

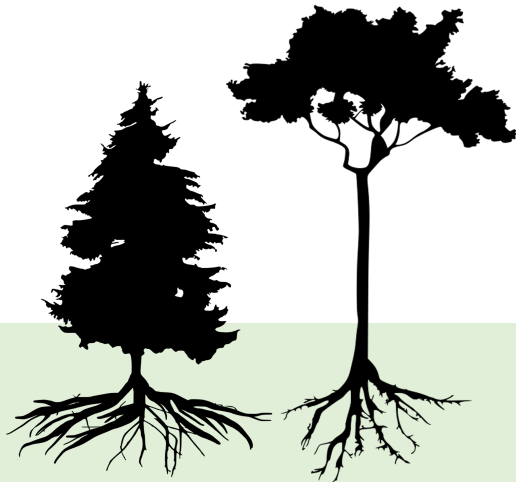
# Atmospheric modulation of evapotranspiration depends on the climatological moisture regime

Claire Zarakas and Abigail Swann

# ET impacts climate, and climate impacts ET

Atmosphere

$\Delta ET \rightarrow \Delta \text{Climate}$

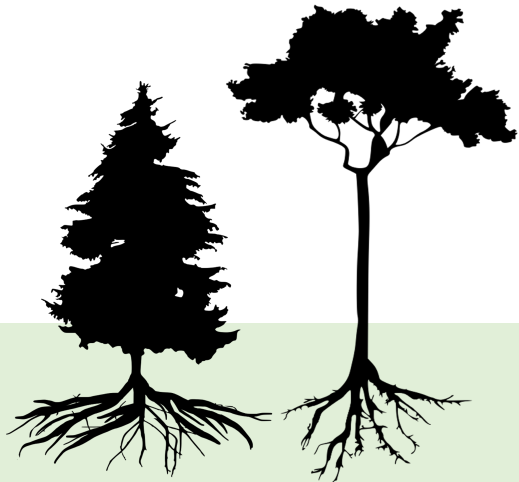


Land

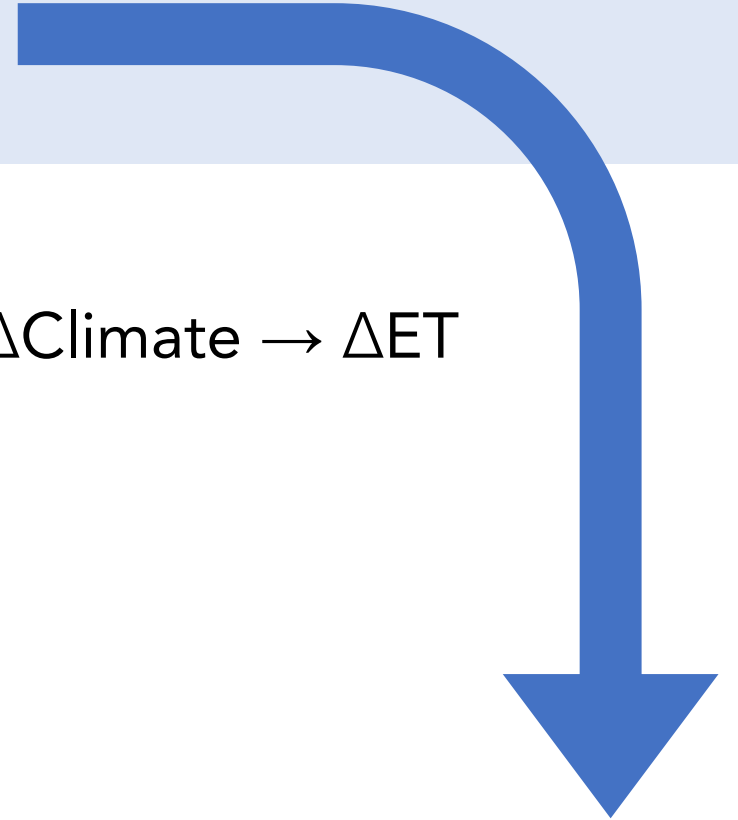
# ET impacts climate, and climate impacts ET

Atmosphere

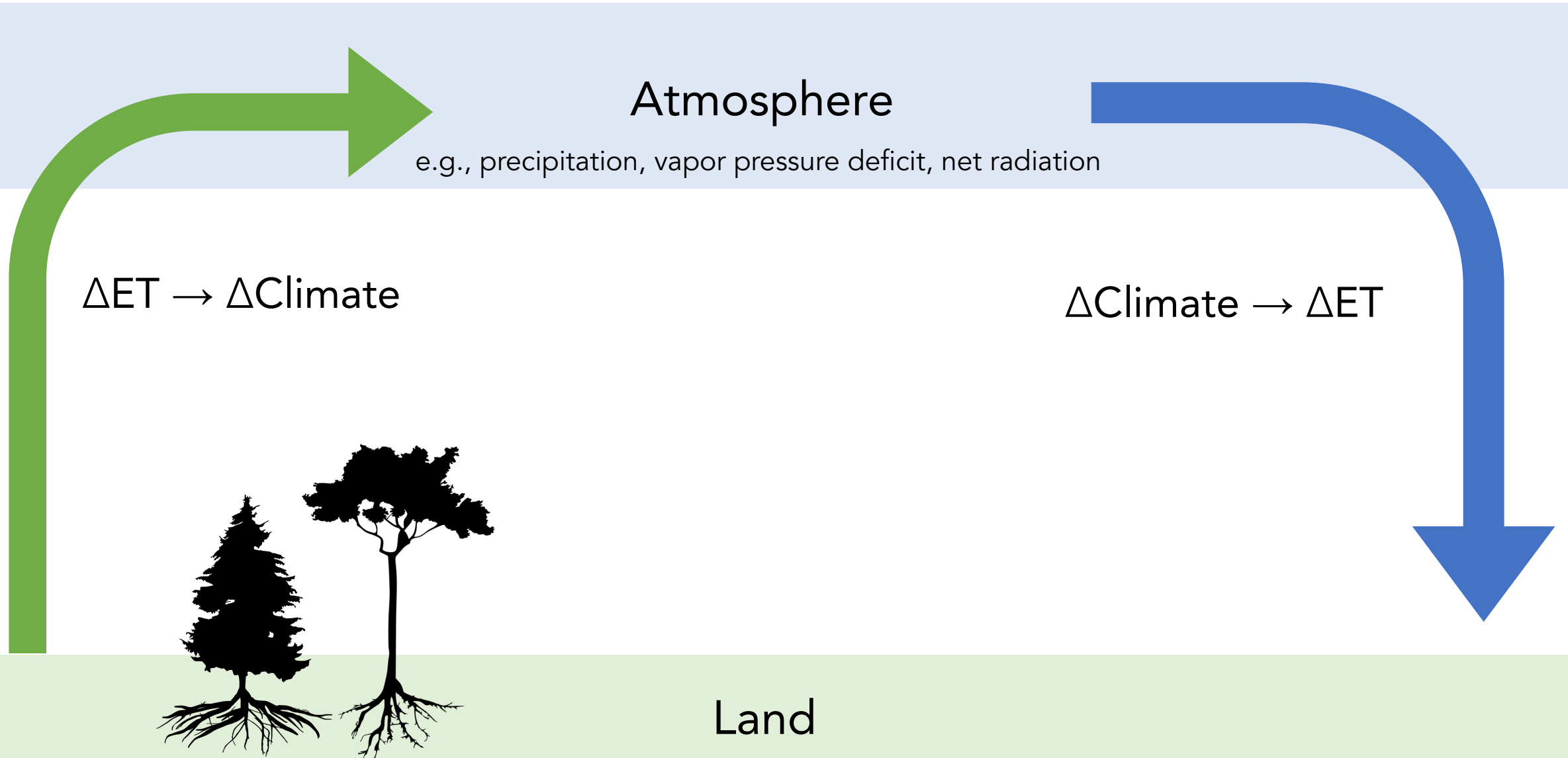
$\Delta\text{Climate} \rightarrow \Delta\text{ET}$



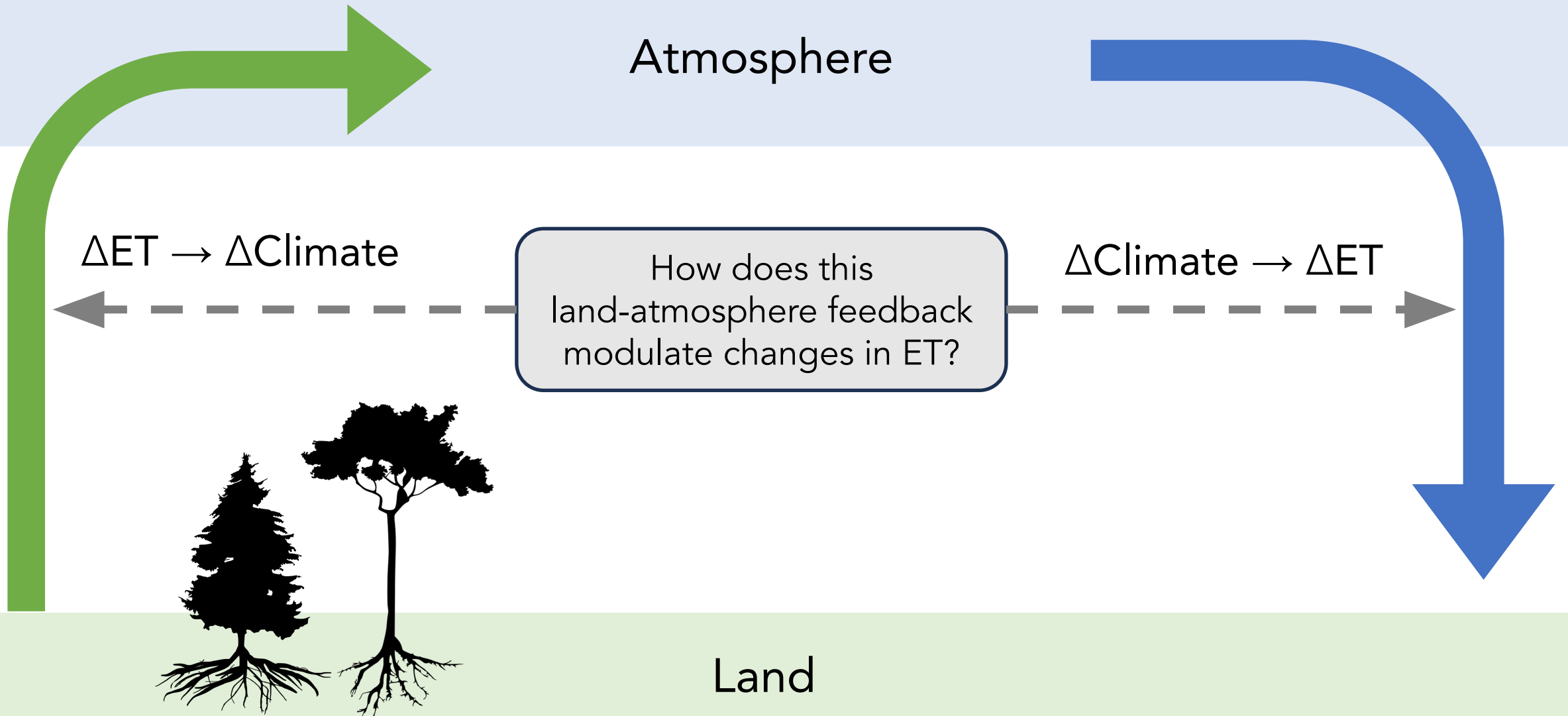
Land



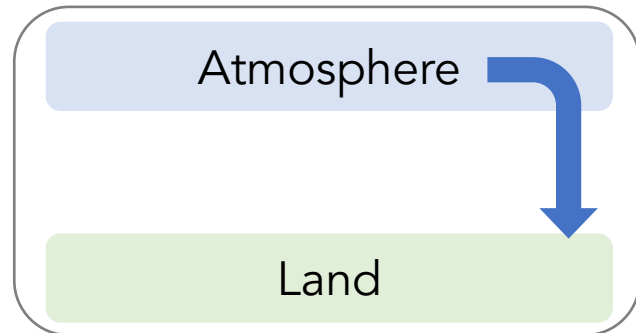
# ET impacts climate, and climate impacts ET



# ET impacts climate, and climate impacts ET



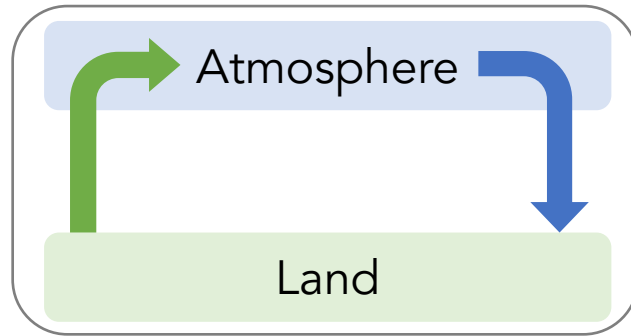
# Most studies are not designed to disentangle land-atmosphere feedbacks



Land-only framework alone:

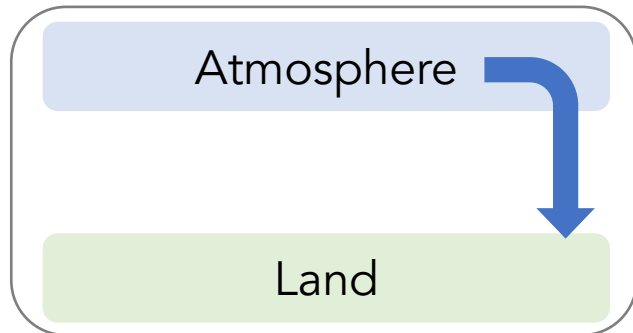
- does not account for land-atmosphere feedbacks

# Most studies are not designed to disentangle land-atmosphere feedbacks



## Coupled framework alone:

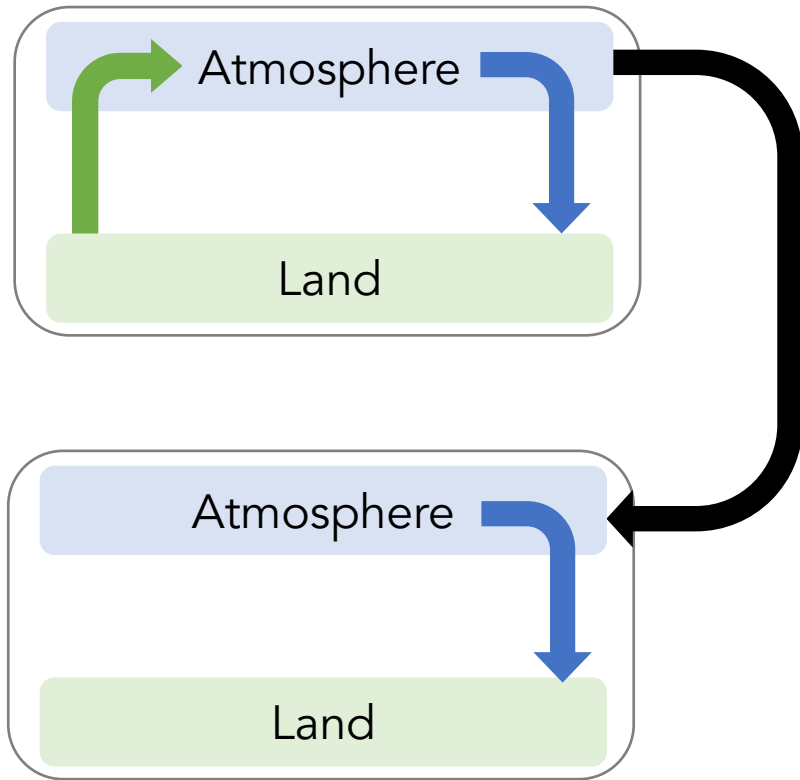
- includes land-atmosphere feedbacks
- does not disentangle how much of the net response is from land-atmosphere feedbacks



