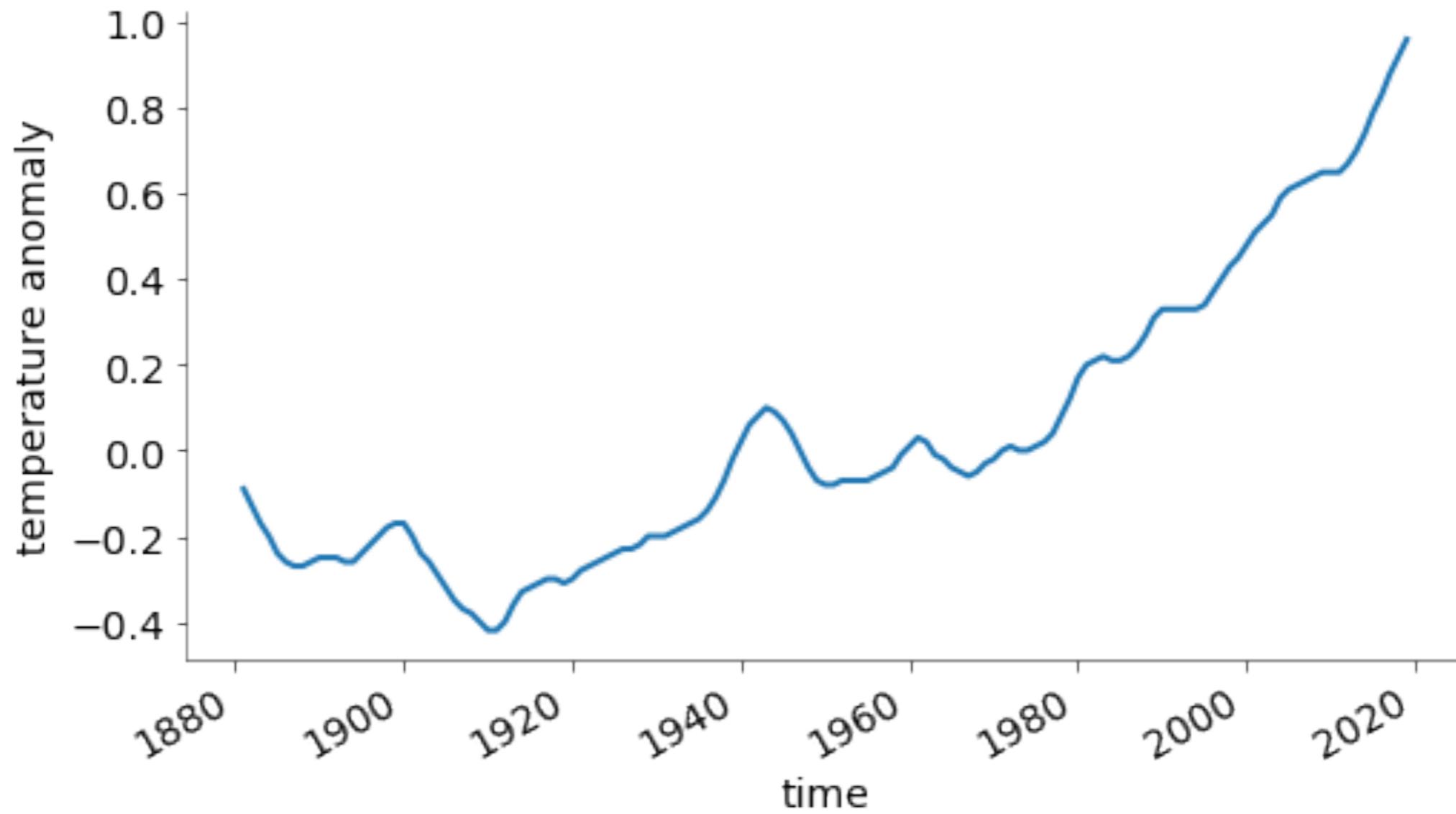


# Potential problems measuring climate sensitivity from the historical record

A. E. Dessler  
Dept. of Atmospheric Sciences  
Texas A&M University

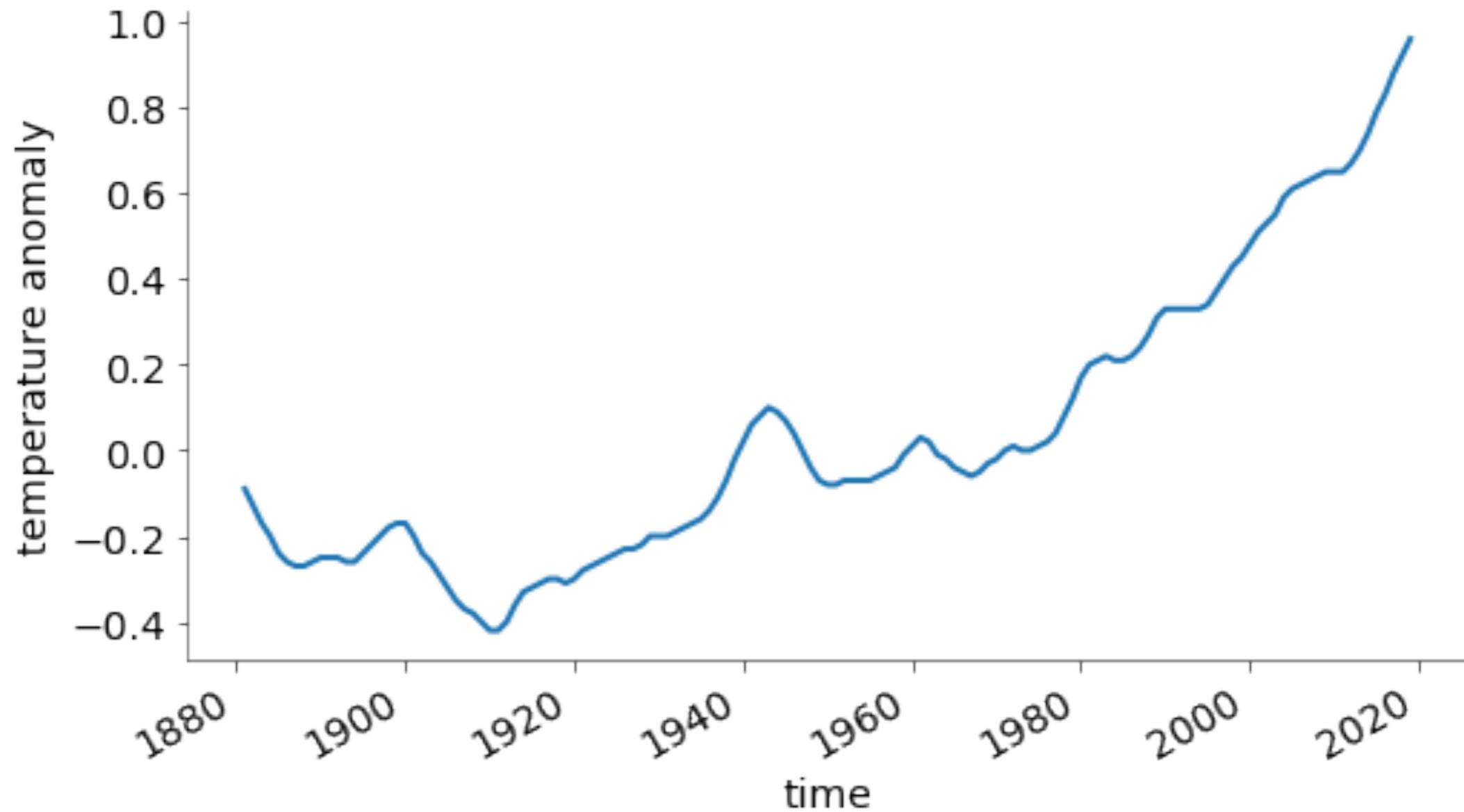




