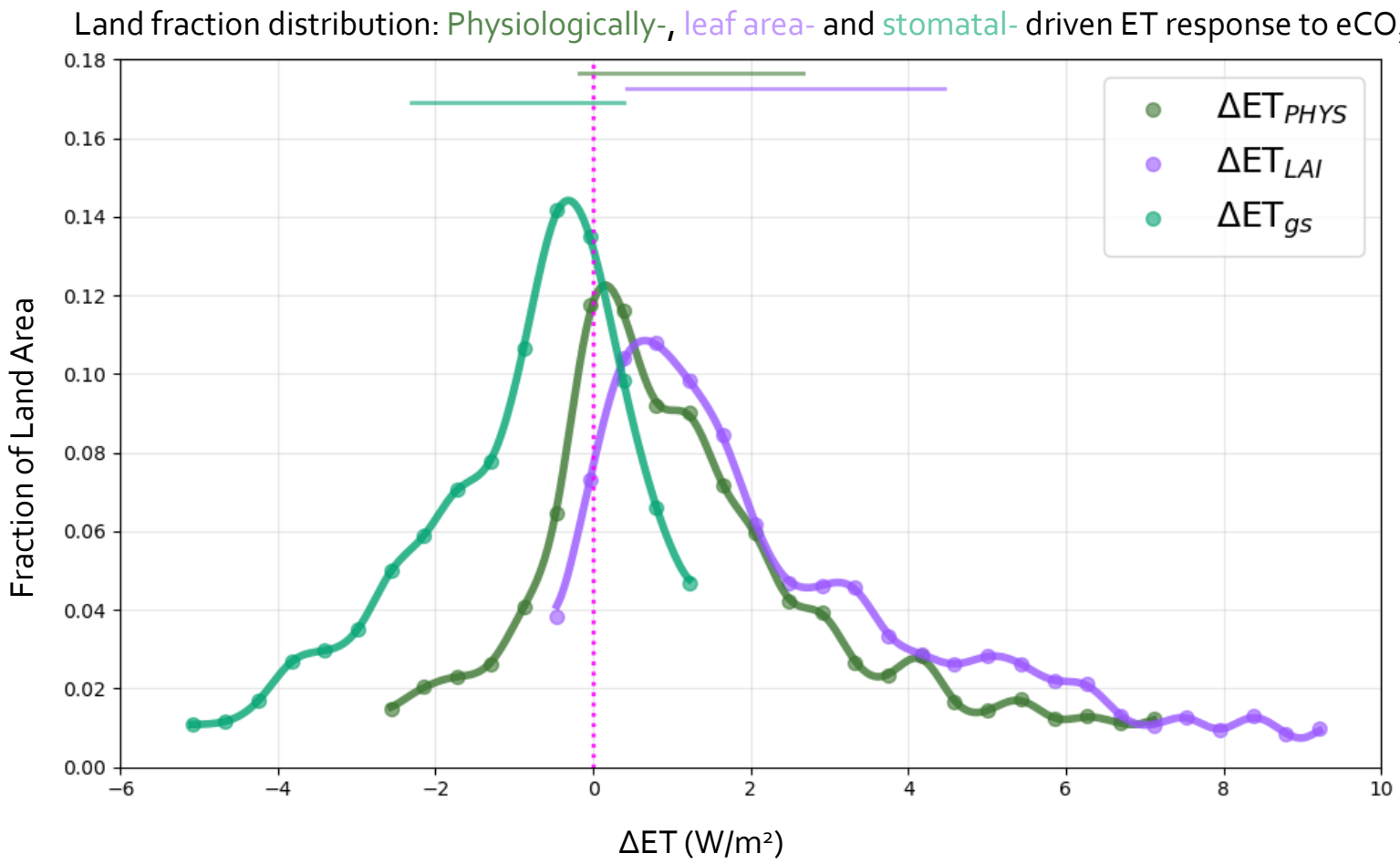
Land fraction distribution: Physiologically-, leaf area- and stomatal- driven ET response to eCO_2



Stomatal closure under eCO_2 drives decreases in ET



$\Delta ET_{gs} > \Delta ET_{LAI}$
in **~15%** of land area



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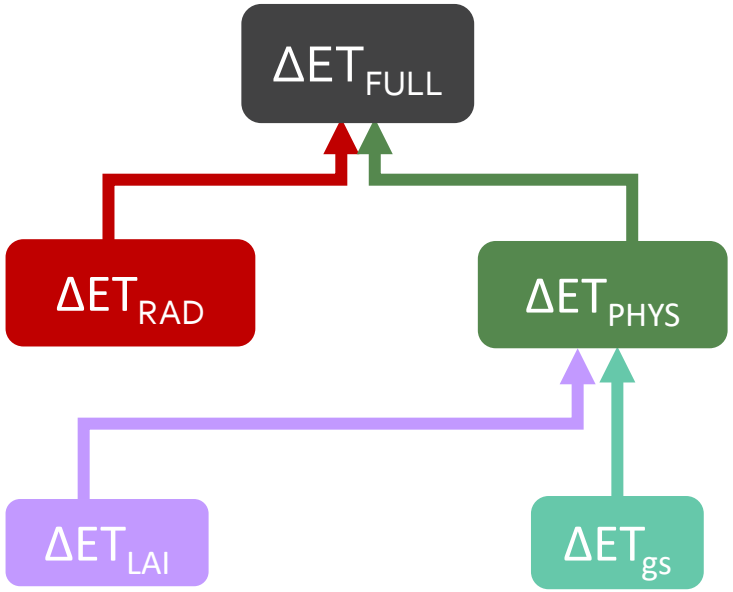