## Land-only framework alone:

- does not account for land-atmosphere feedbacks

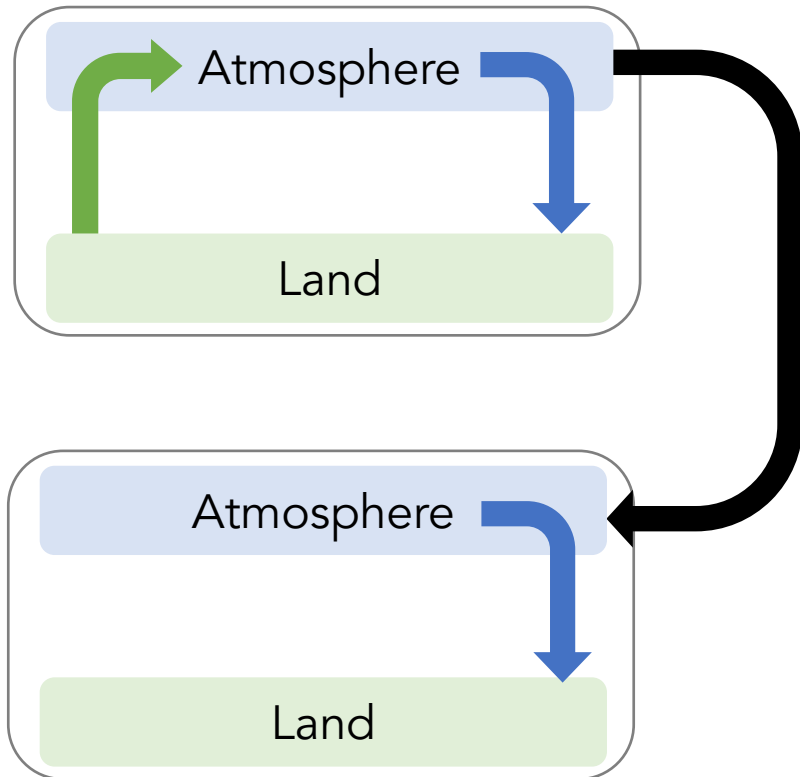
# Using paired perturbed parameter ensembles (PPEs) to isolate the impact of atmospheric feedbacks



- Ran two perturbed parameter ensemble (PPEs):
  - coupled: dynamic atmosphere
  - land-only: atmosphere from coupled default simulation
- Ran one-at-a-time simulations that perturbed 18 land parameters to min and max values



# Using paired perturbed parameter ensembles (PPEs) to isolate the impact of atmospheric feedbacks

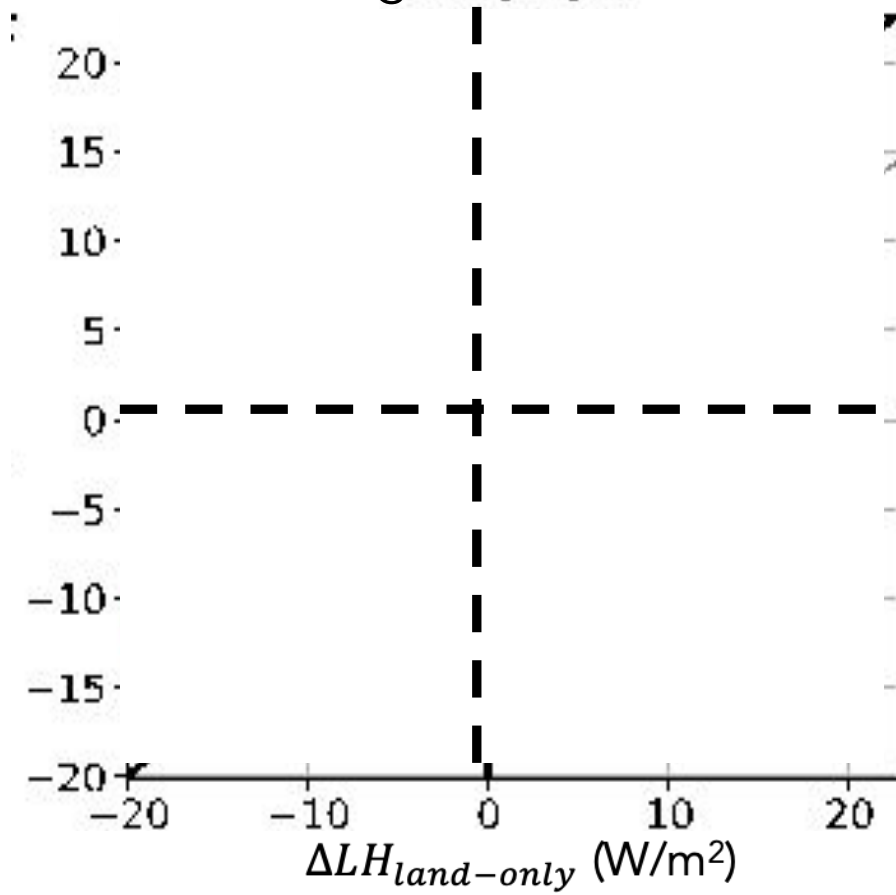


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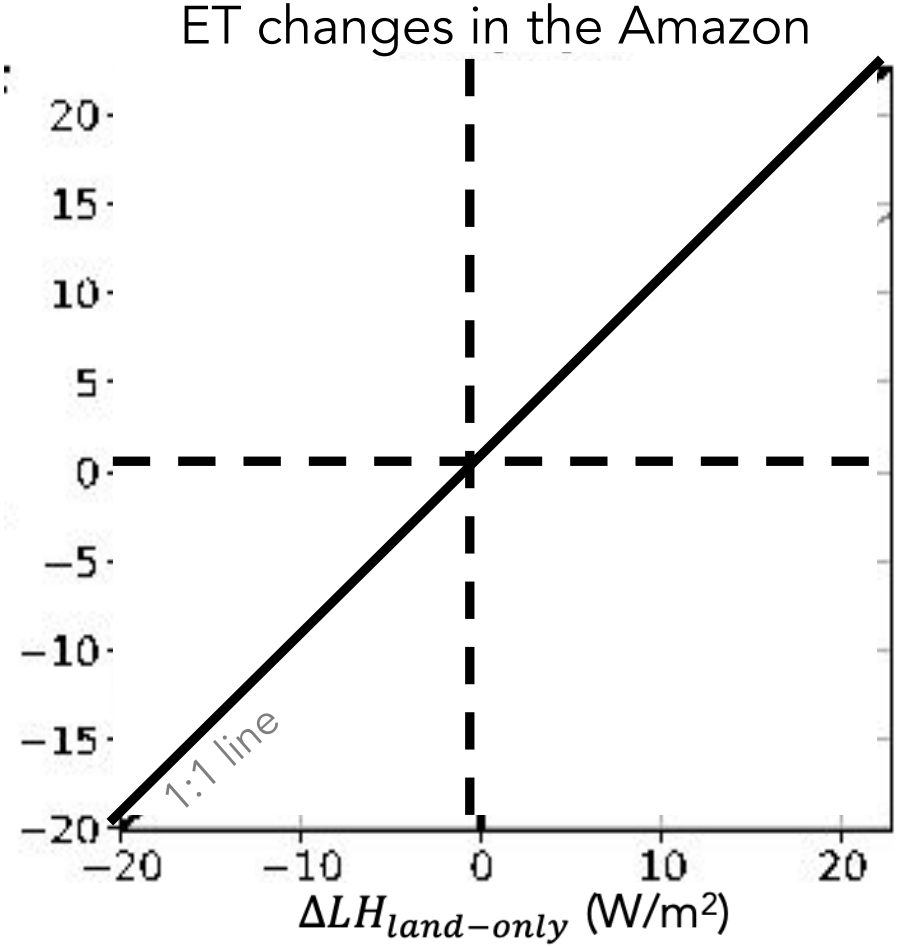
This study is using PPEs as a tool to learn about land-atmosphere feedbacks (not a parameter estimation/uncertainty study!)

# Pairwise comparison of land-only and coupled simulations

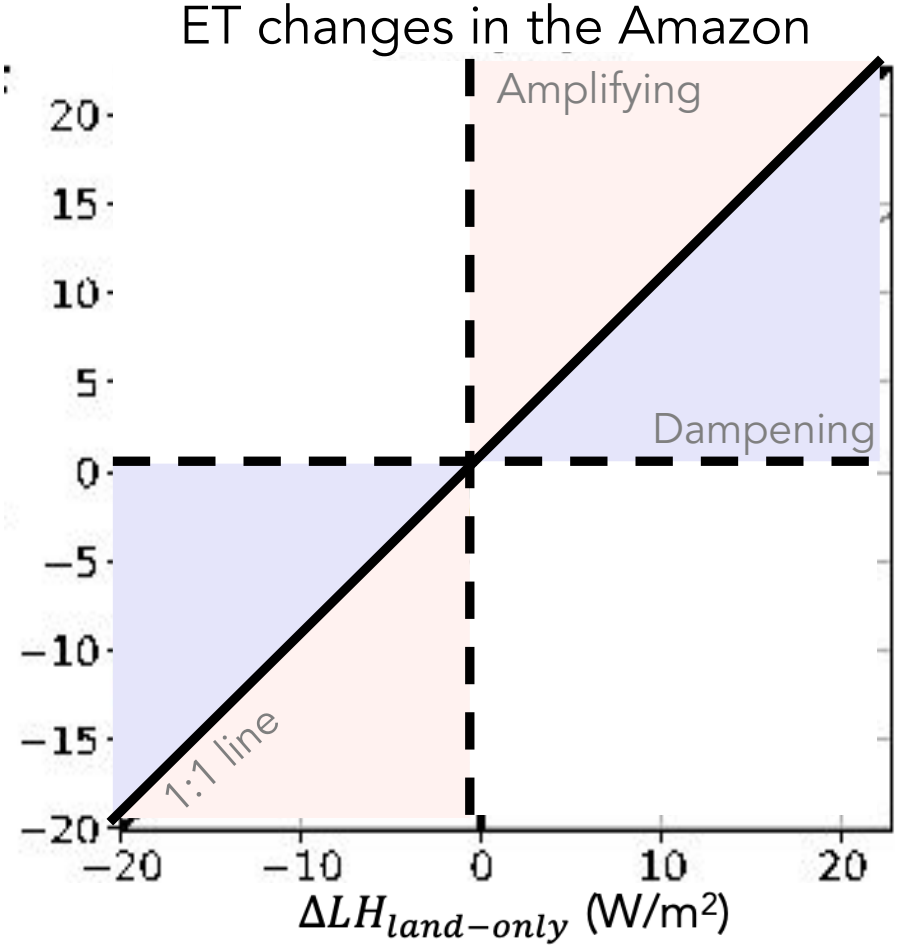
ET changes in the Amazon



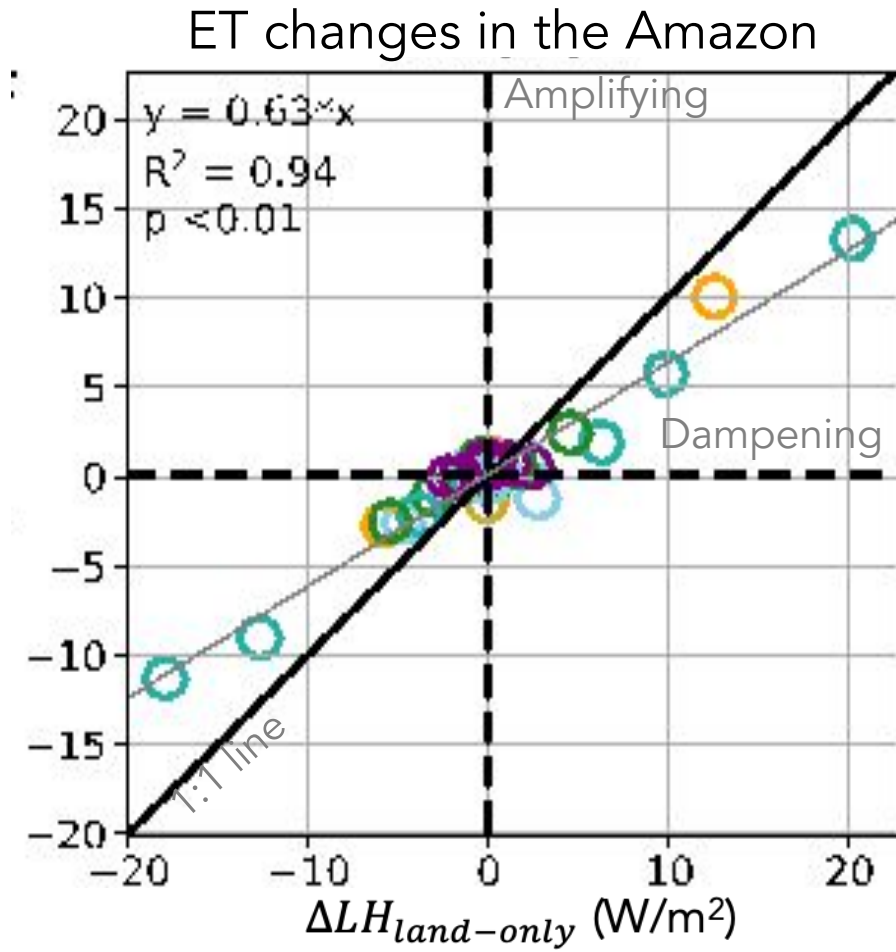
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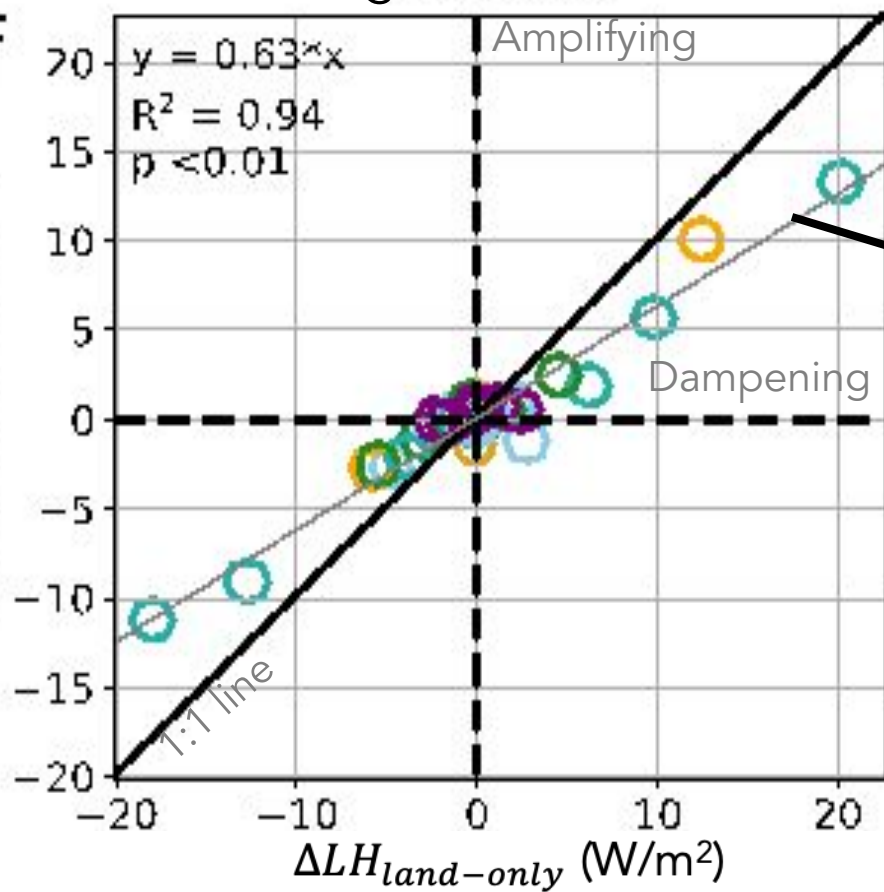