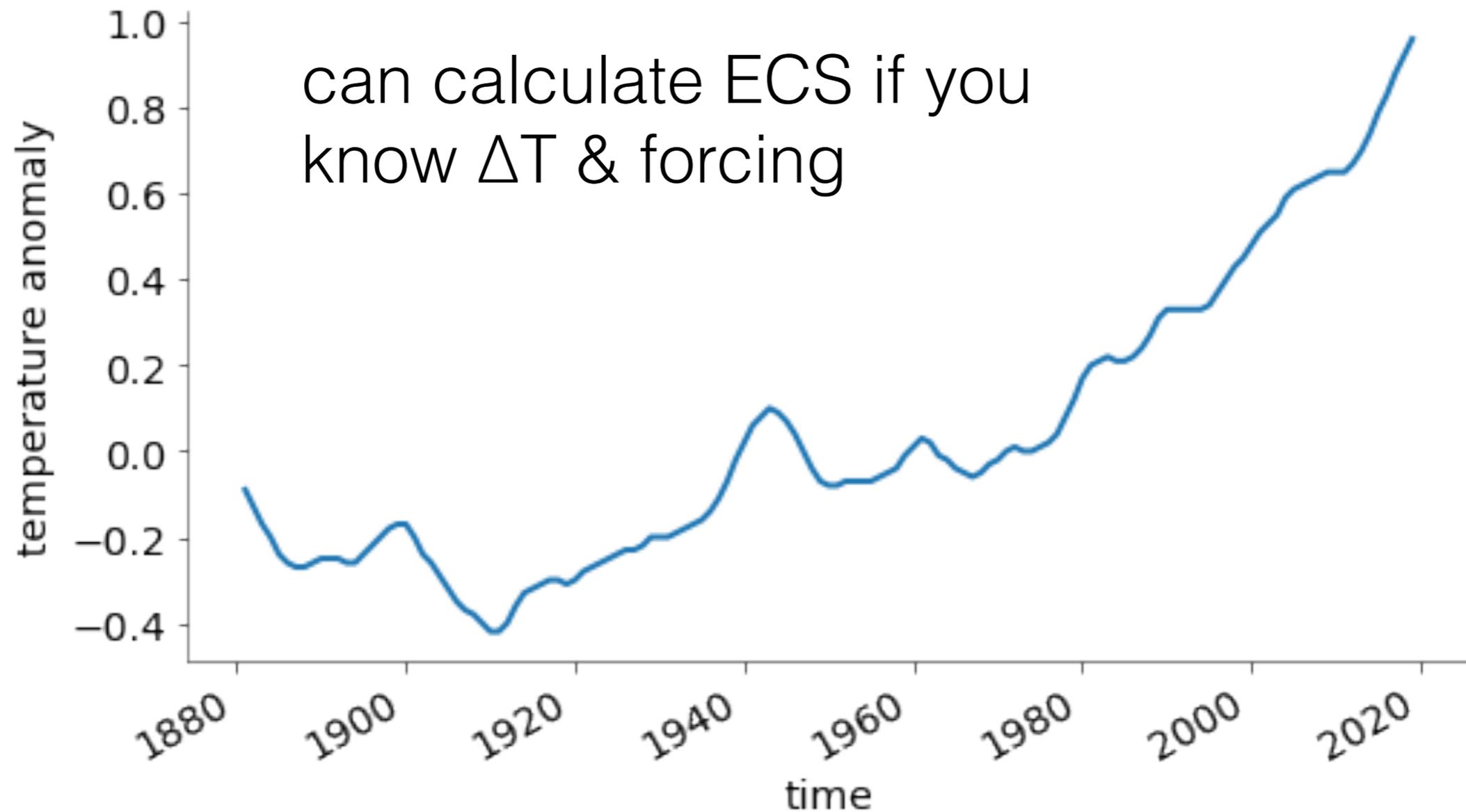
smoothed GISTEMP v4



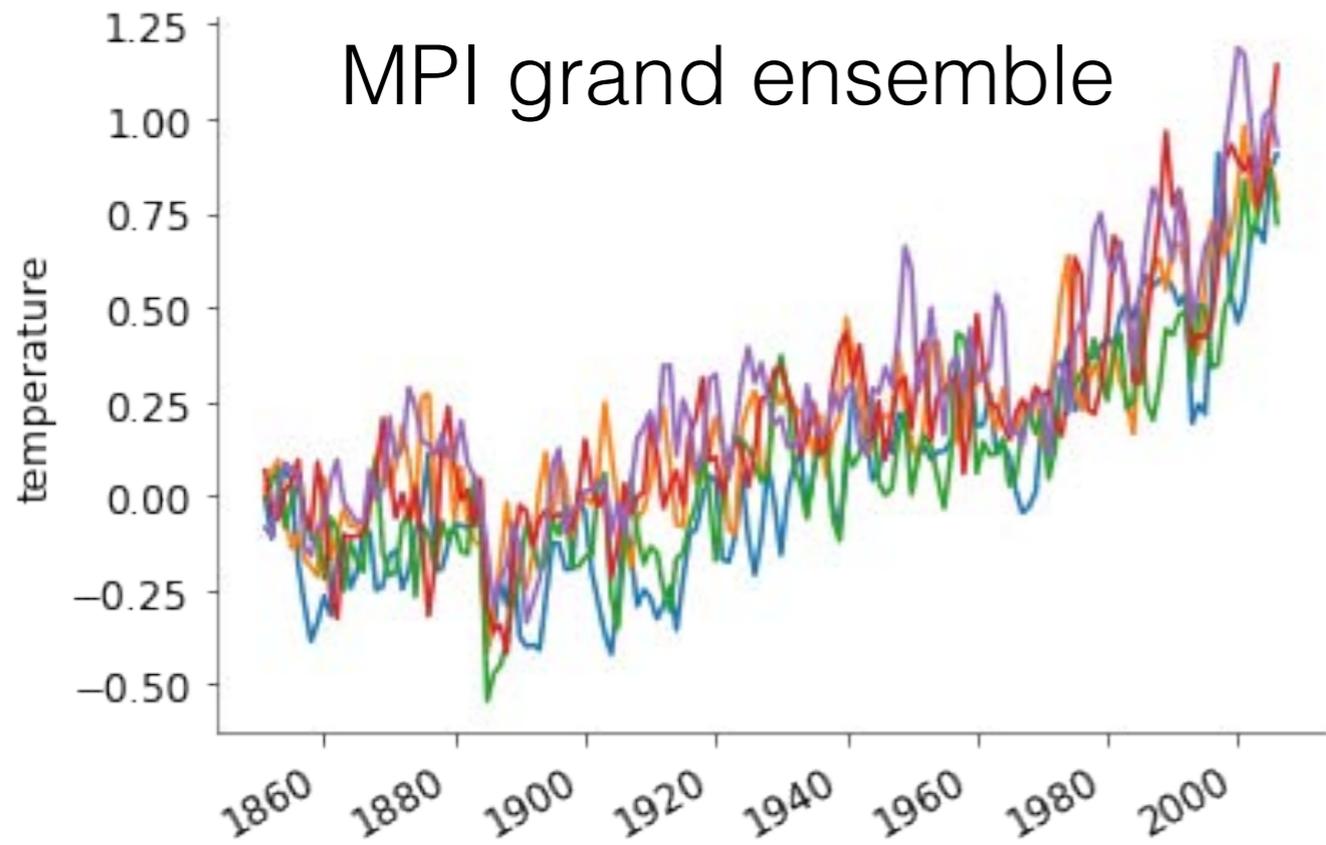
ECS = equilibrium climate sensitivity (equilibrium warming after CO<sub>2</sub> is doubled)