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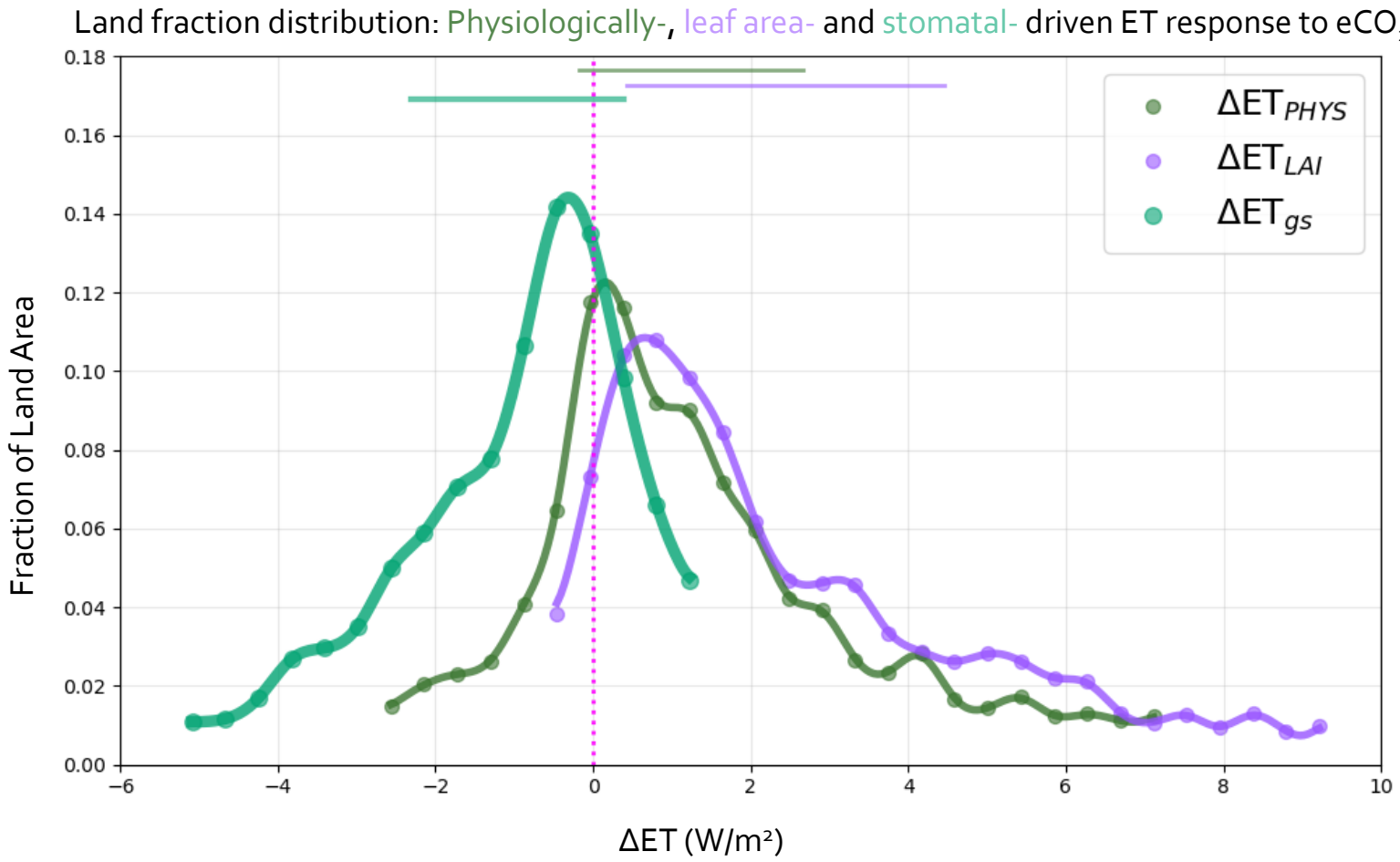