# Atmospheric feedbacks dampen ET changes in the Amazon

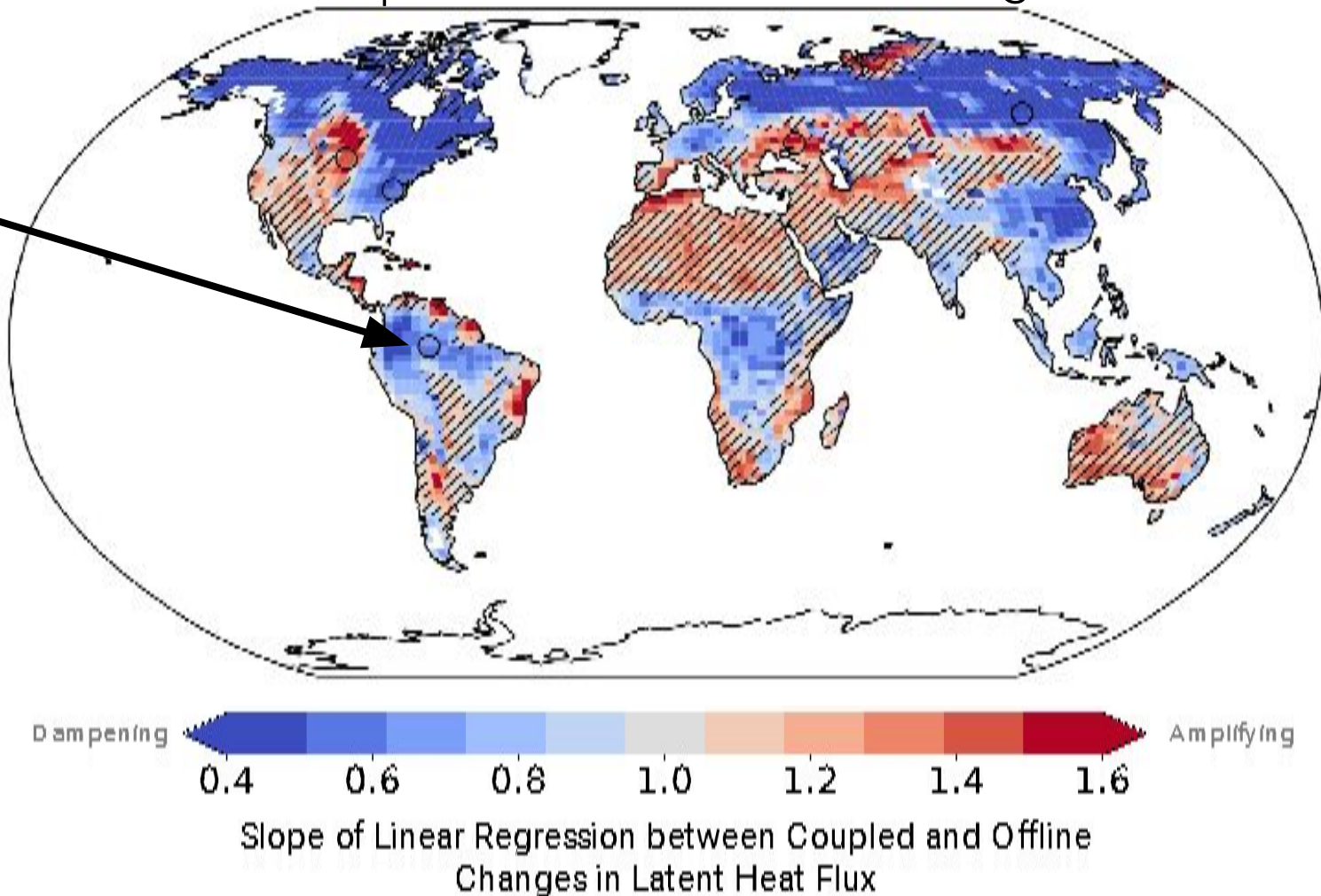


# Atmospheric feedbacks' influence on ET varies spatially

## ET changes in the Amazon



## Atmospheric modulation of ET changes



Stippling indicates not statistically significantly different from 1

# Budyko (1956) conceptual framework for constraints on land ET

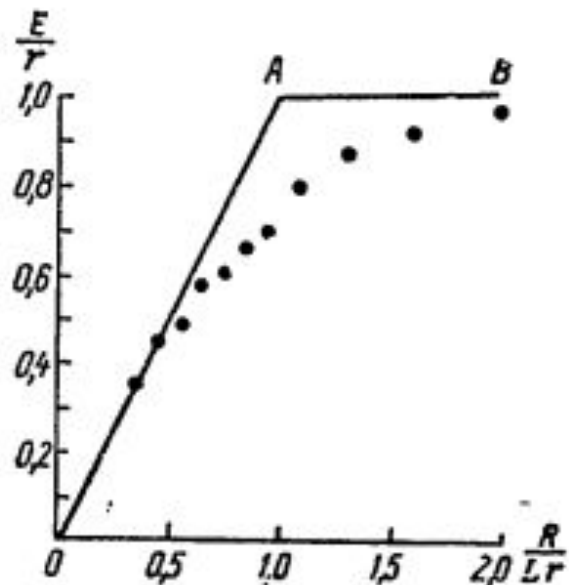


Figure 47

Dependence of the evaporation and precipitation ratio on the radiational index of dryness.

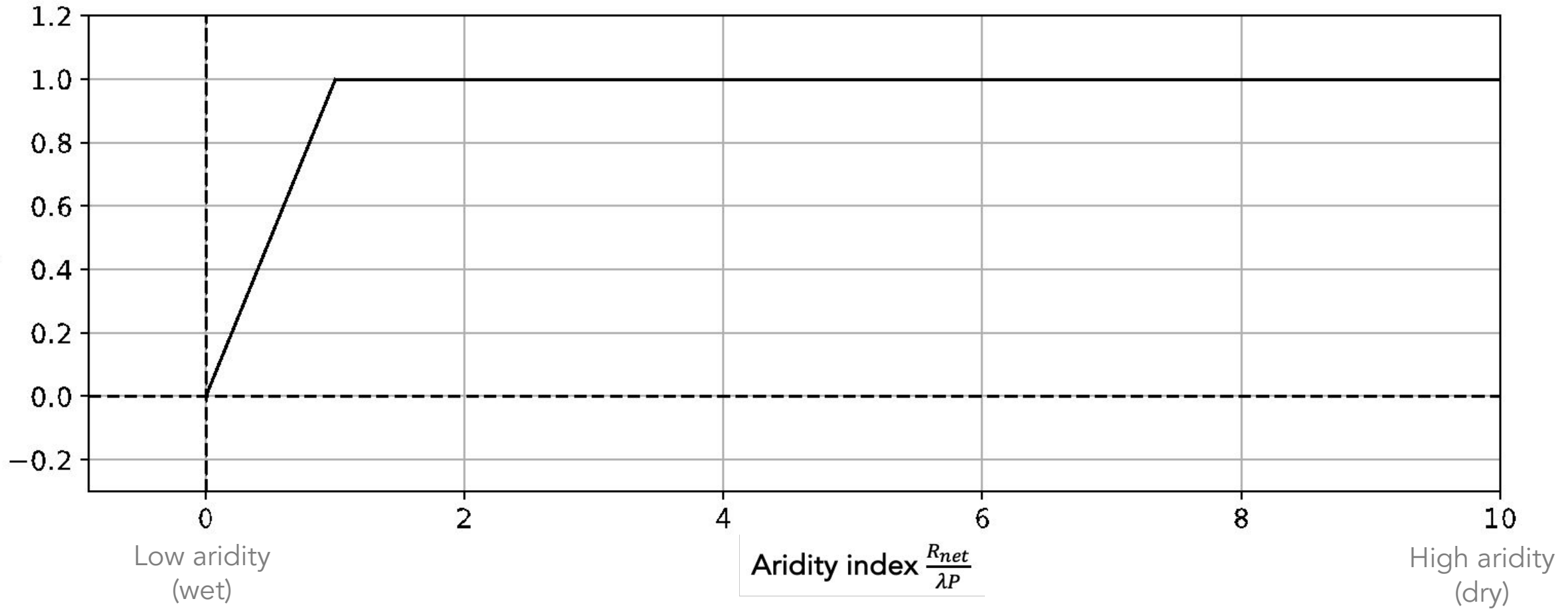
THE HEAT BALANCE OF THE EARTH'S SURFACE

by M.I. BUDYKO

Translated by  
Nina A. Stepanova  
Office of Climatology

from  
(Teplovoj balans zemnoj poverkhnosti.  
Gidrometeorologicheskoe izdatel'stvo,  
Leningrad, 1956.  
255 pages)

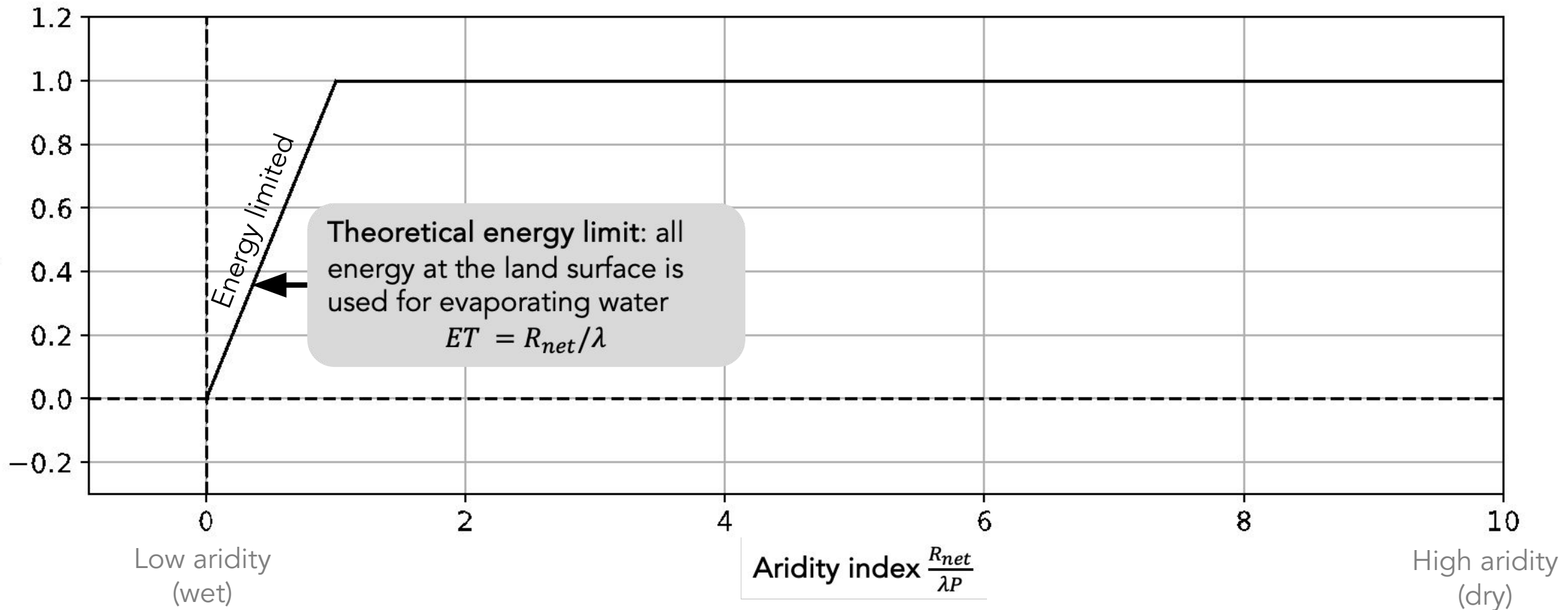
# Budyko (1956) conceptual framework for constraints on land ET



$R_{net}$  = net radiation at the land surface;  $ET$  = evapotranspiration;  $P$  = precipitation;  $\lambda$  = latent heat of vaporization