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## MPI grand ensemble



see also:

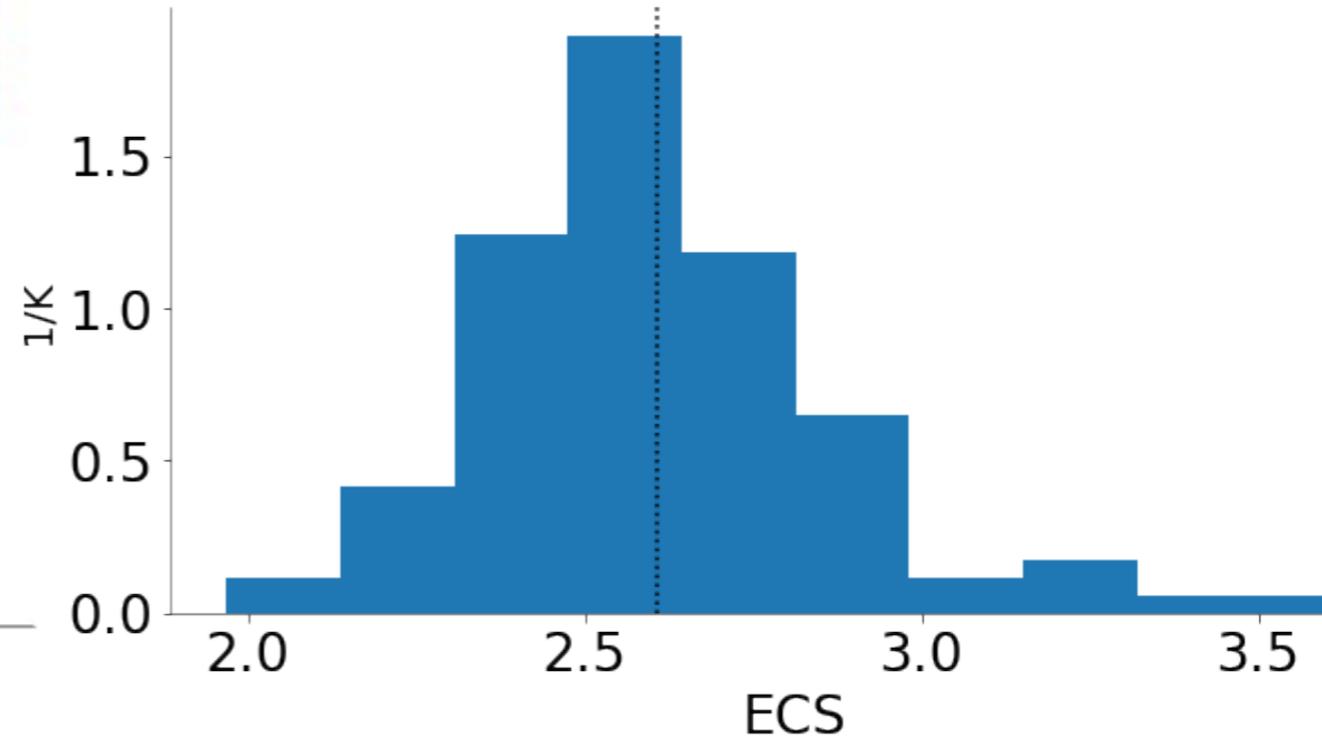
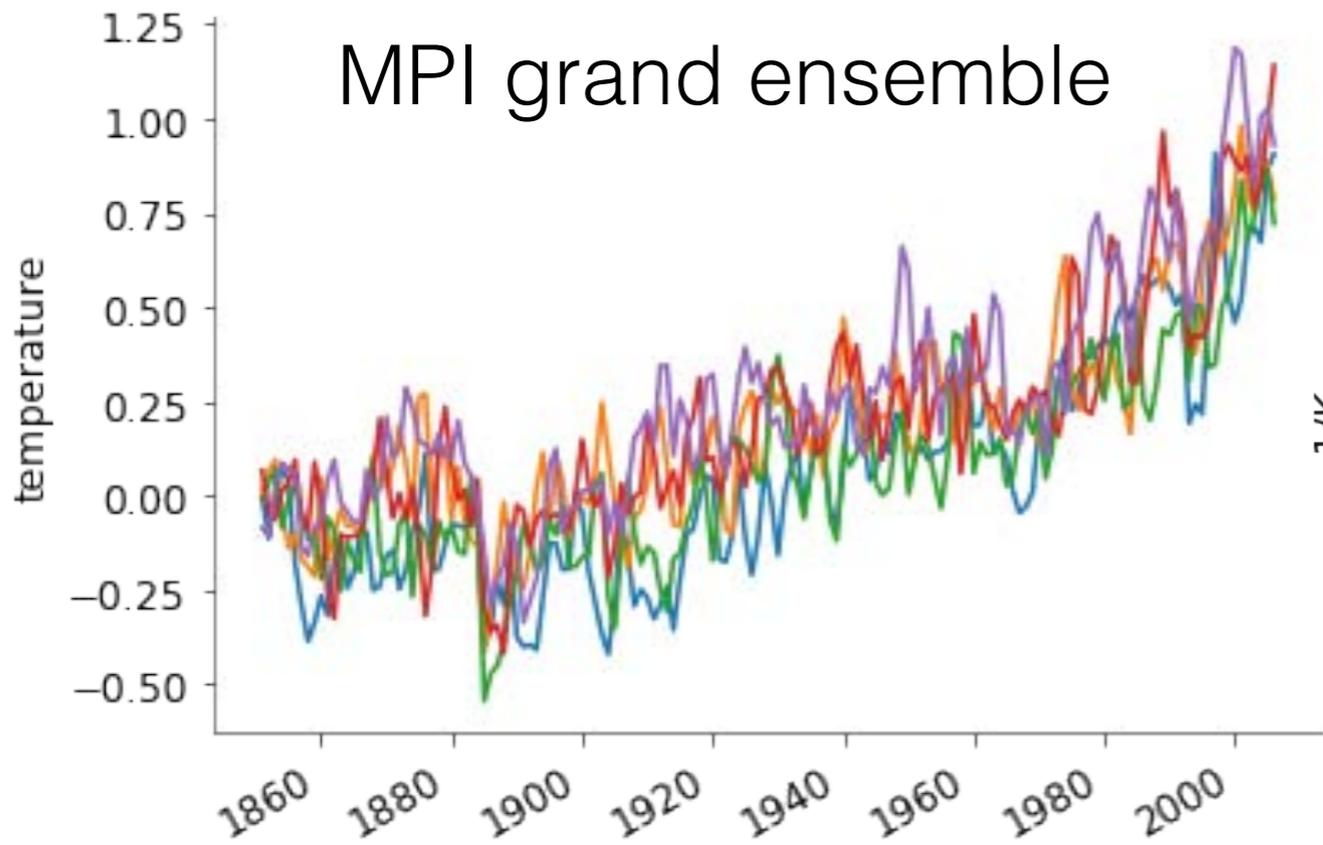
Gregory and Andrews, 2016

Zhou et al., 2016

Marvel et al., 2018

Andrews et al., 2018

# MPI grand ensemble



Dessler et al. 2018

see also:

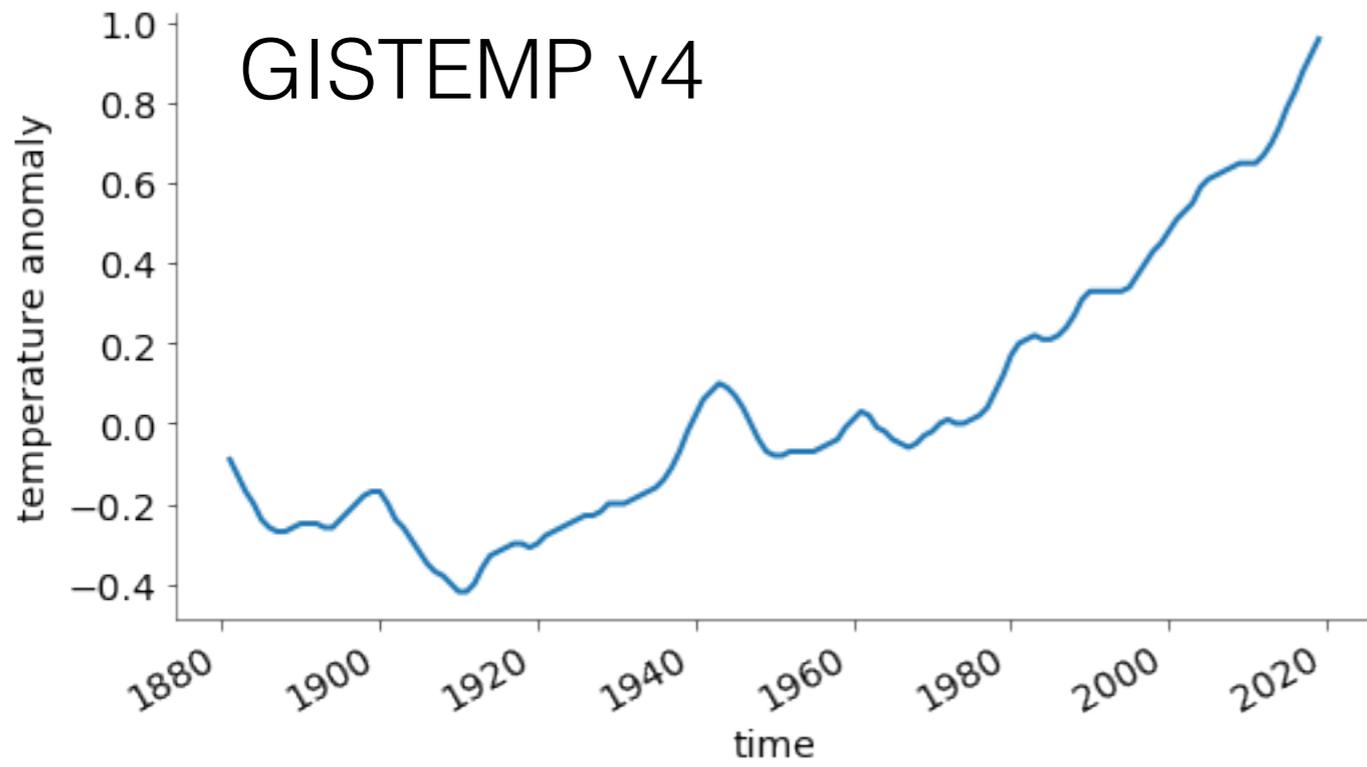
Gregory and Andrews, 2016

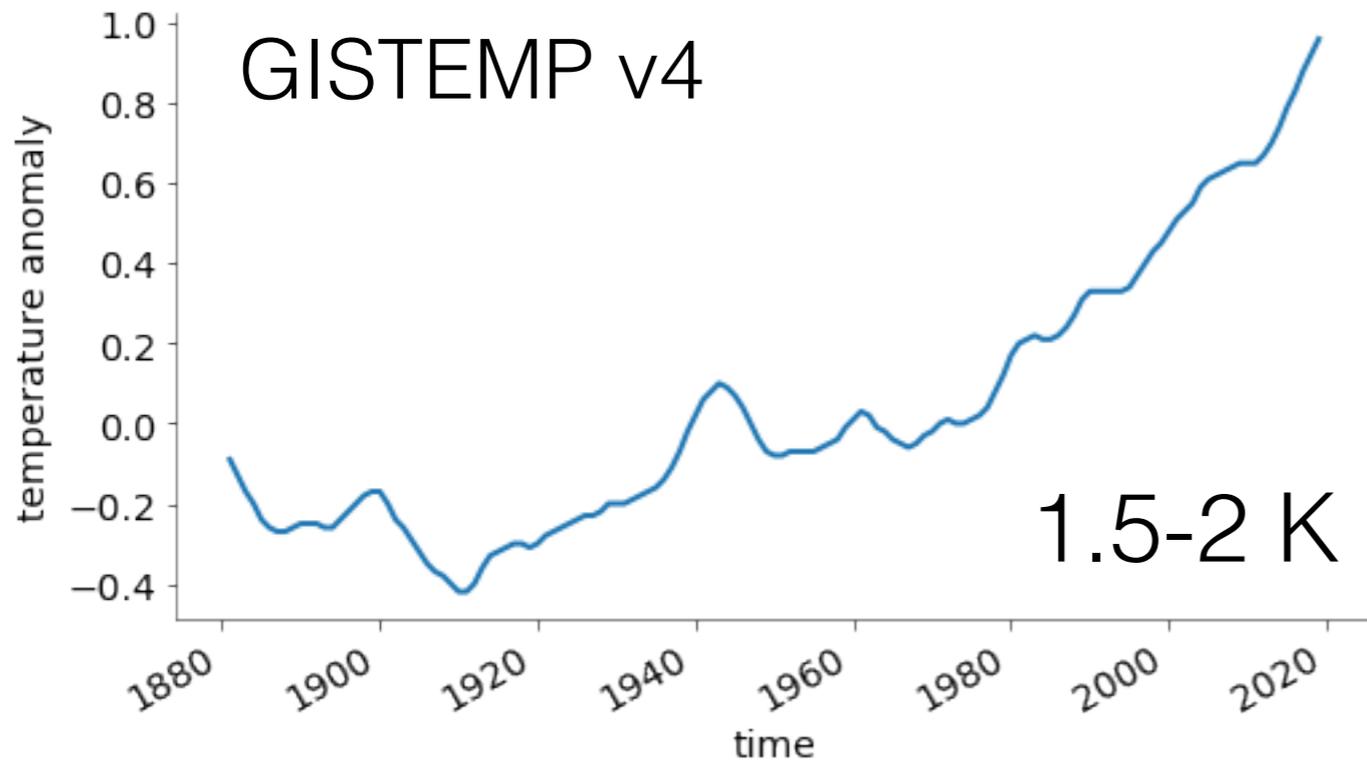
Zhou et al., 2016