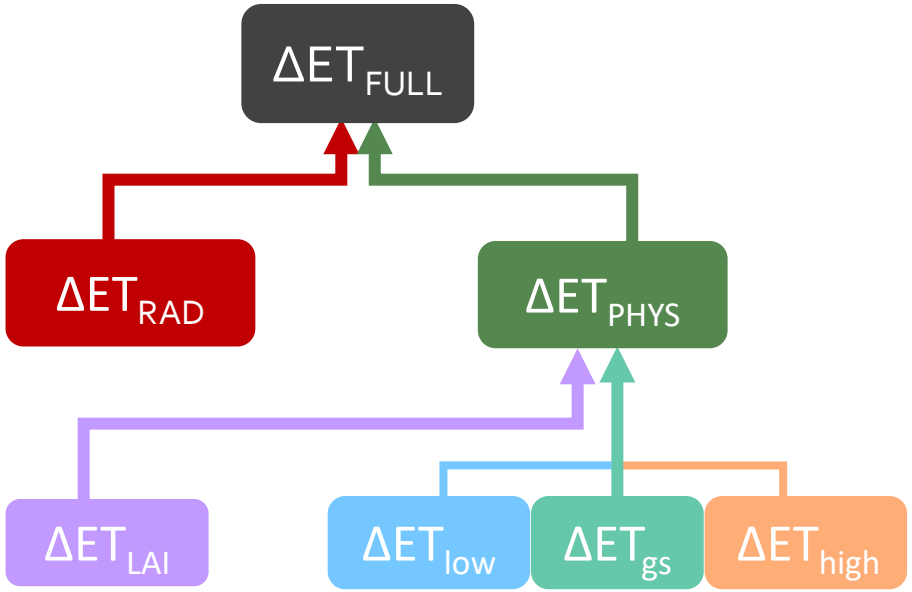
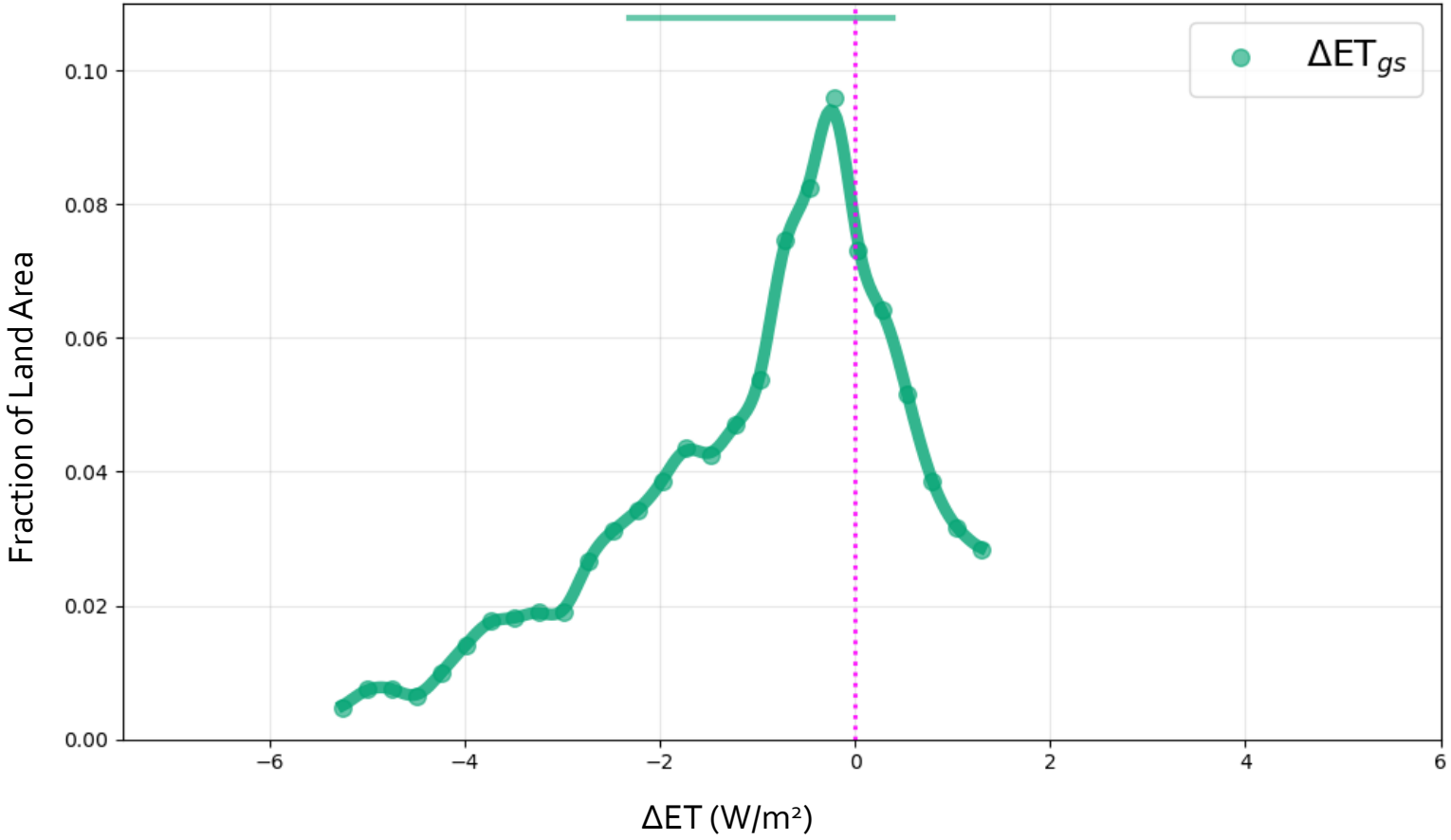
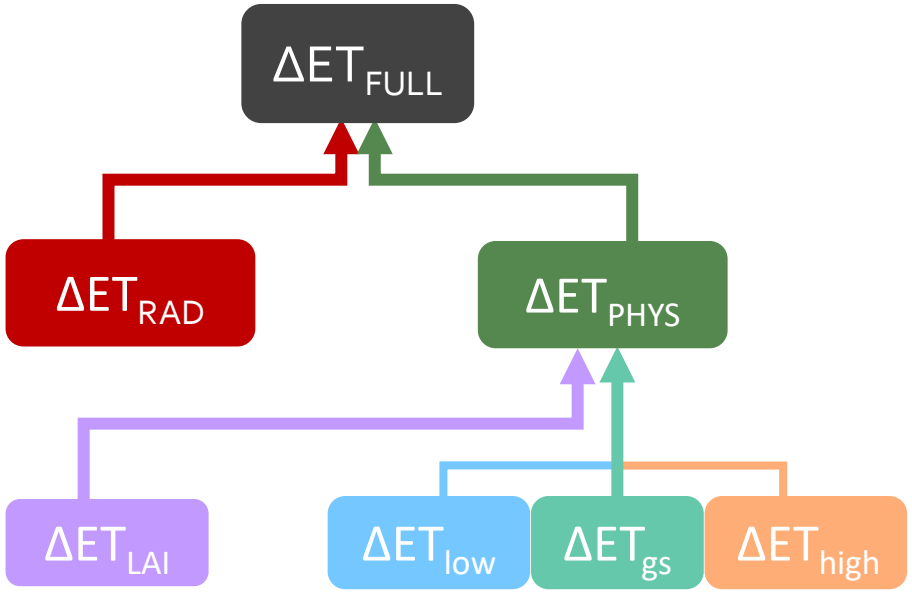