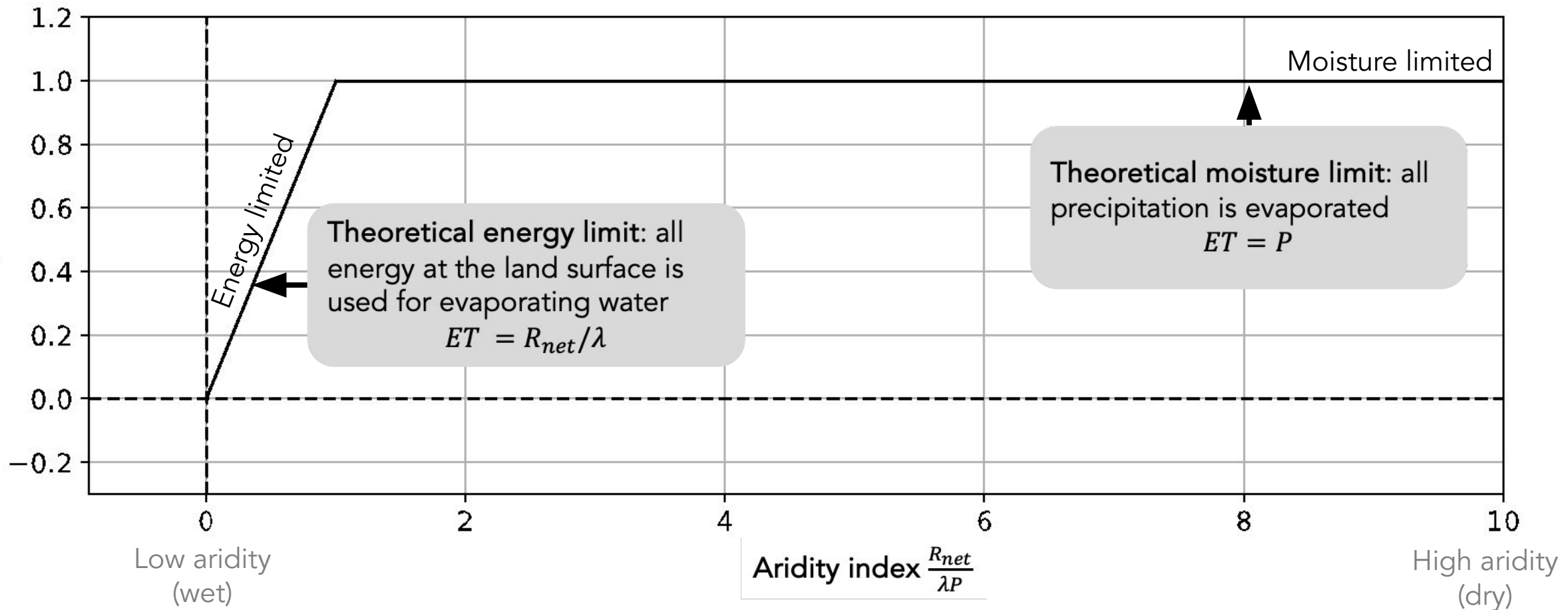


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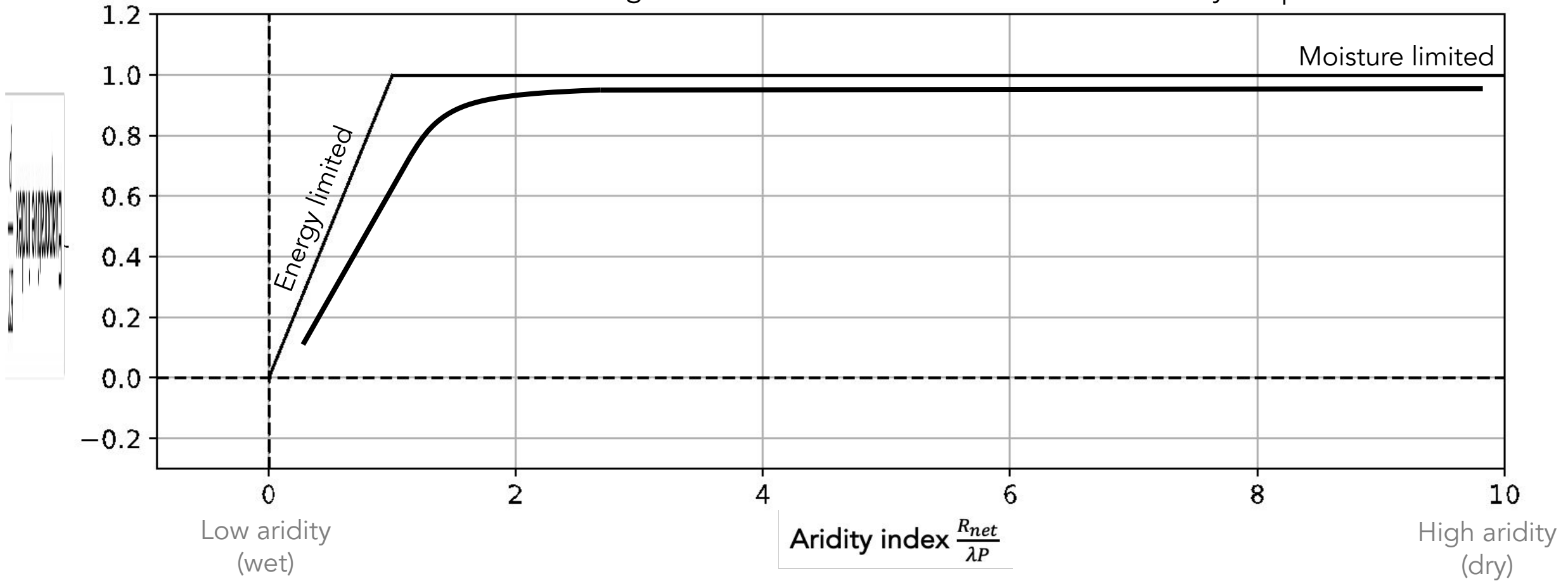
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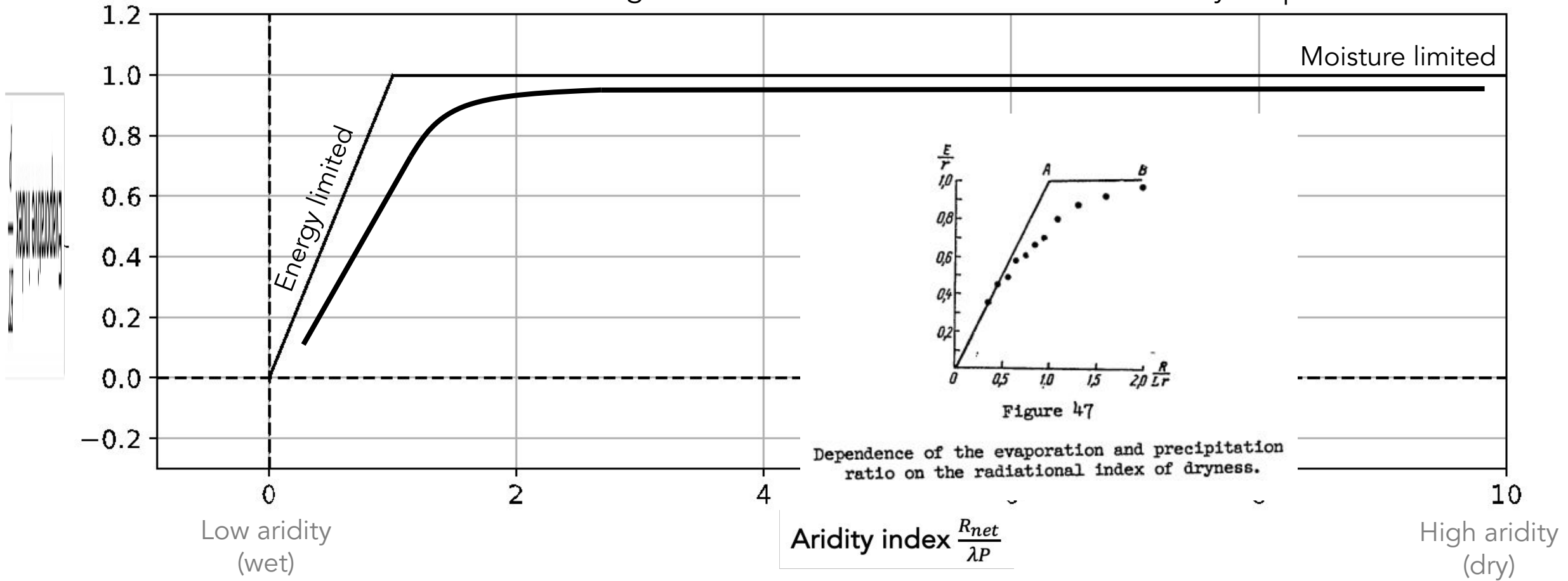
Distribution of all land grid cells in our reference simulation in Budyko space



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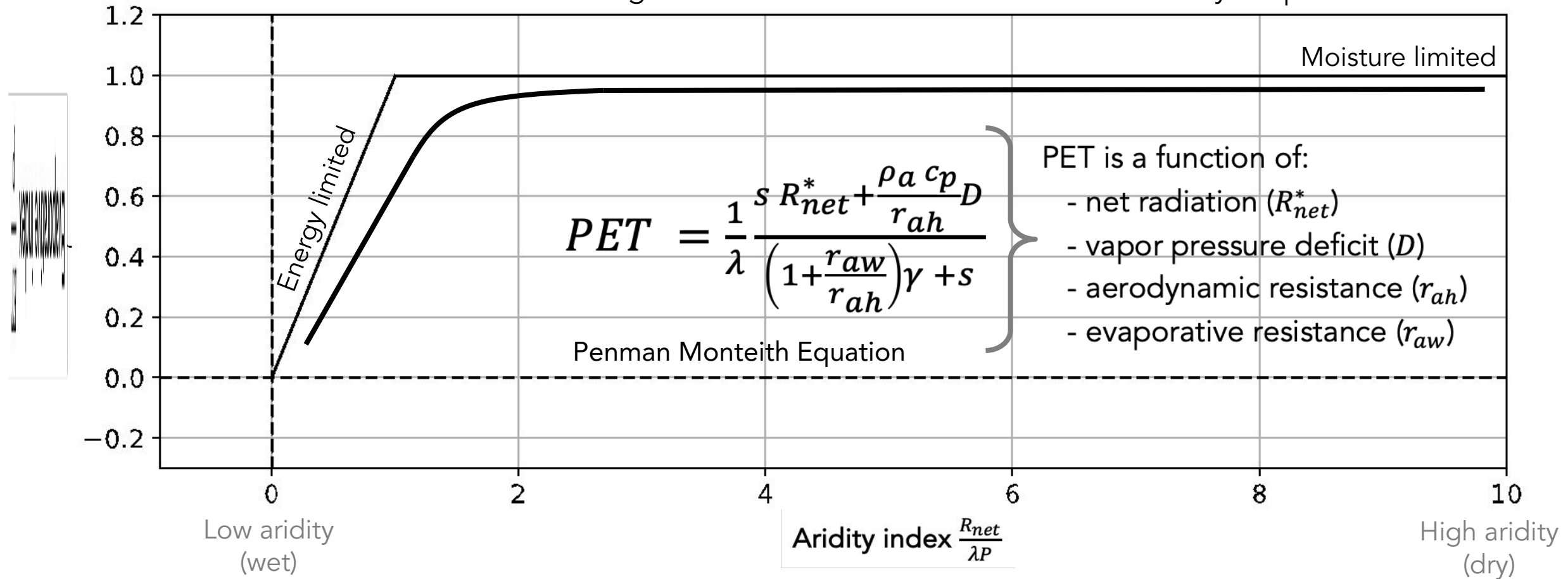
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Distribution of all land grid cells in our reference simulation in Budyko space

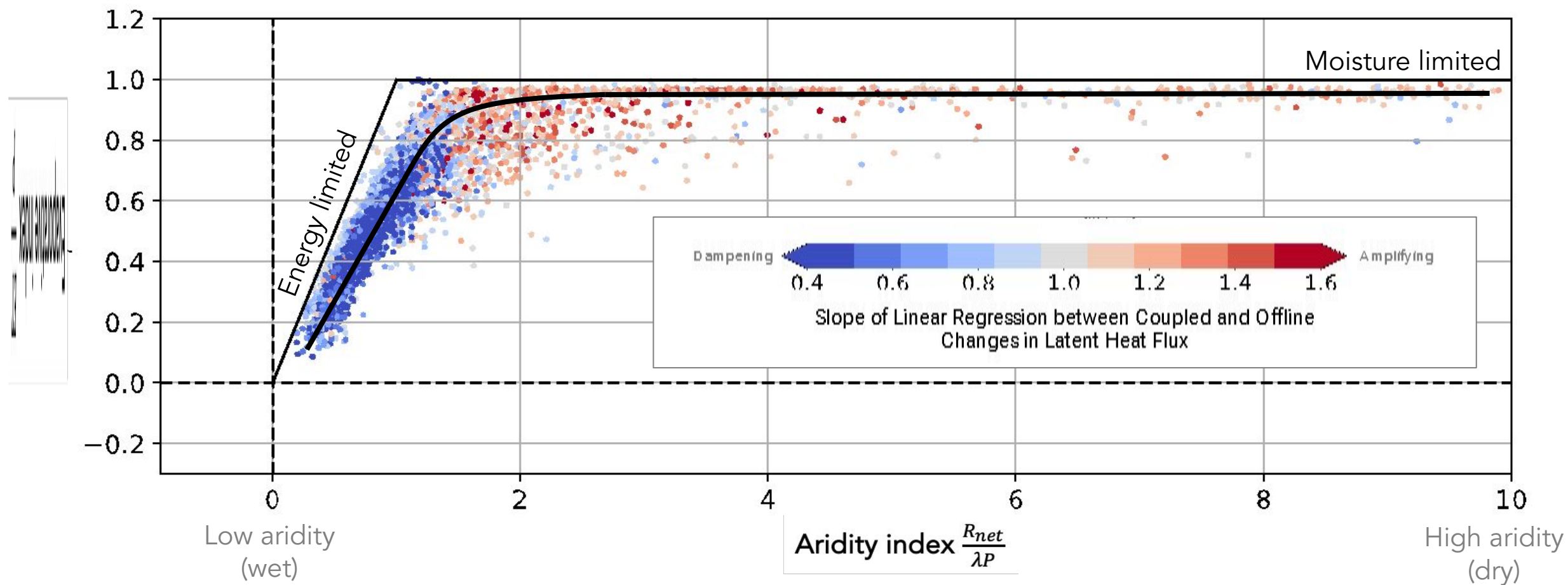


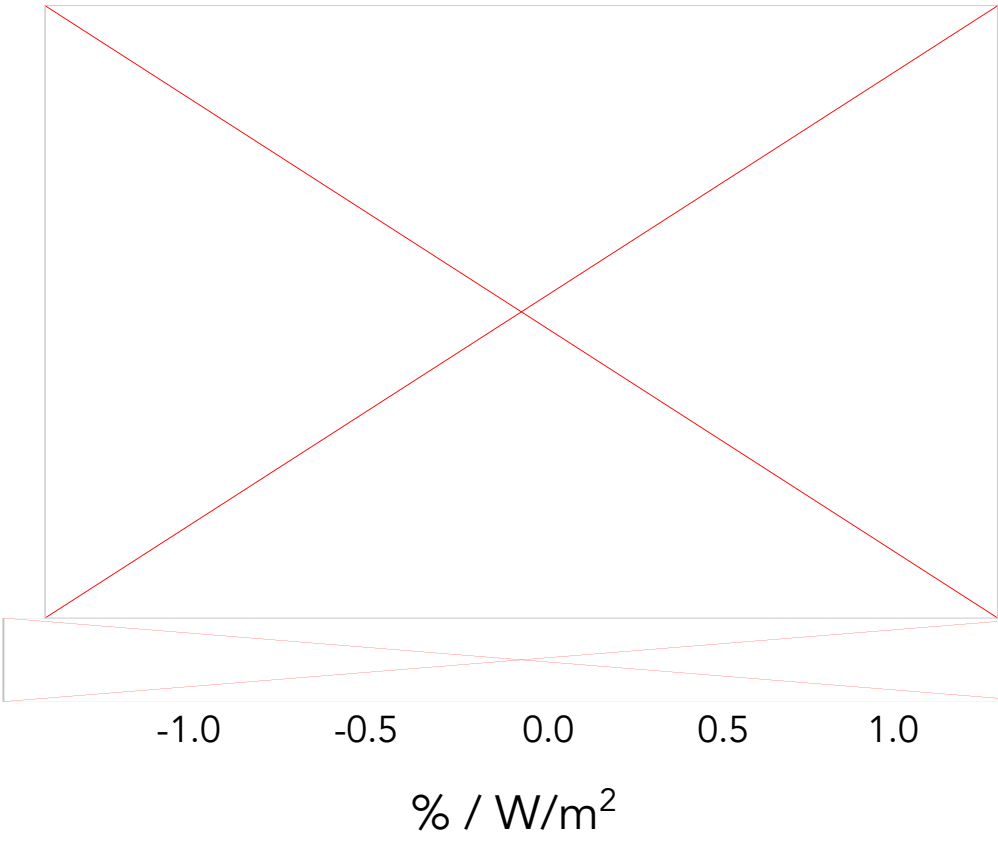
# Potential evapotranspiration (PET) depends on more than net radiation