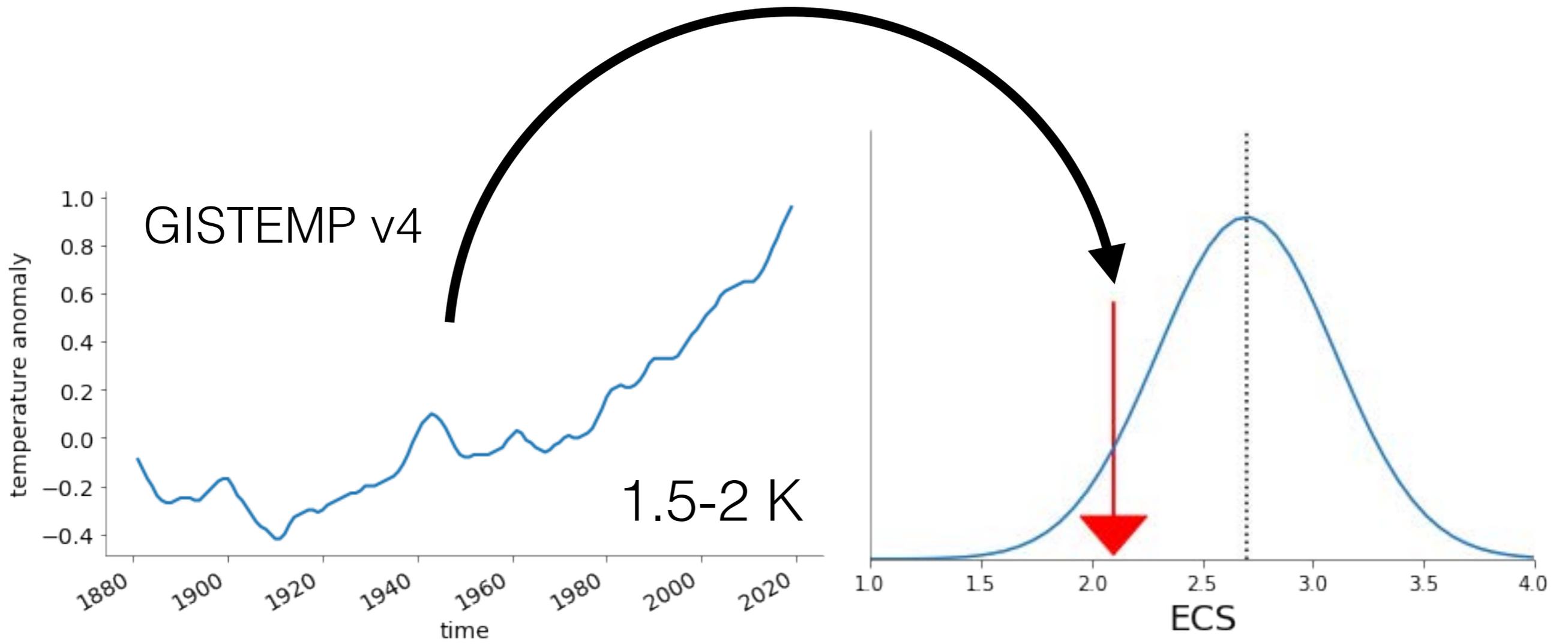
Marvel et al., 2018

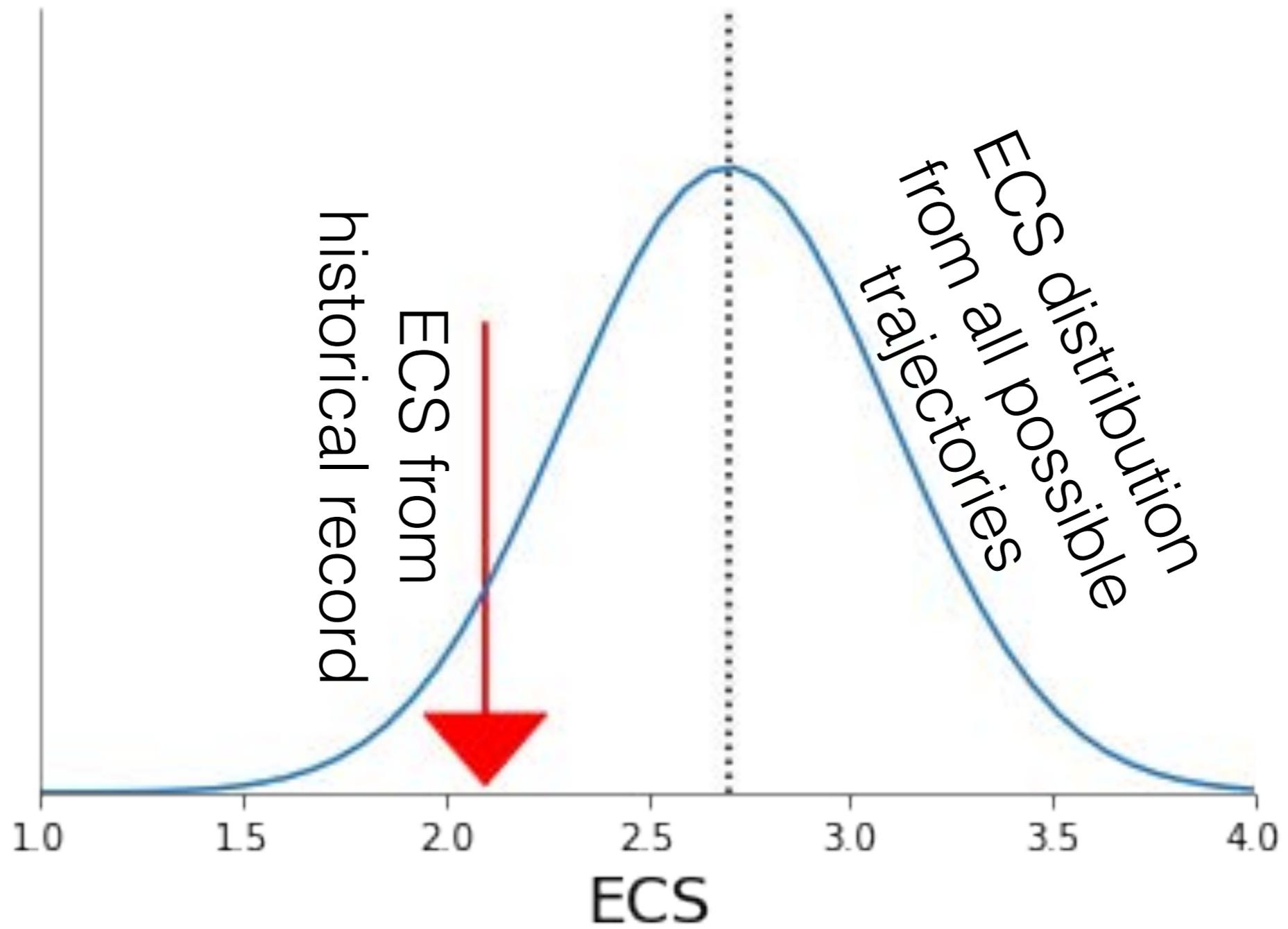
Andrews et al., 2018