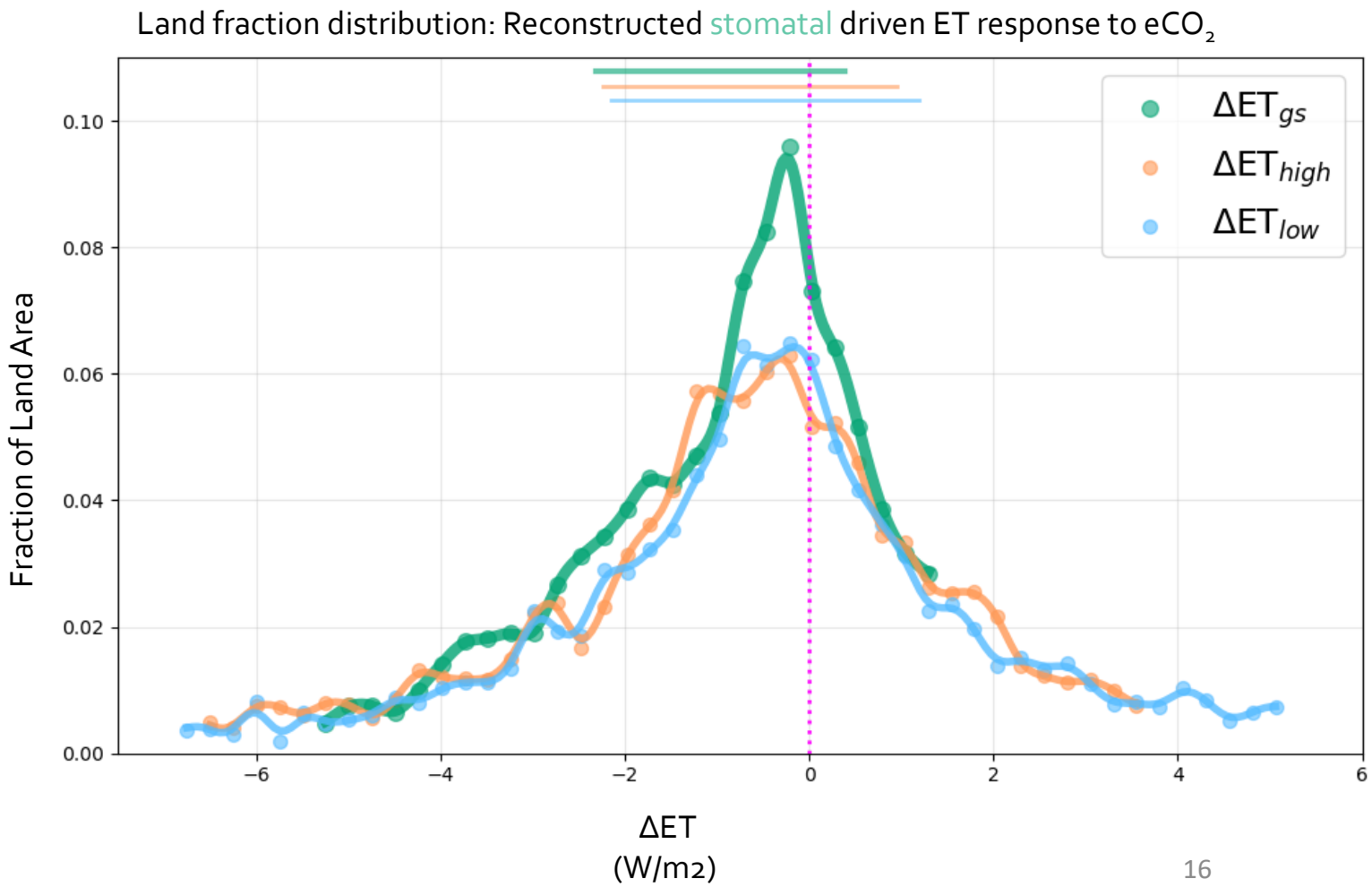
Land fraction distribution: Reconstructed stomatal driven ET response to eCO_2