Distribution of all land grid cells in our reference simulation in Budyko space



# Influence of atmospheric feedbacks depends on the climatological moisture regime

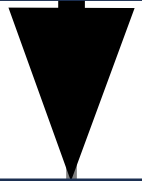




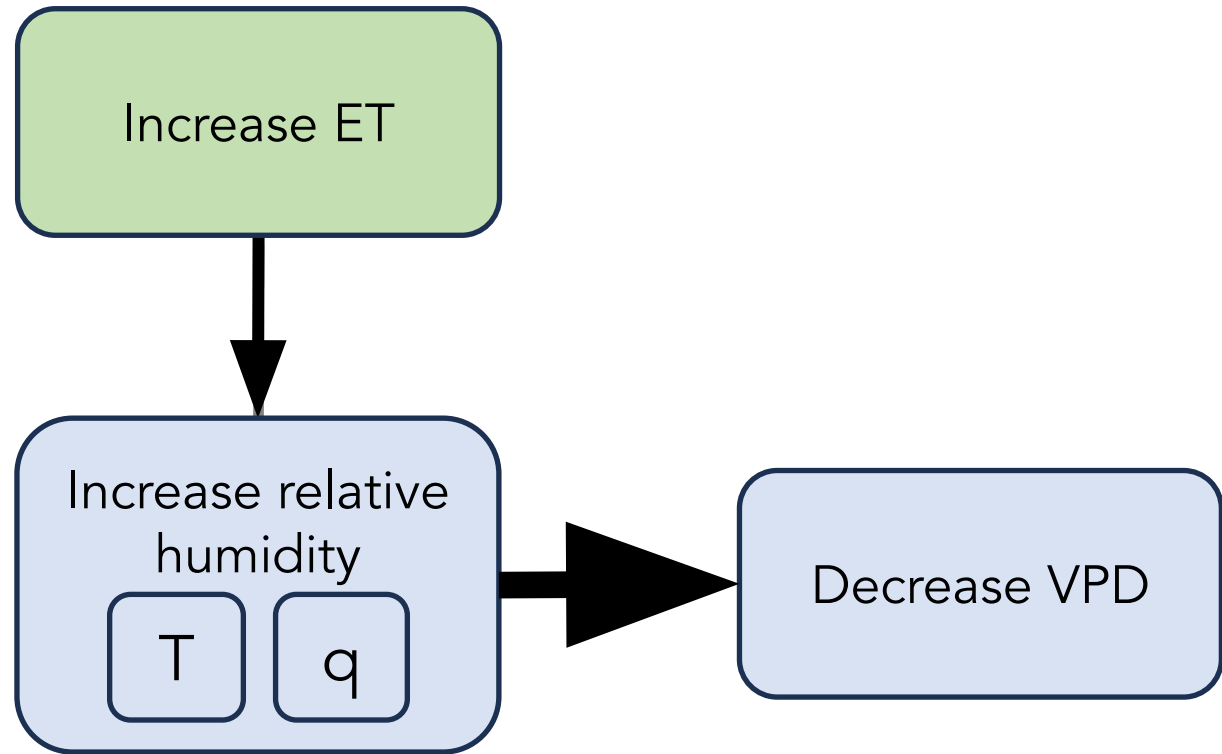
Increase ET

Increase relative humidity

T q

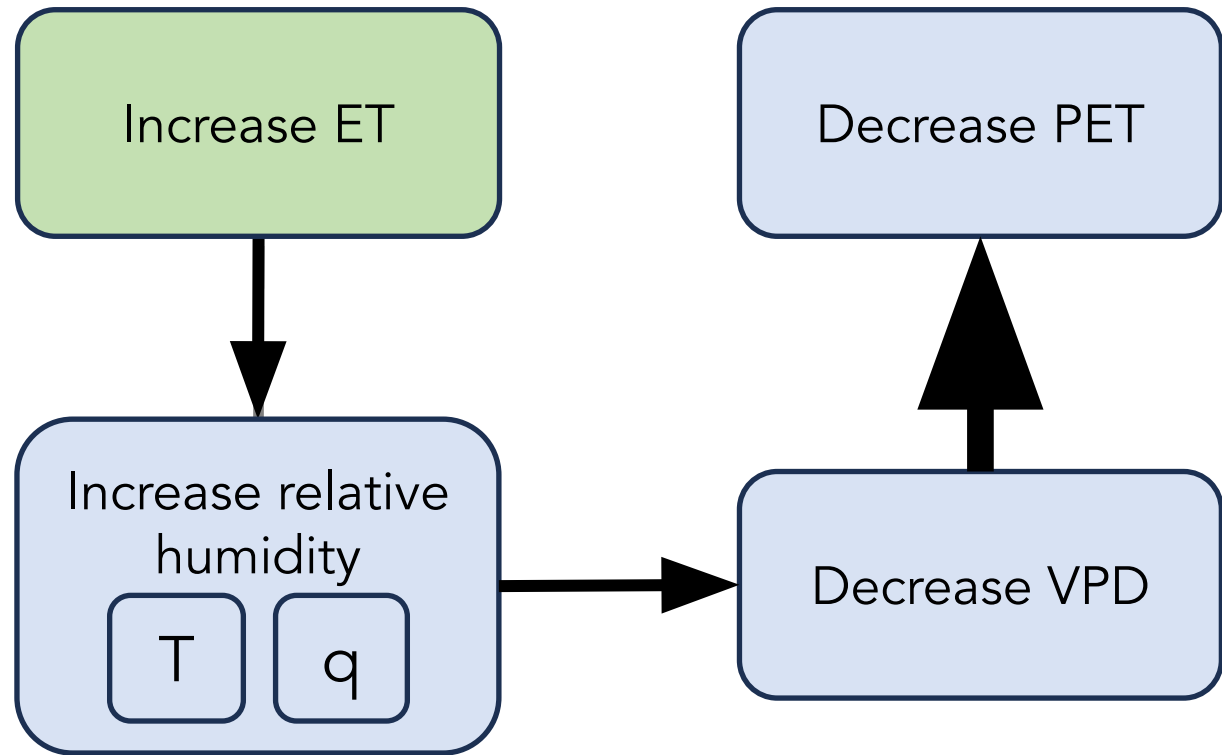


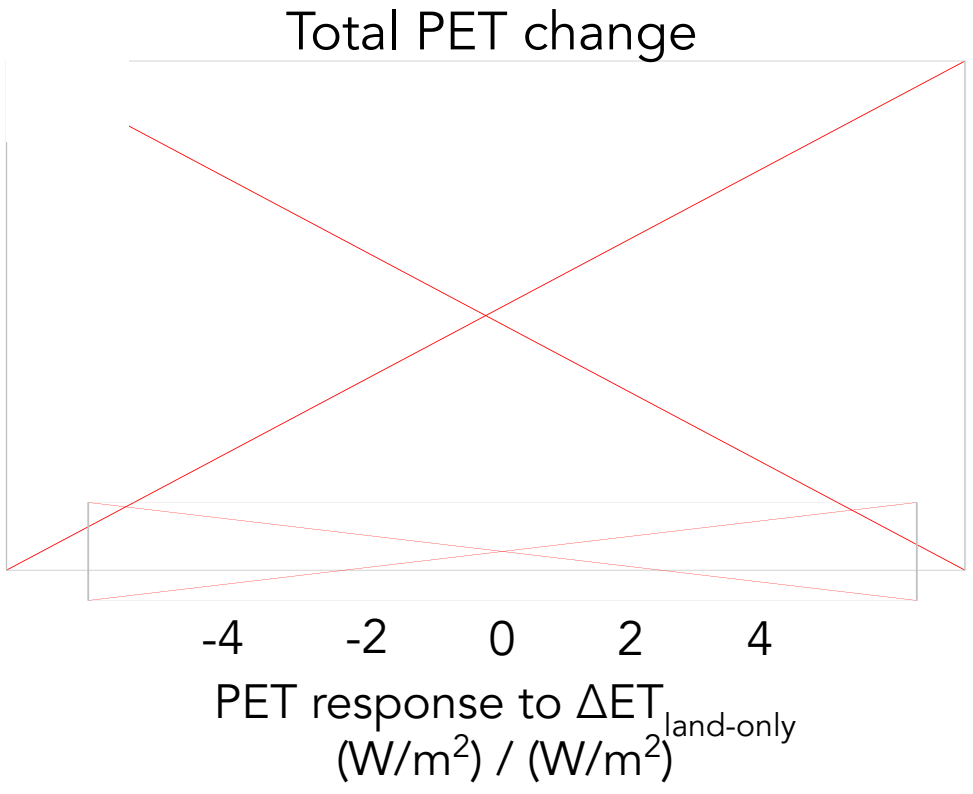
Dominant mechanism in wet  
(energy-limited) regime:



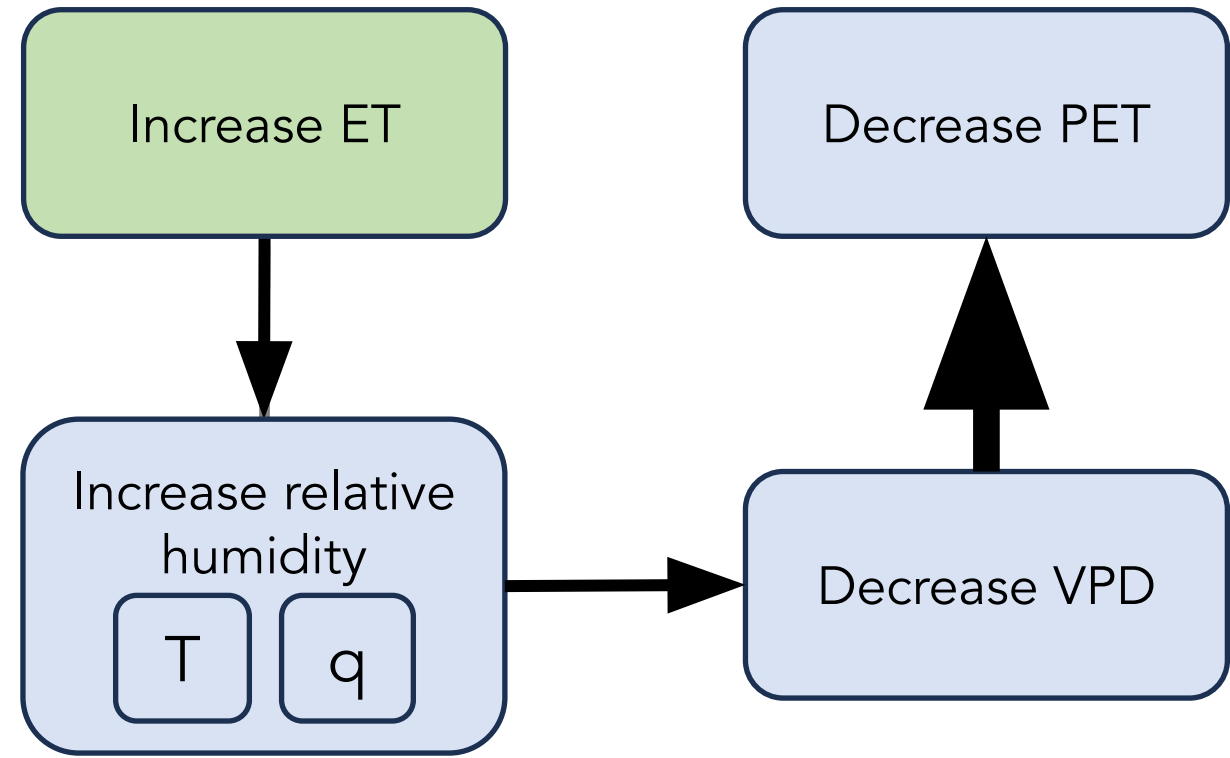


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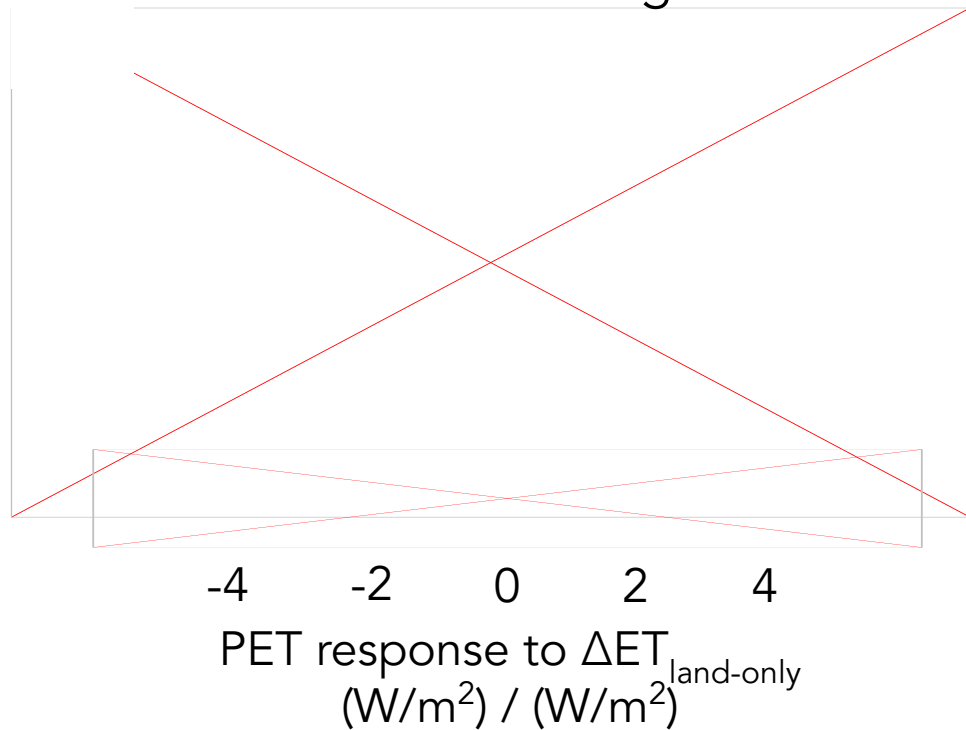




Dominant mechanism in wet  
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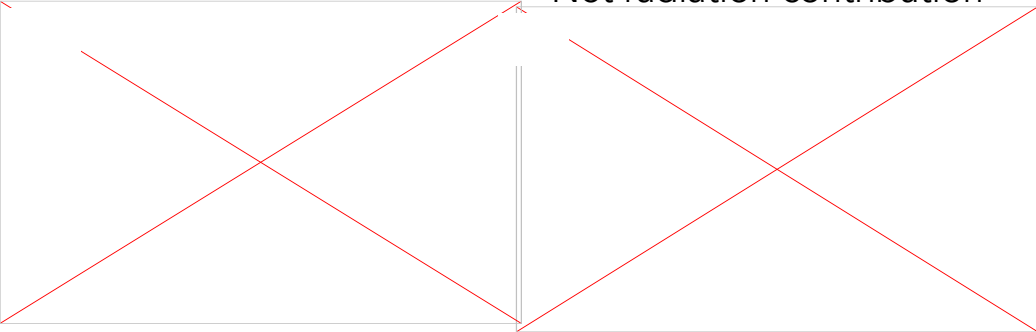