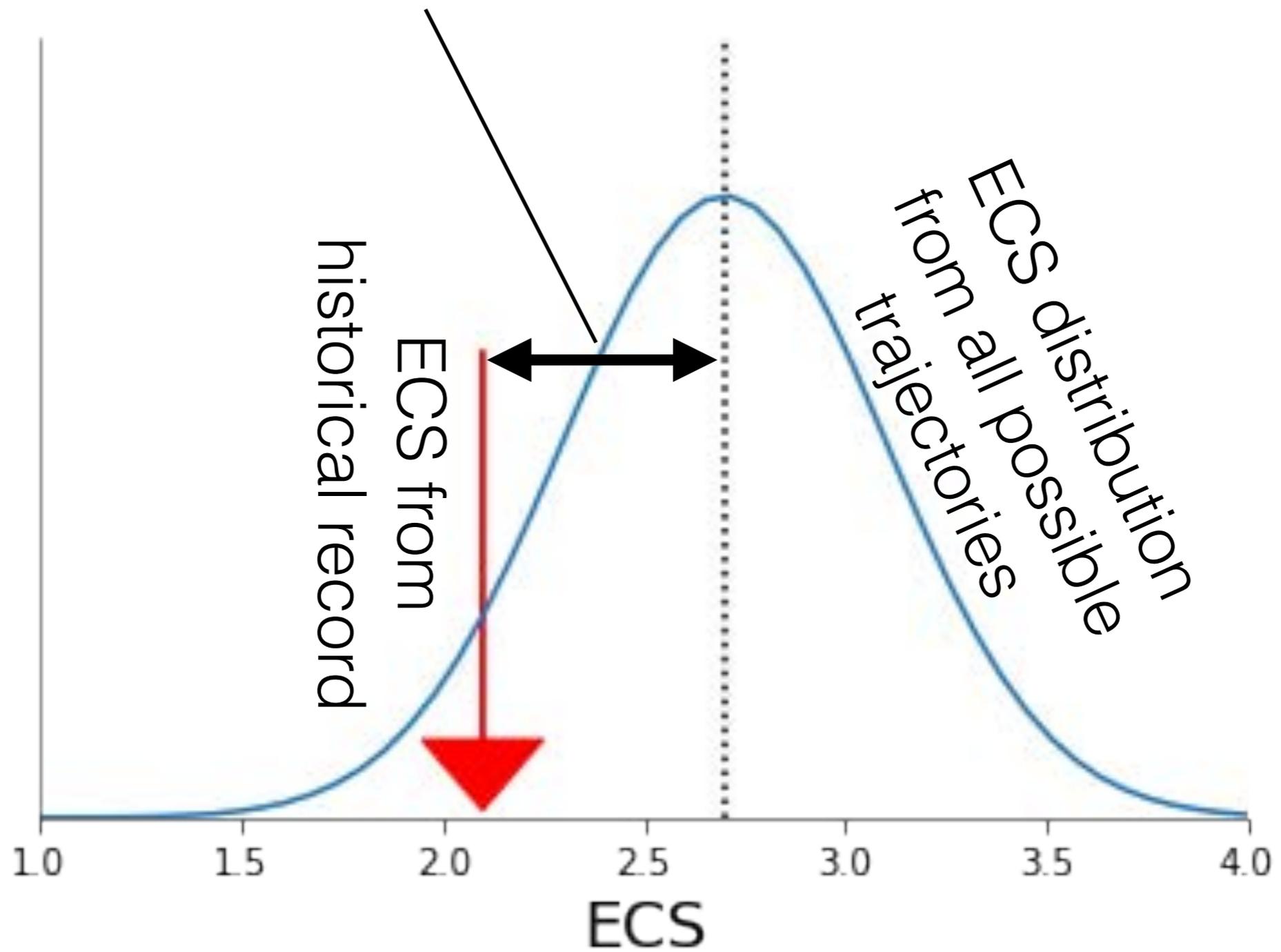


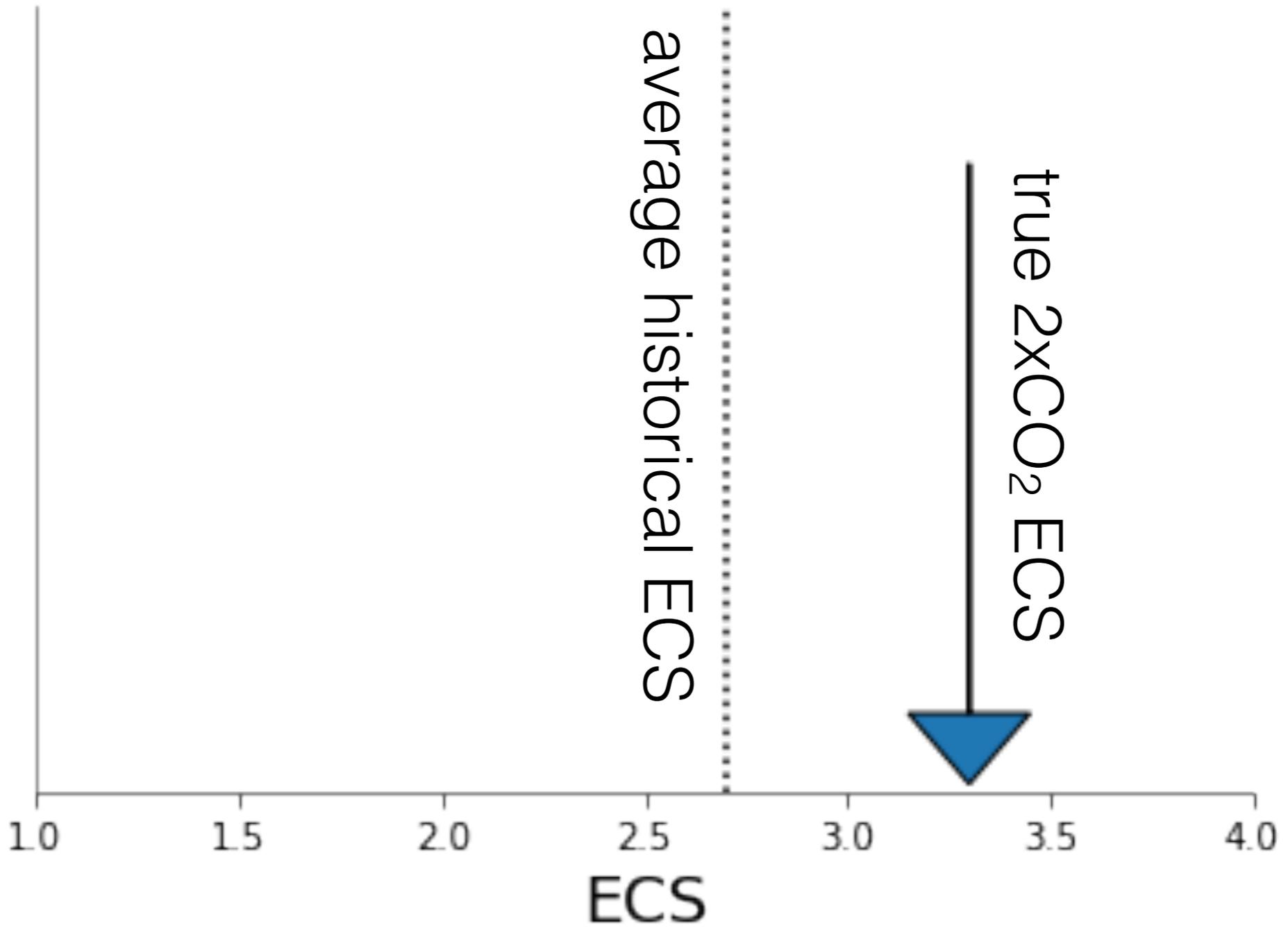




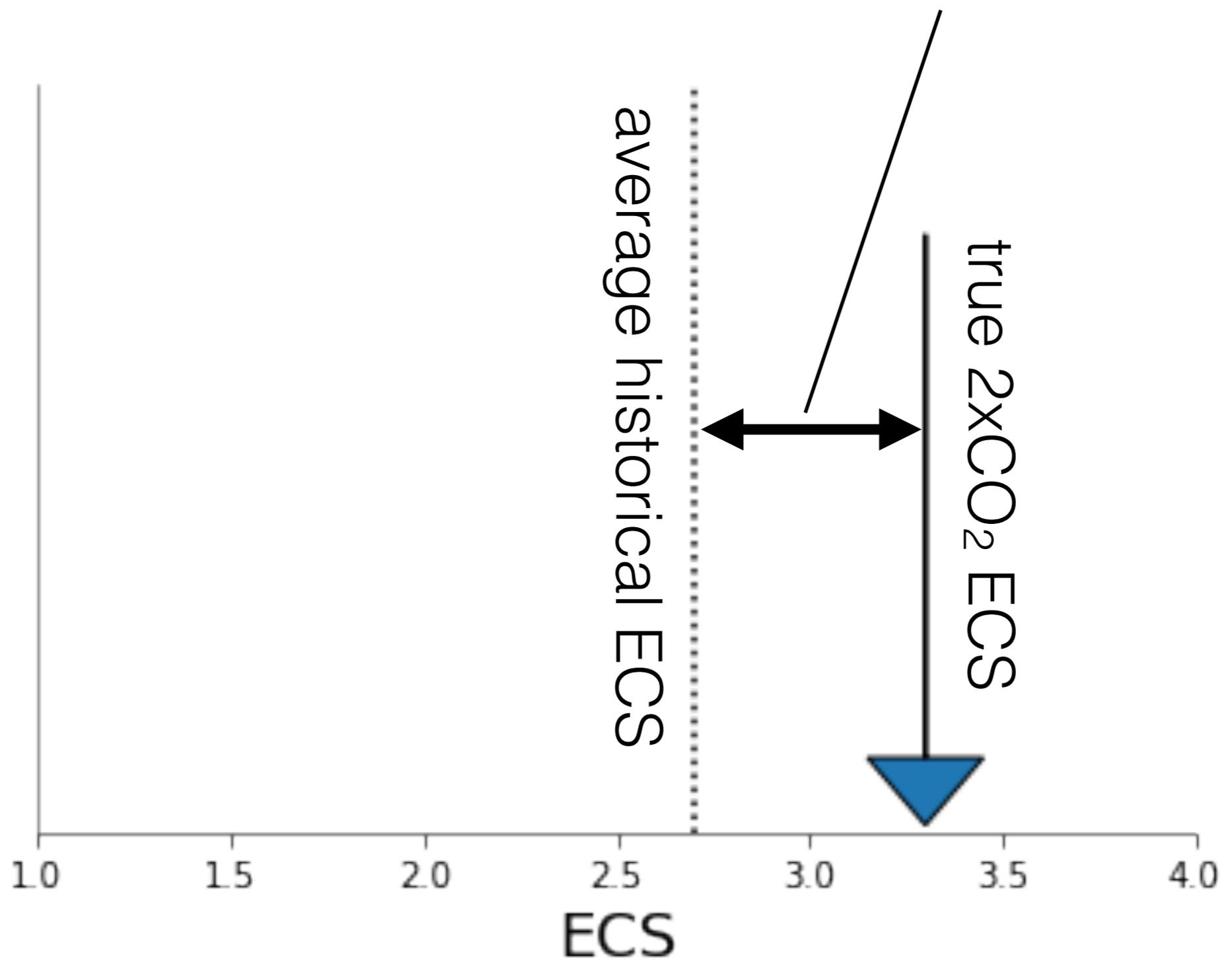