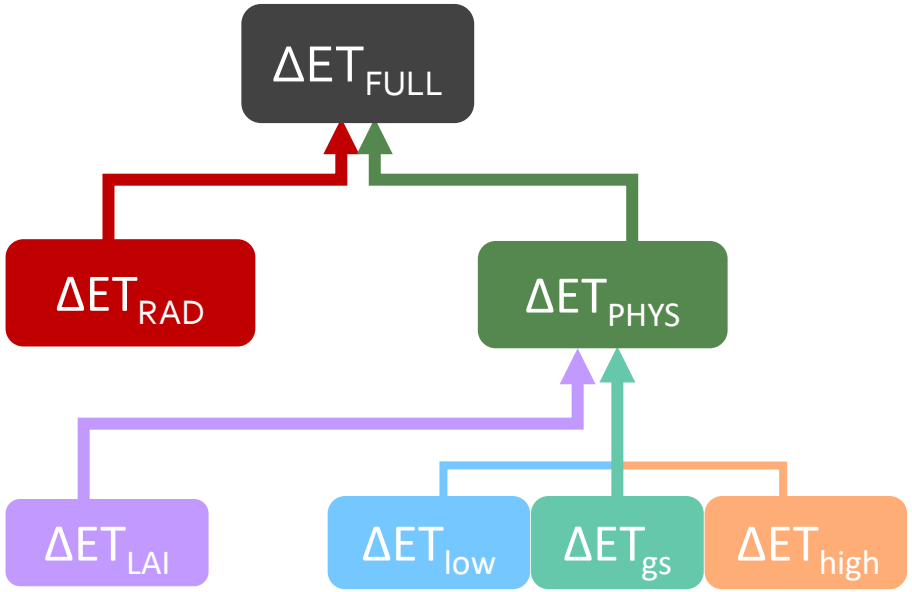
Stomatal uncertainty suggests a *more positive* stomatal driven ET response