Total PET change

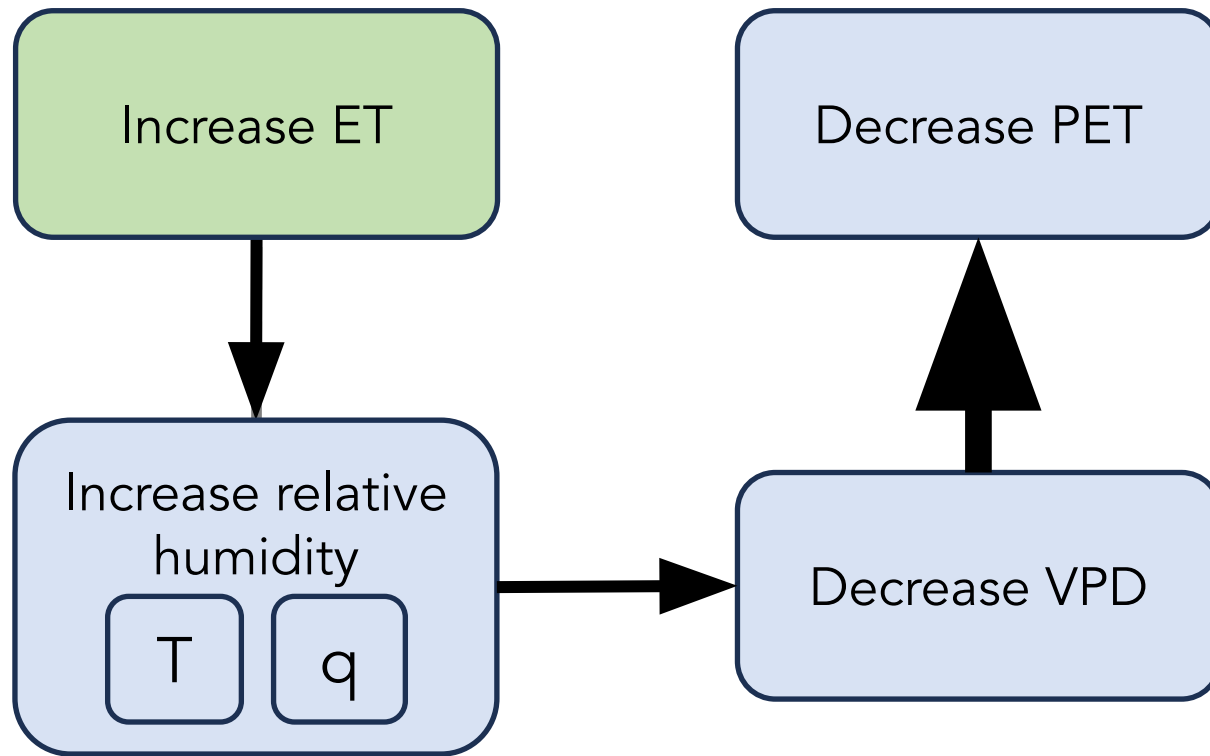


VPD contribution

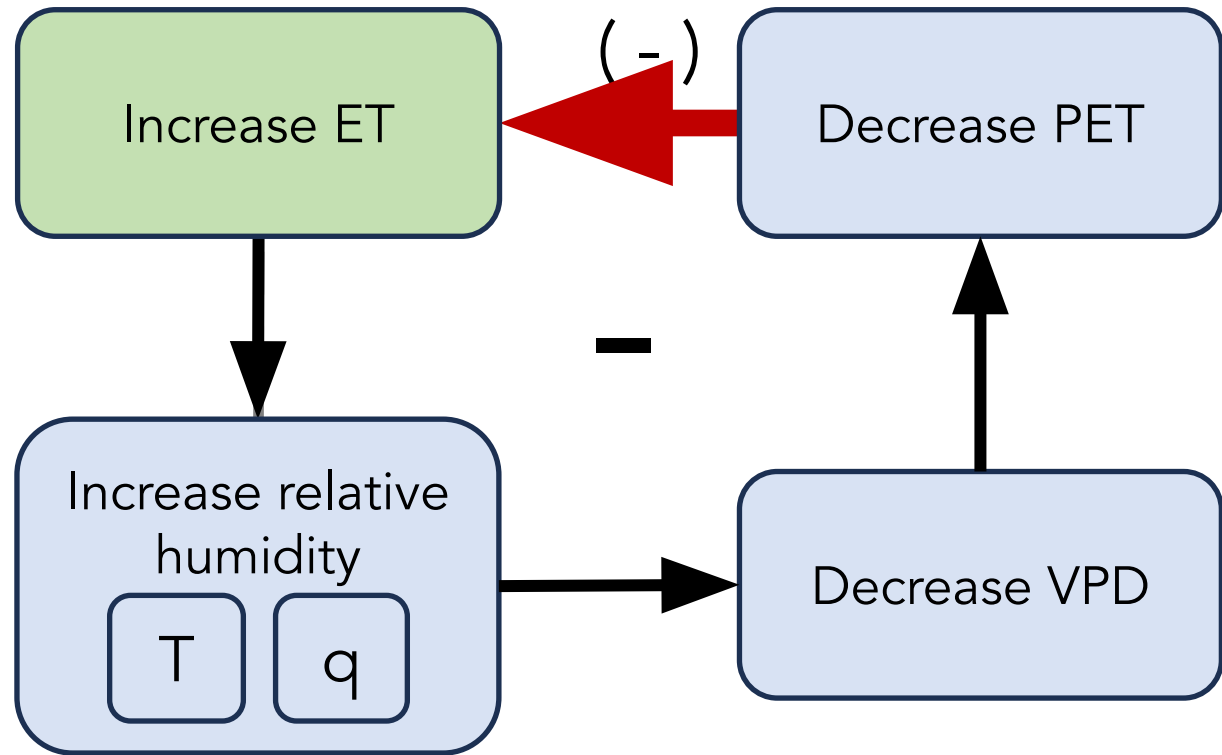
Net radiation contribution



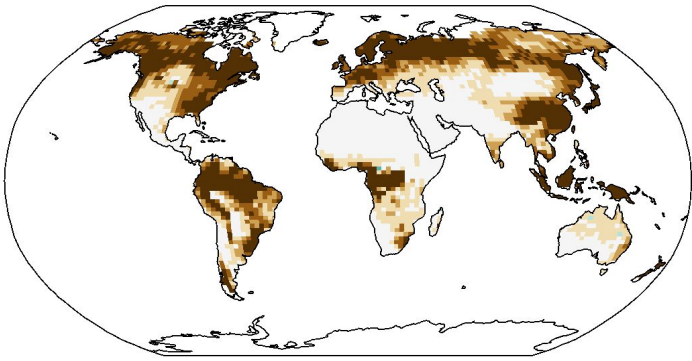
Dominant mechanism in wet  
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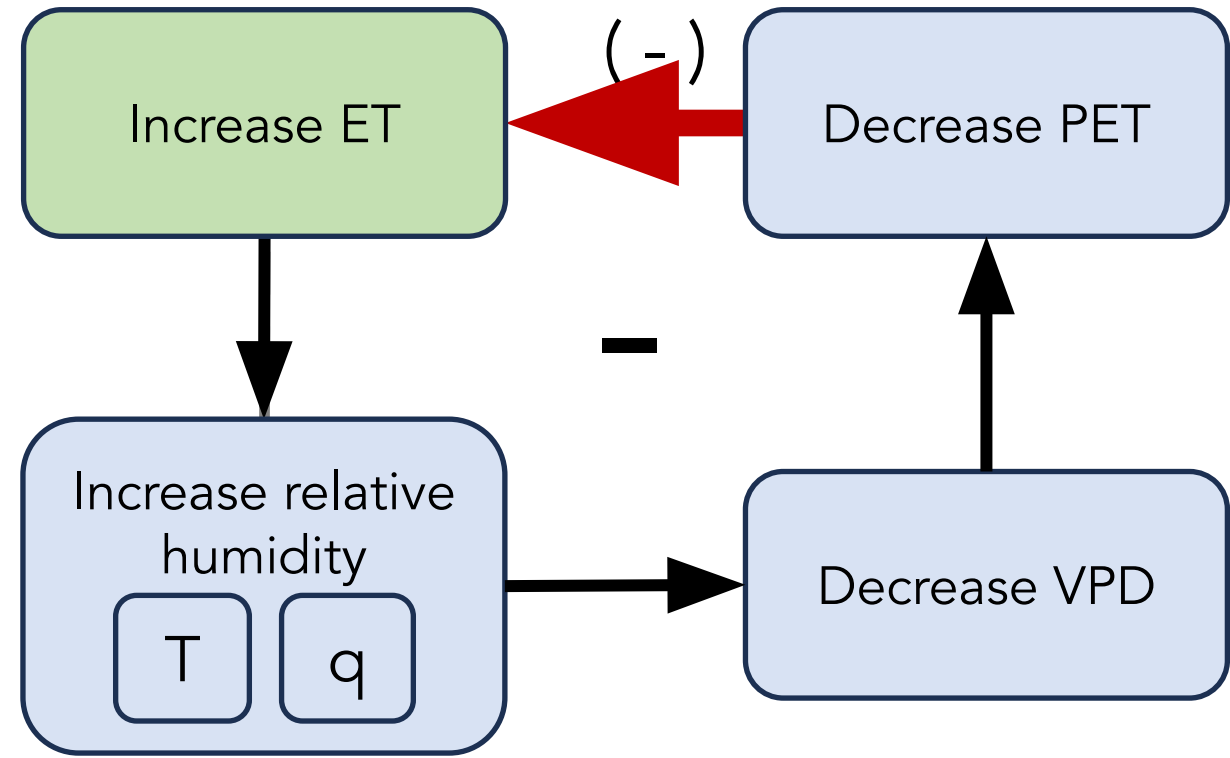
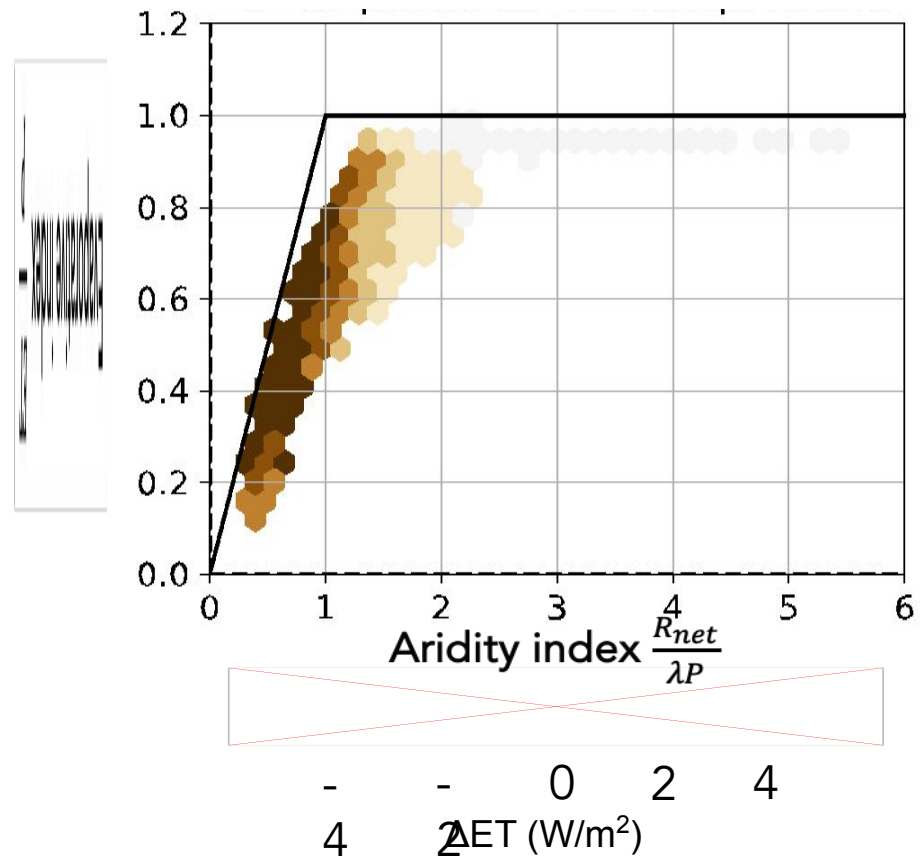
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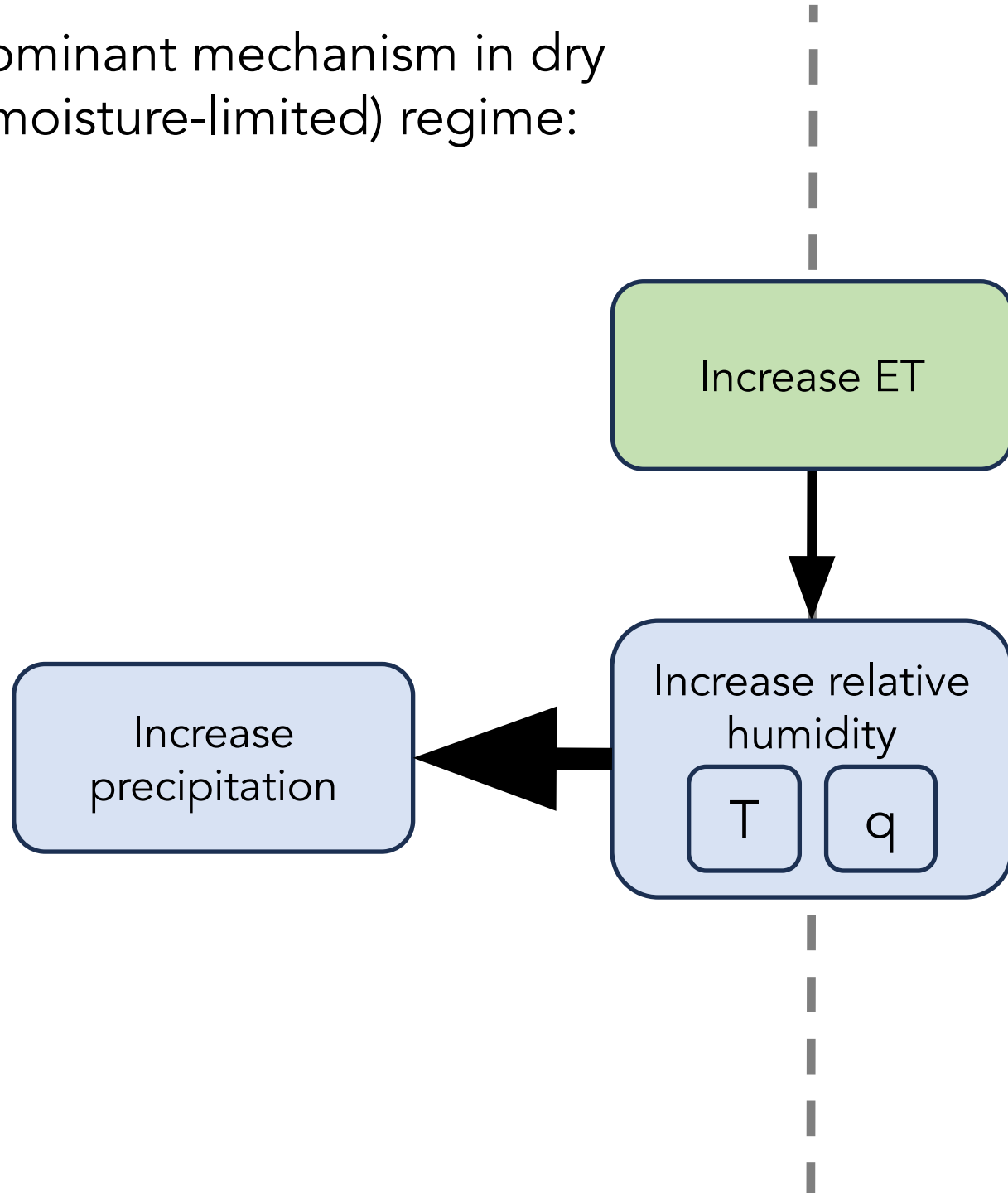
ET response to synthetic meteorology simulations that decrease PET by decreasing temperature