“unforced pattern effect”



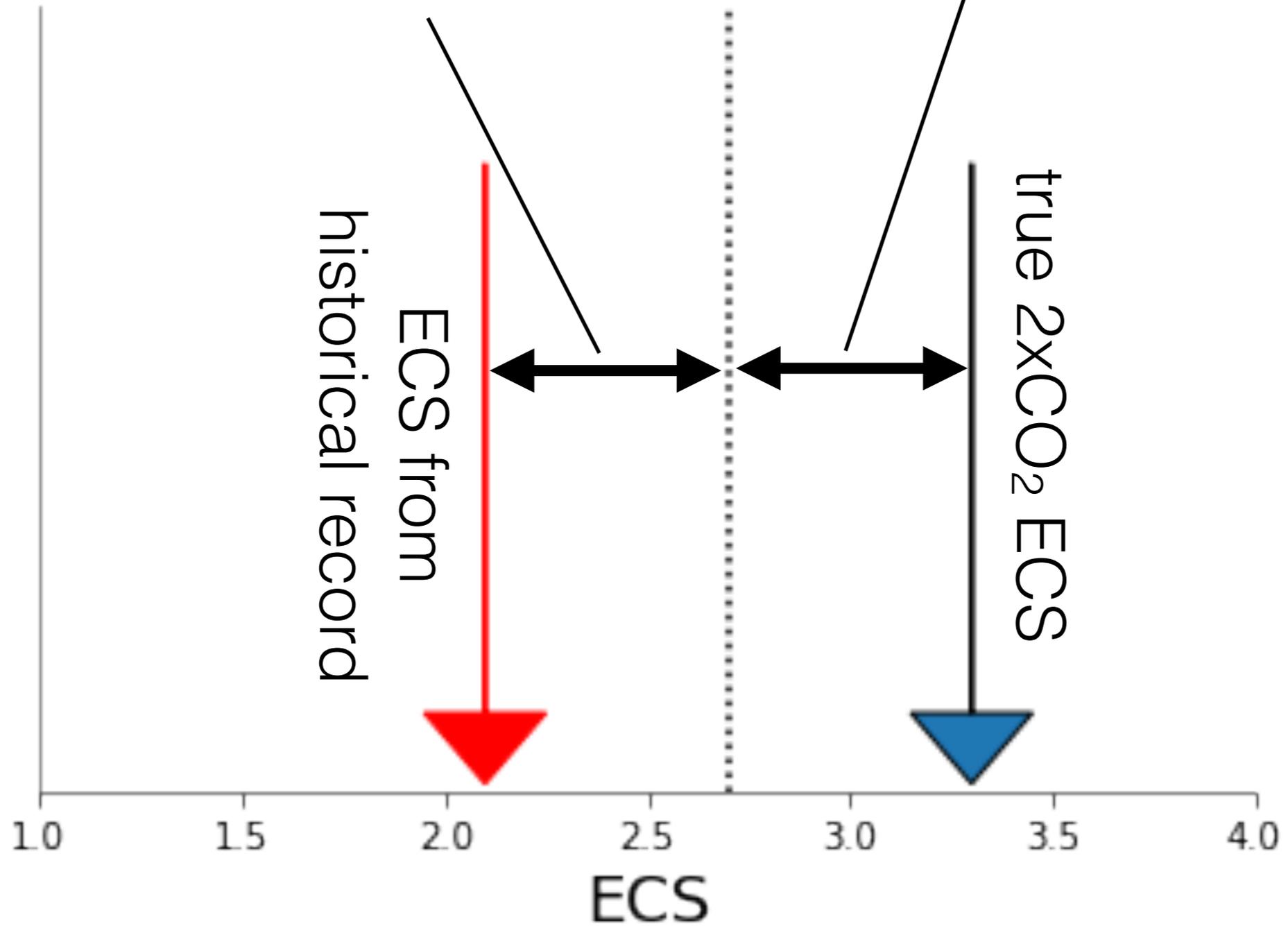


“forced pattern effect”



“forced pattern effect”