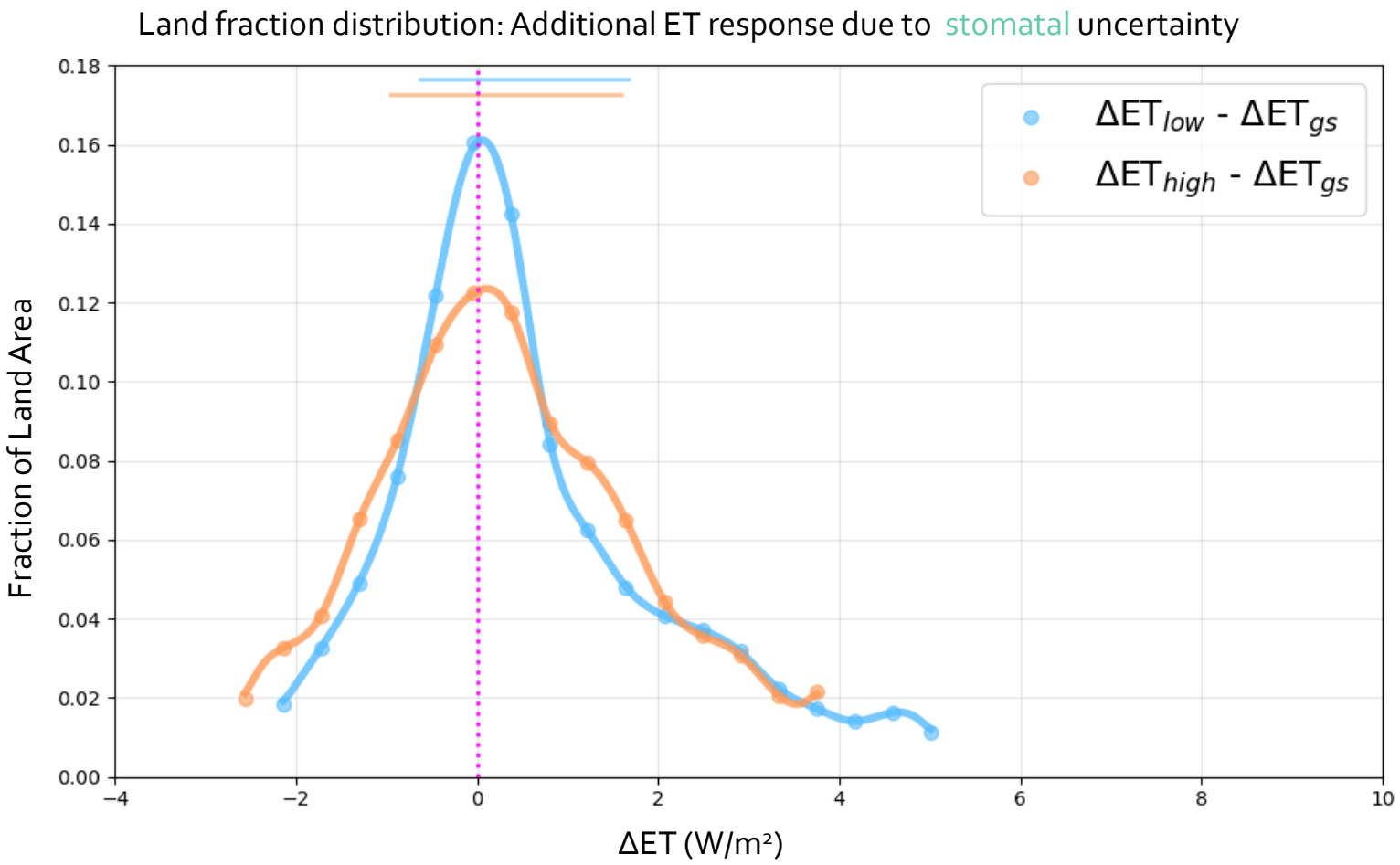


Stomatal uncertainty driven ET response is large relative to ΔET_{gs}

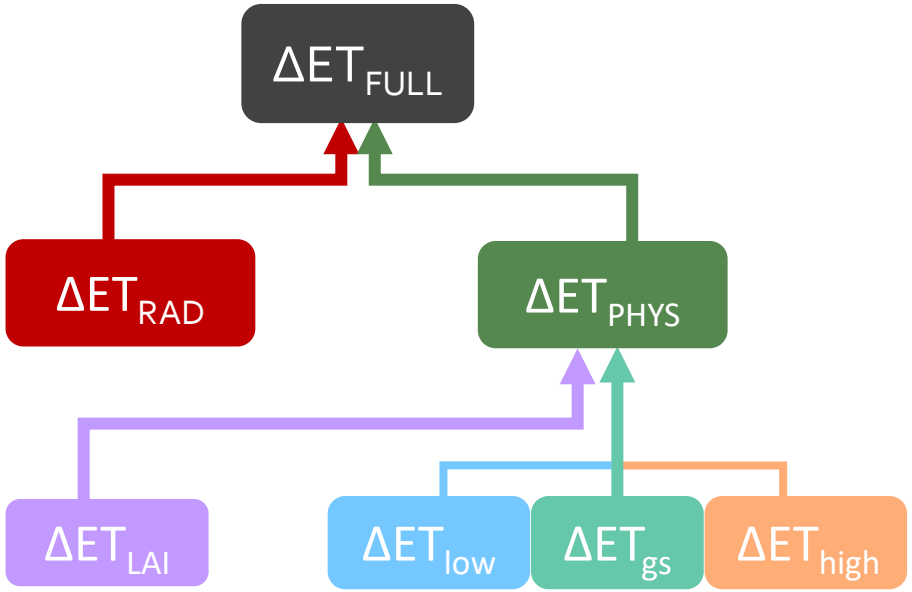


Stomatal uncertainty driven ET response is large relative to ΔET_{gs}

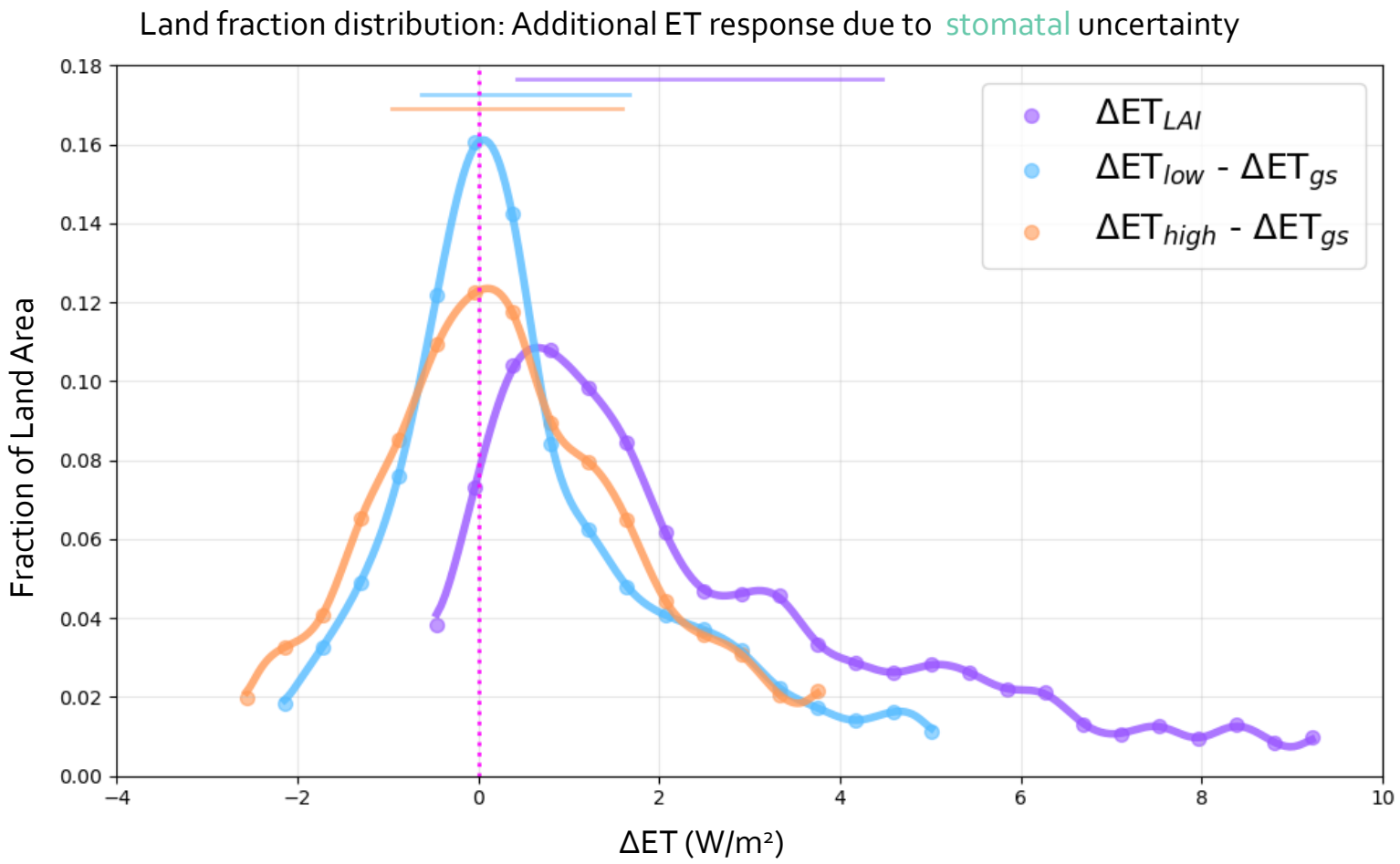




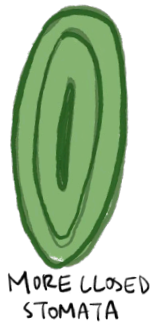