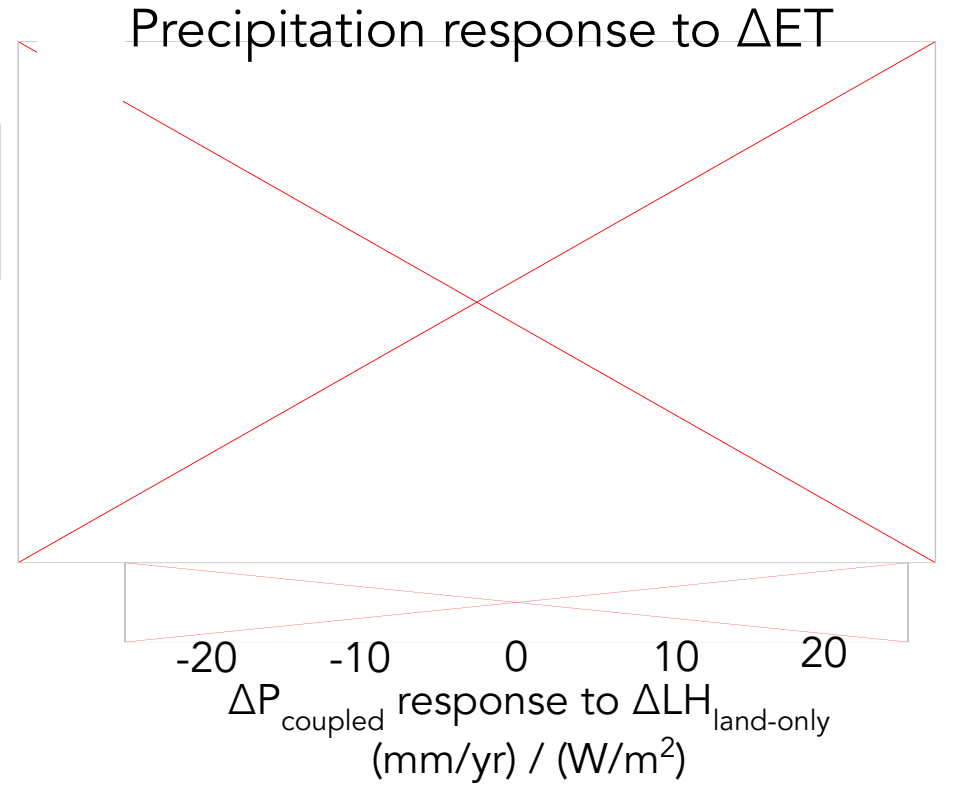
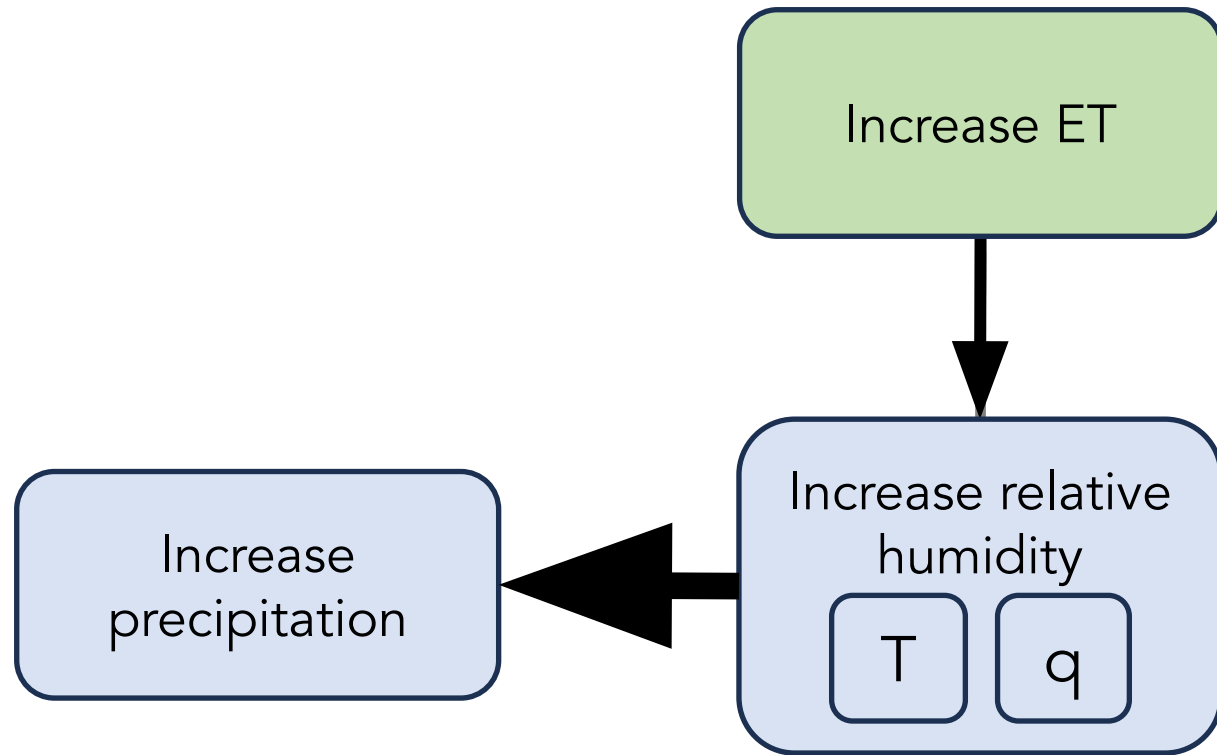
Dominant mechanism in wet (energy-limited) regime:



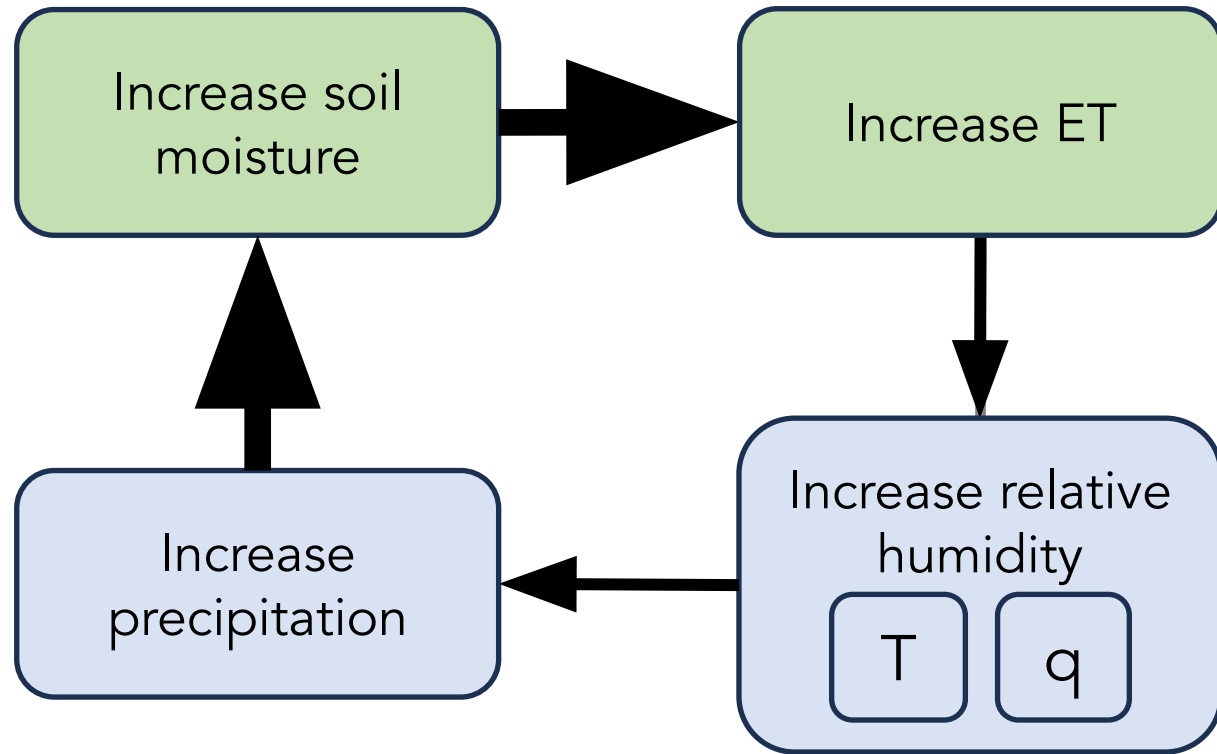
Dominant mechanism in dry  
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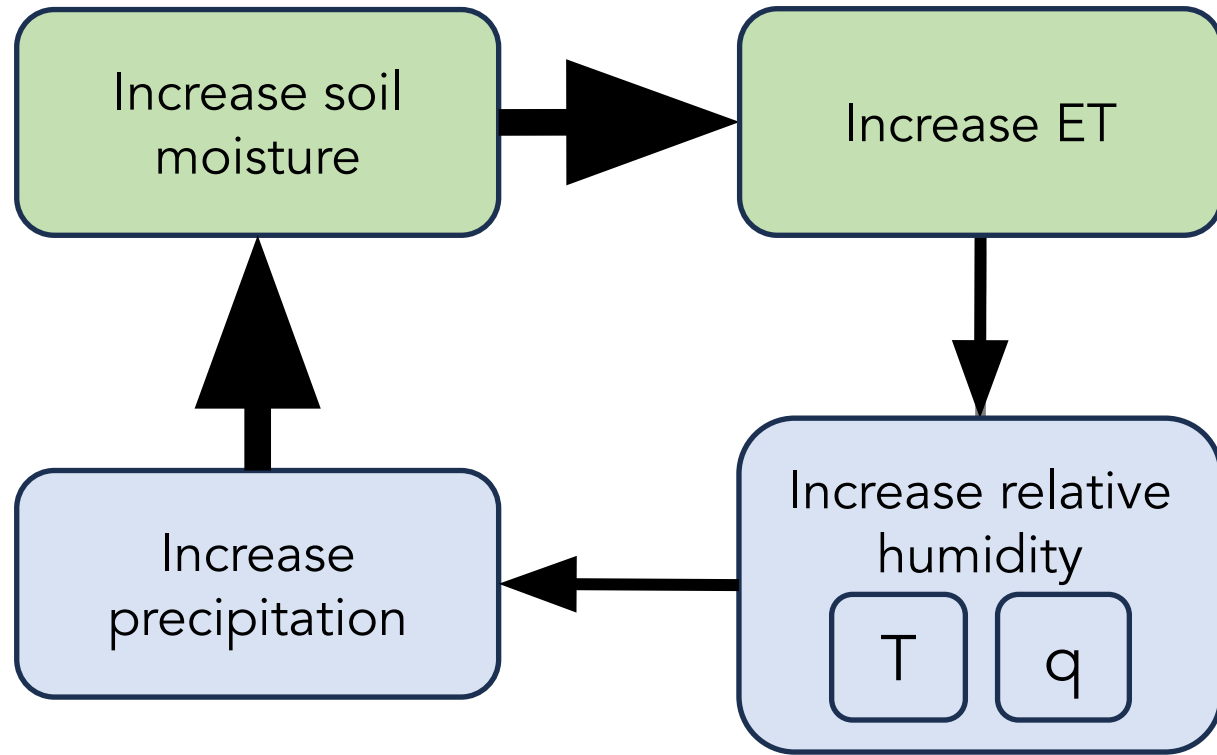


Dominant mechanism in dry  
(moisture-limited) regime:

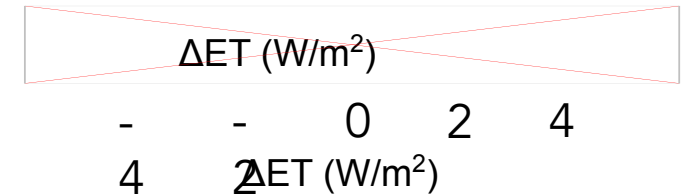
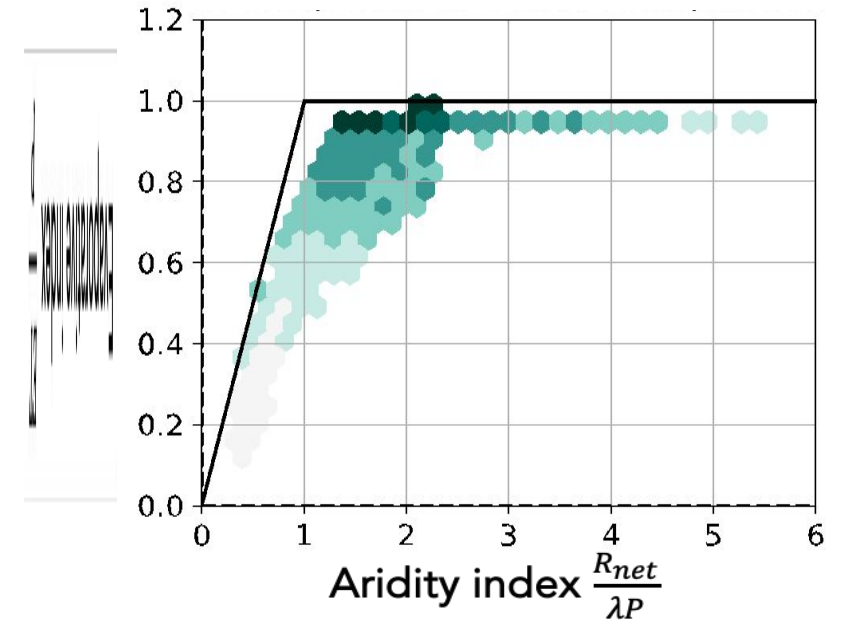




Dominant mechanism in dry (moisture-limited) regime:

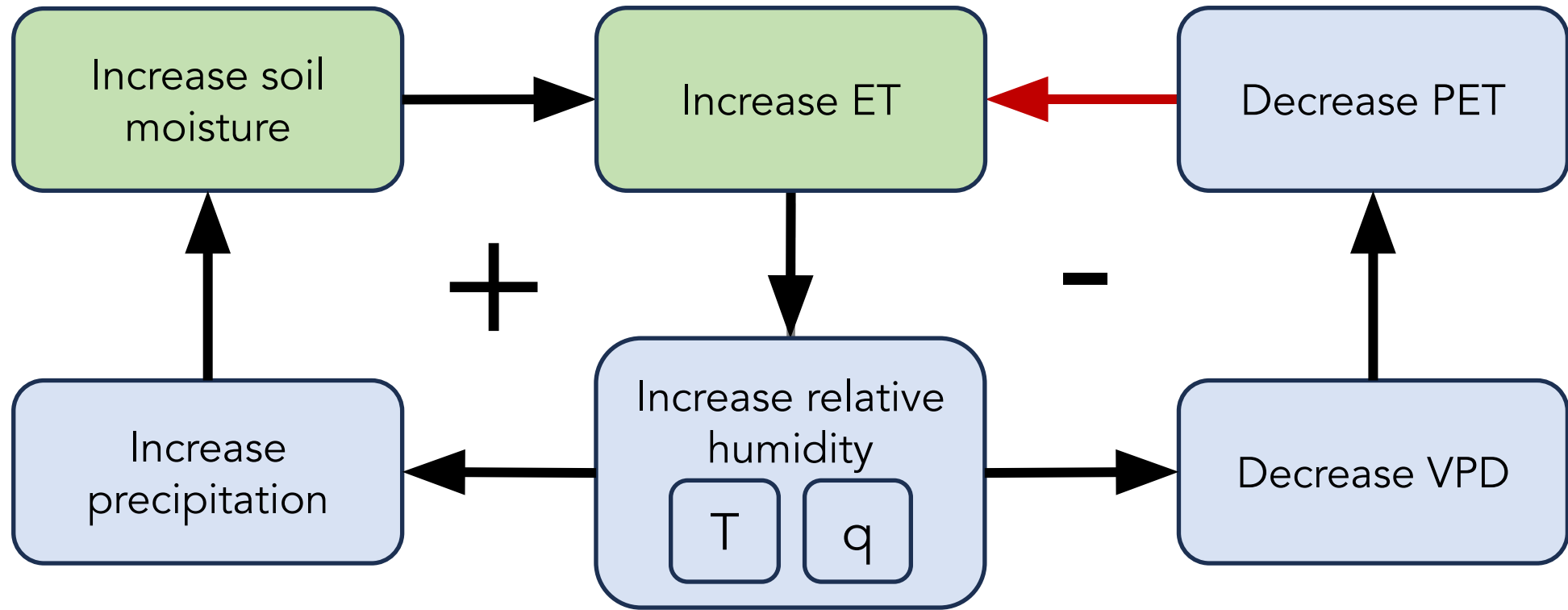


ET Response to +10% Precipitation



Dominant mechanism in dry  
(moisture-limited) regime:

Dominant mechanism in wet  
(energy-limited) regime:



# Linearly decompose different atmospheric drivers' contribution to the feedback

Precipitation sensitivity to land-only ET change

$$\frac{\partial P_{coupled}}{\partial ET_{land-only}}$$

Quantified by linear regression

**X**

ET sensitivity to precipitation change

$$\frac{\partial ET}{\partial P_{coupled}}$$

Quantified using synthetic meteorology simulations

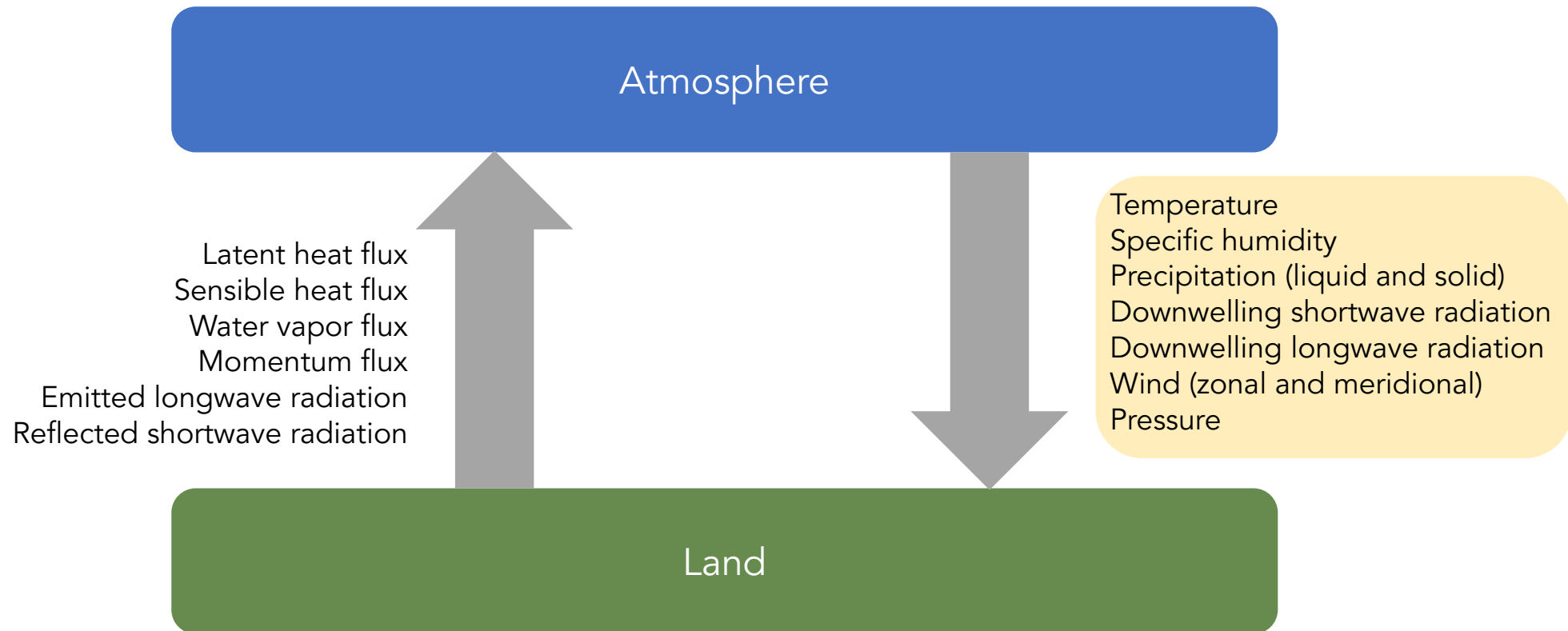
**=**

ET modulation by ET-precipitation feedback

$$\Delta ET_{feedback,P} = \frac{\partial ET_{coupled} - \partial ET_{land-only}}{\partial ET_{land-only}}$$

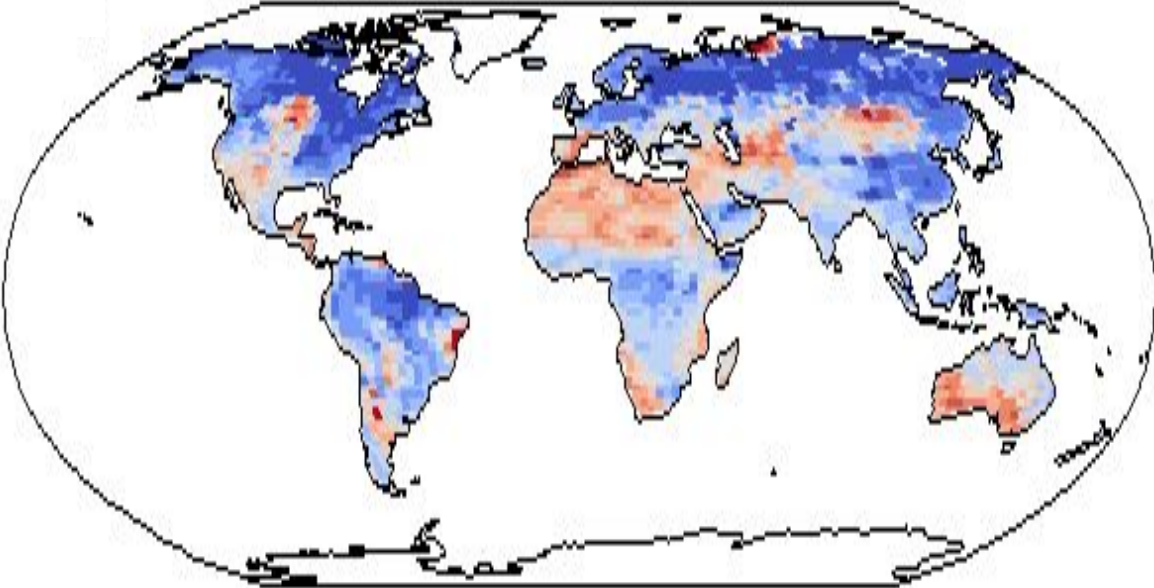
# Linearly decompose different atmospheric drivers' contribution to the feedback

$$\Delta ET_{feedback} = \Delta ET_{feedback,P} + \Delta ET_{feedback,T} + \Delta ET_{feedback,q} + \Delta ET_{feedback,SW} + \dots$$

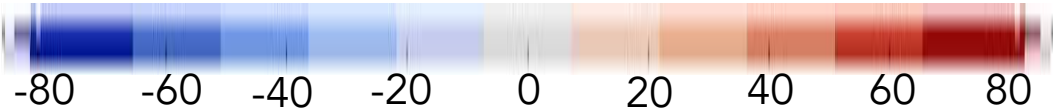
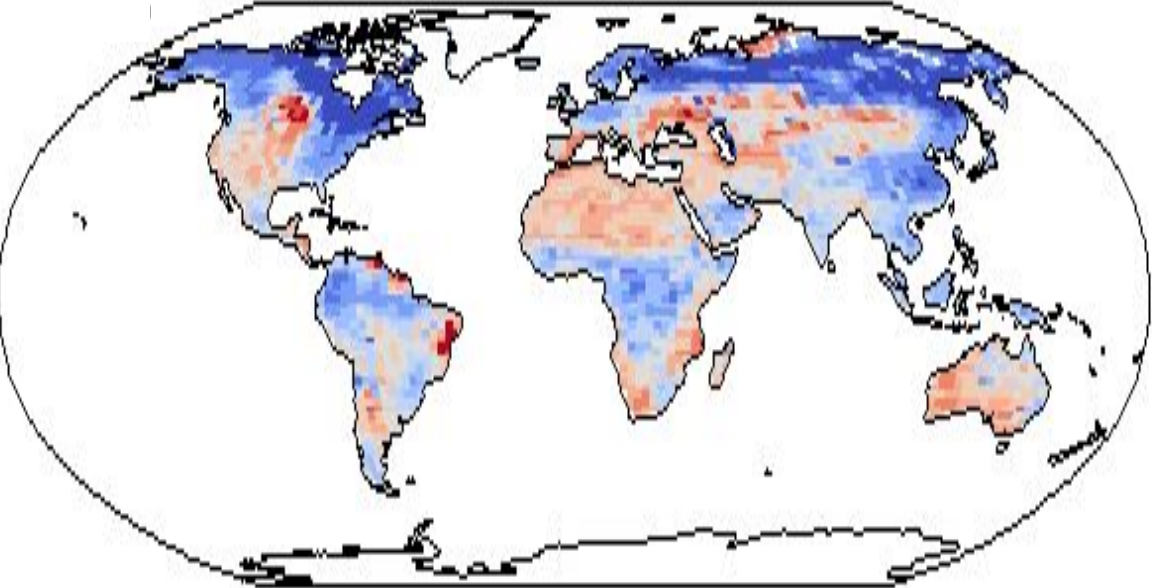


# Our decomposition captures the dependence on moisture regime

Linear Reconstruction



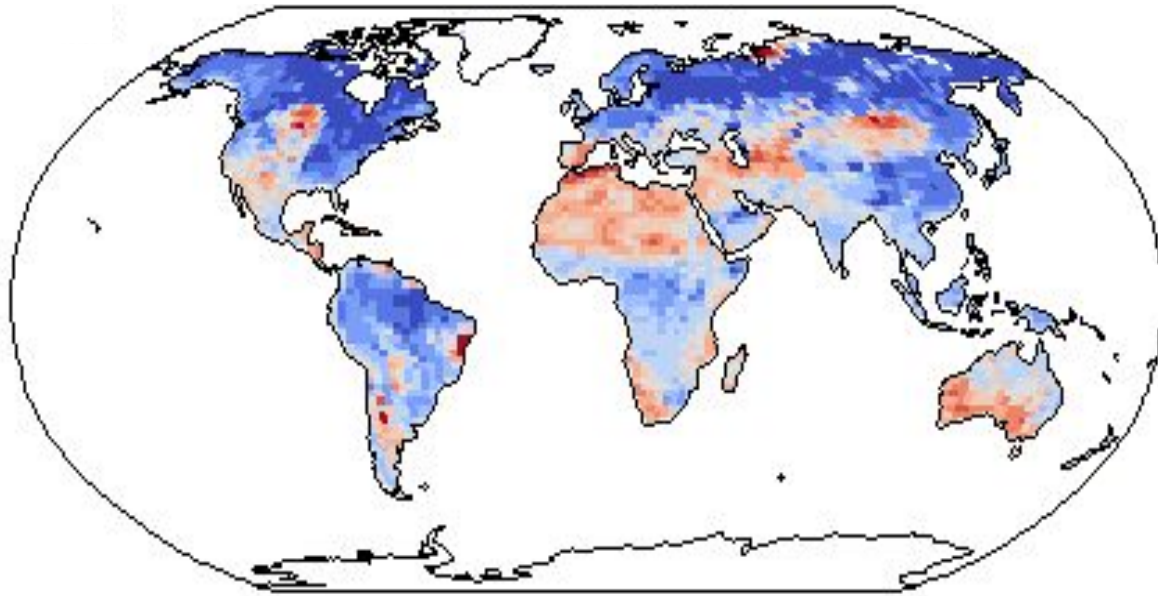
Actual



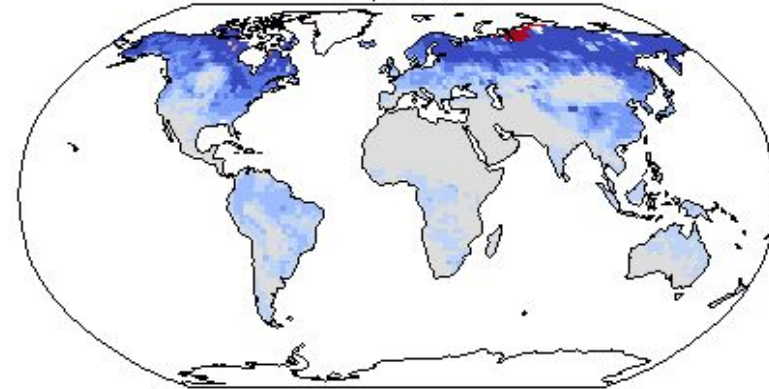
Change in ET due to atmospheric feedbacks (%)

# Spatial variation mostly explained by temperature and precipitation

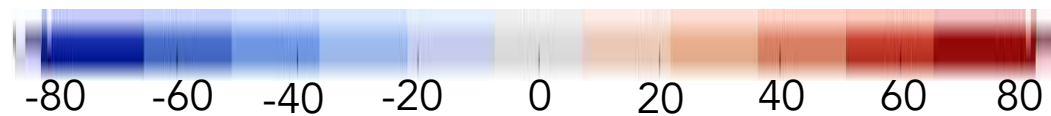
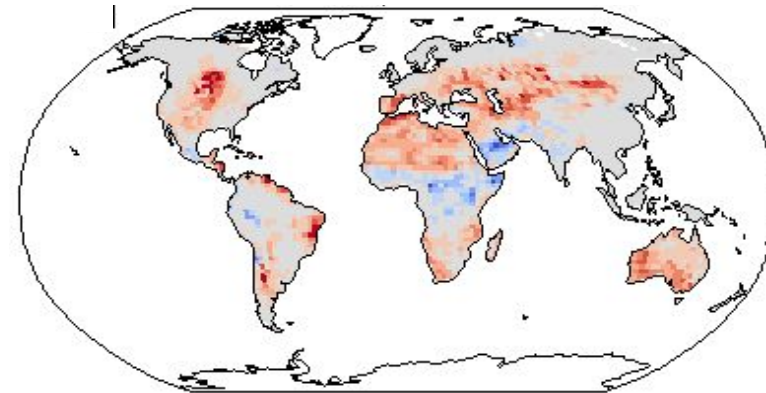
## Linear Reconstruction



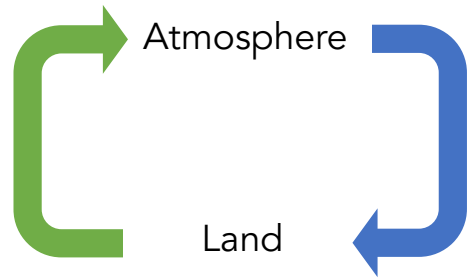
## ET-Temperature Feedback



## ET-Precipitation Feedback



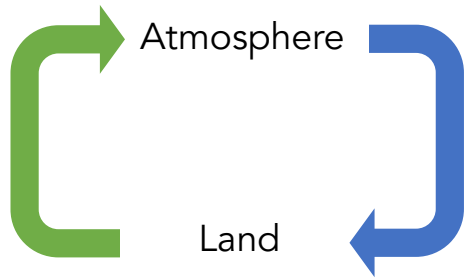
Change in ET due to atmospheric feedbacks (%)



## Take home points

Land-atmosphere feedbacks dampen ET changes in energy-limited regions and amplify ET changes in some moisture-limited regions

- Energy-limited regions: Feedback driven by changes in PET
- Moisture-limited regions: Feedback where  $ET \uparrow \rightarrow \text{precipitation} \uparrow$



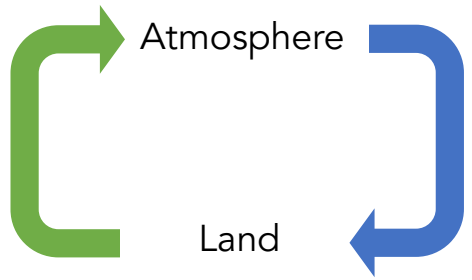
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→ Need to develop, evaluate, and benchmark land models in a coupled context





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- Moisture-limited regions: Feedback where  $ET \uparrow \rightarrow \text{precipitation} \uparrow$

→ Need to develop, evaluate, and benchmark land models in a coupled context

→ Using a land-only framework to assess the ET response to any land surface change will overestimate ET changes in wet places and underestimate ET changes in some dry places