Additional ΔET from stomatal uncertainty is comparable to ΔET_{LAI}



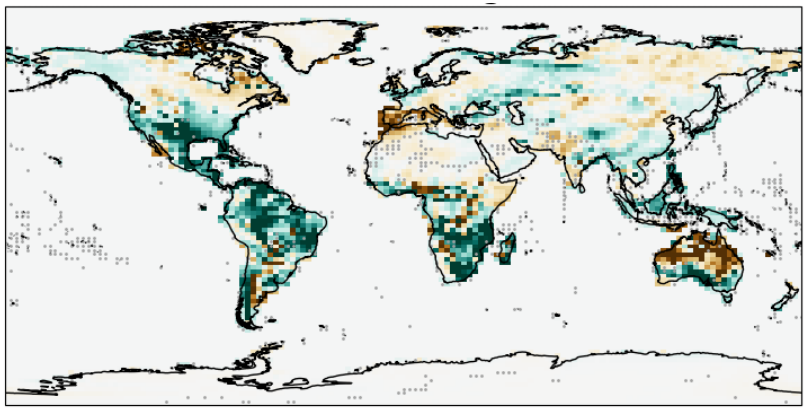
Stomatal uncertainty driven ΔET > ΔET_{LAI} in **~34%** of land area



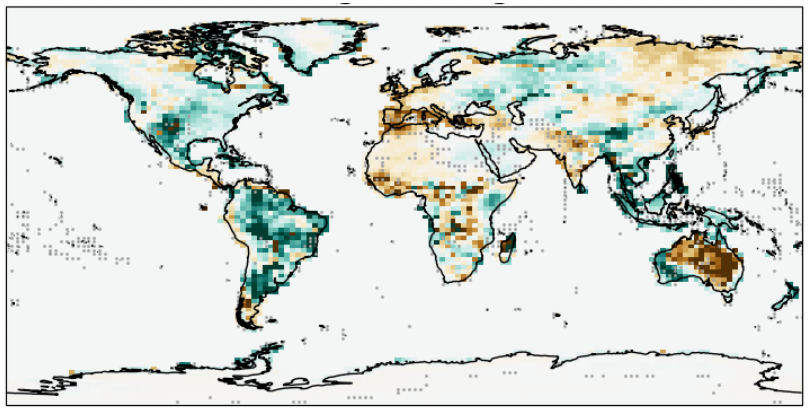
Both low and high g_{1M} have similar increases of additional ET response?

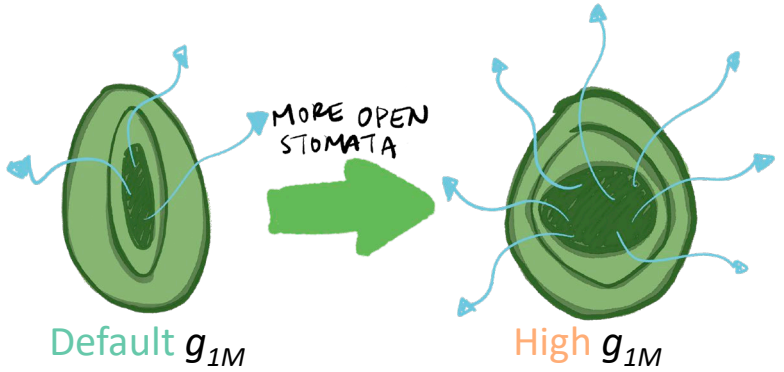


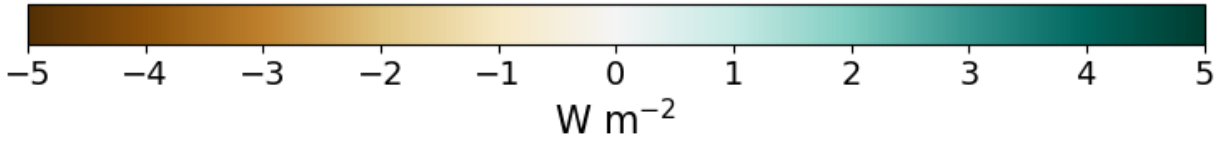
Additional ET response to eCO_2 due to low g_{1M}



Additional ET response to eCO_2 due to high g_{1M}







Summary

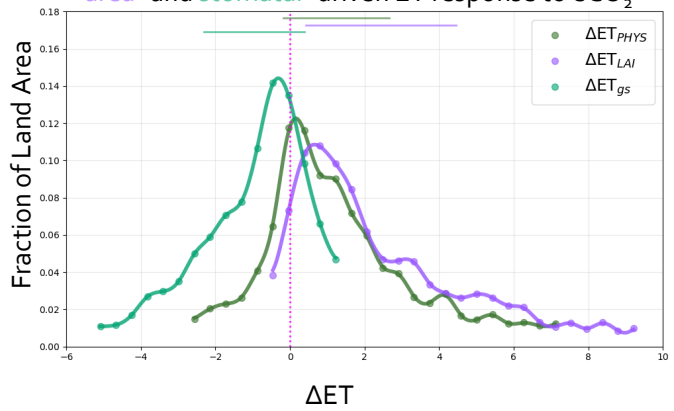
Physiological influence accounts for ~25% of ET response to eCO_2

Physiological influence is largely driven by leaf area, and stomata and leaf area have opposing effects on ET

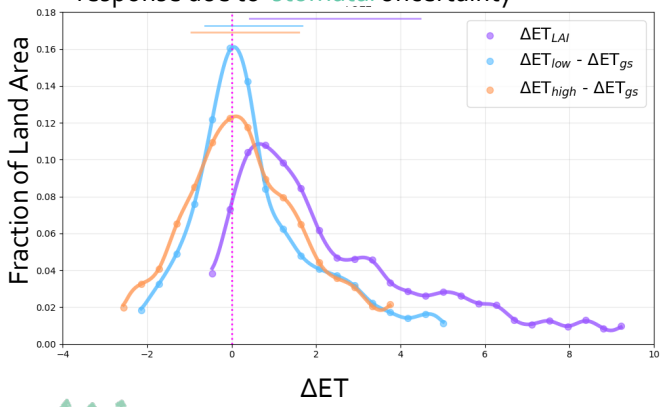
Stomatal uncertainty > leaf area growth effects on ET ~34% of land

Both high and low g_{1M} cause increases in ET under eCO_2 for different reasons

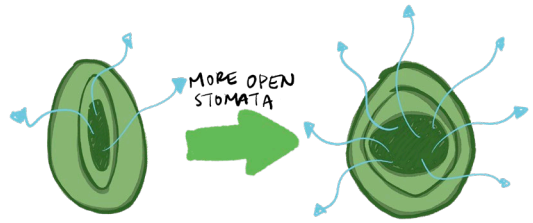
Land fraction distribution: Physiologically-, leaf area- and stomatal- driven ET response to eCO_2



Land fraction distribution: Additional ET response due to stomatal uncertainty



For low g_{1M}



For high g_{1M}

Contact: amyxliu@uw.edu