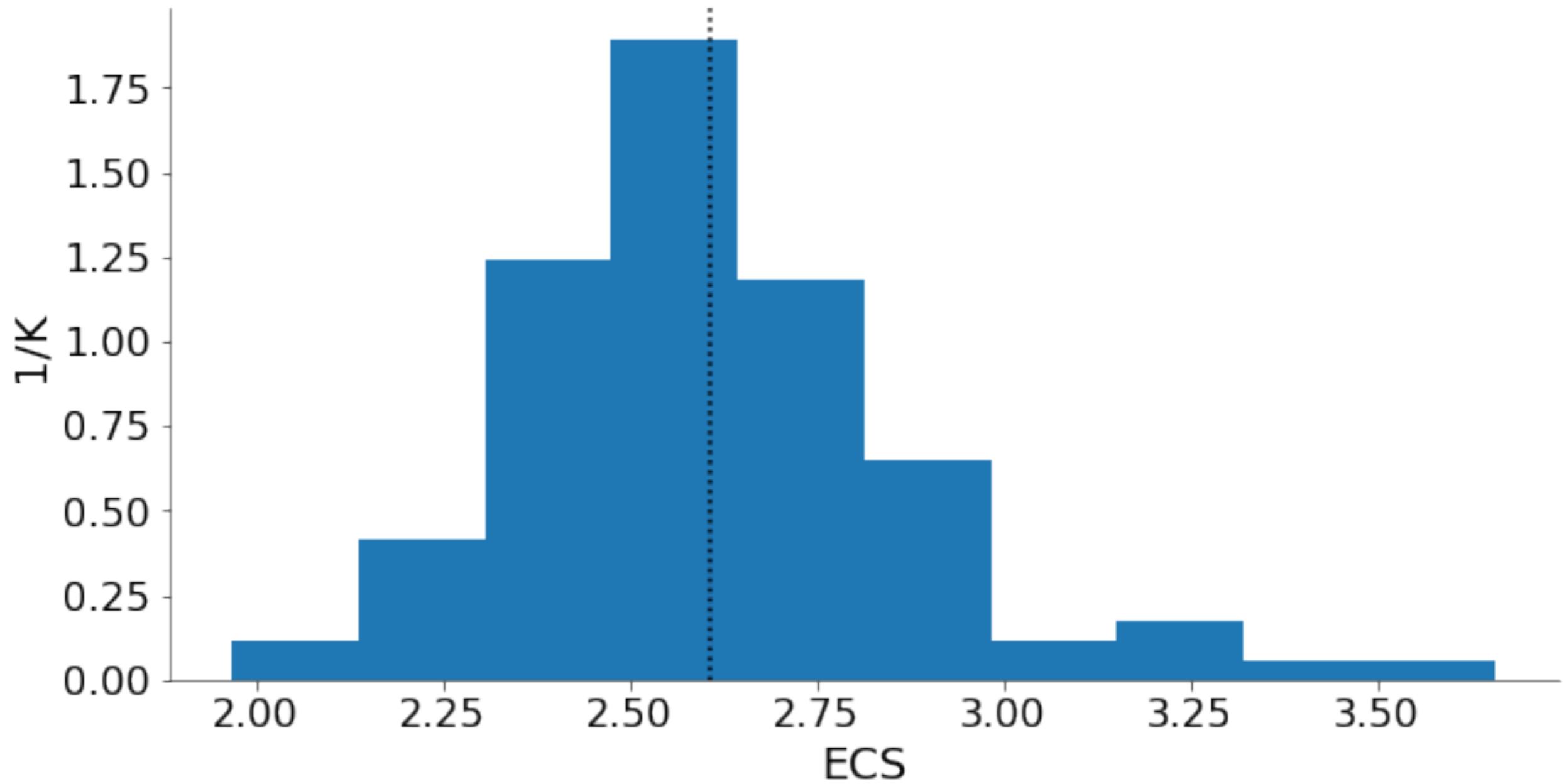
“unforced pattern effect”



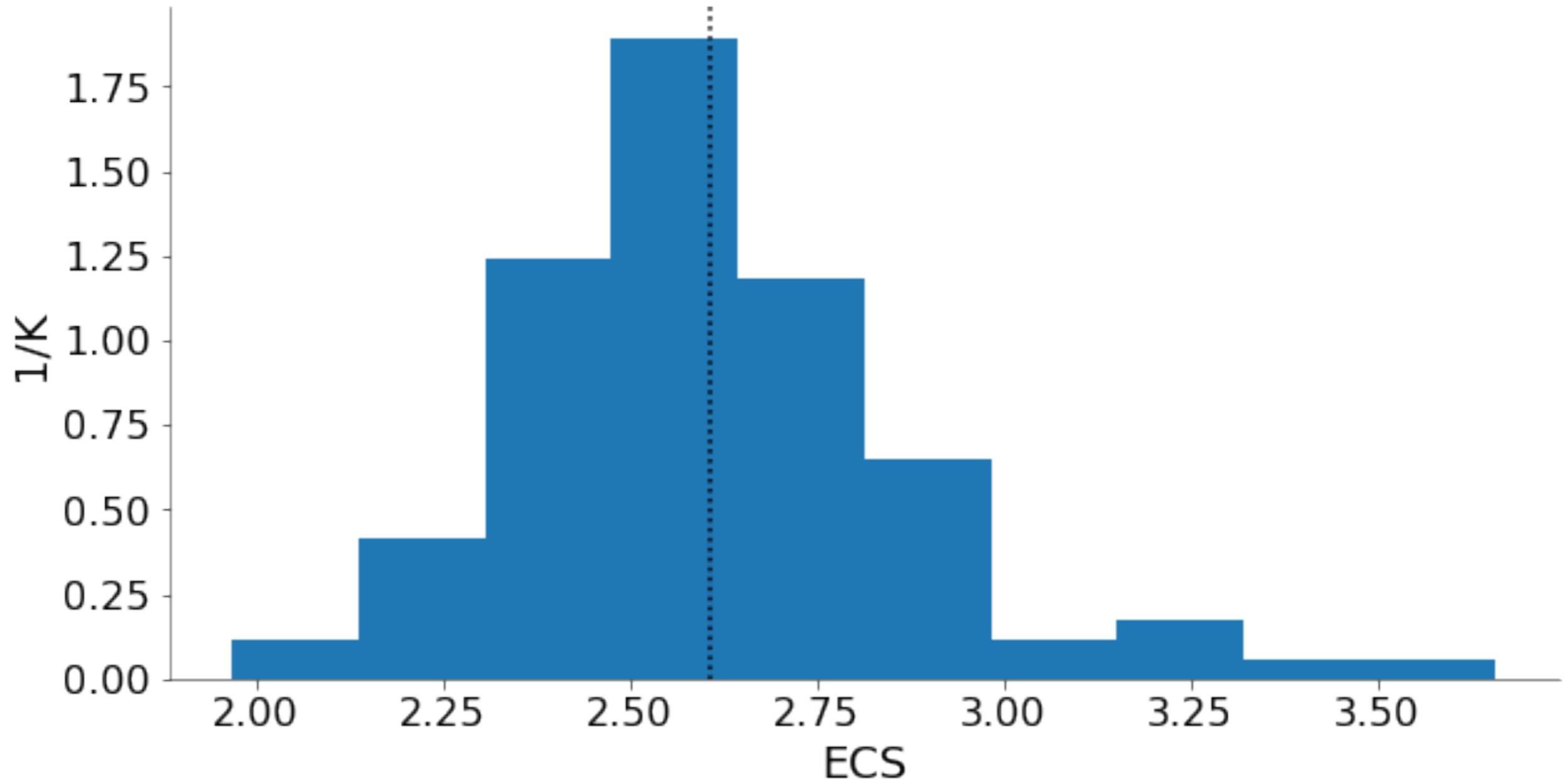
# MPI Grand Ensemble

- MPI-ESM 1.1 [Maher et al., JAMES, 2019]
- 100 historical runs [155 years each, 1850-2005], each with identical historical forcing
- only difference is initial conditions
- calculate ECS from each ensemble member

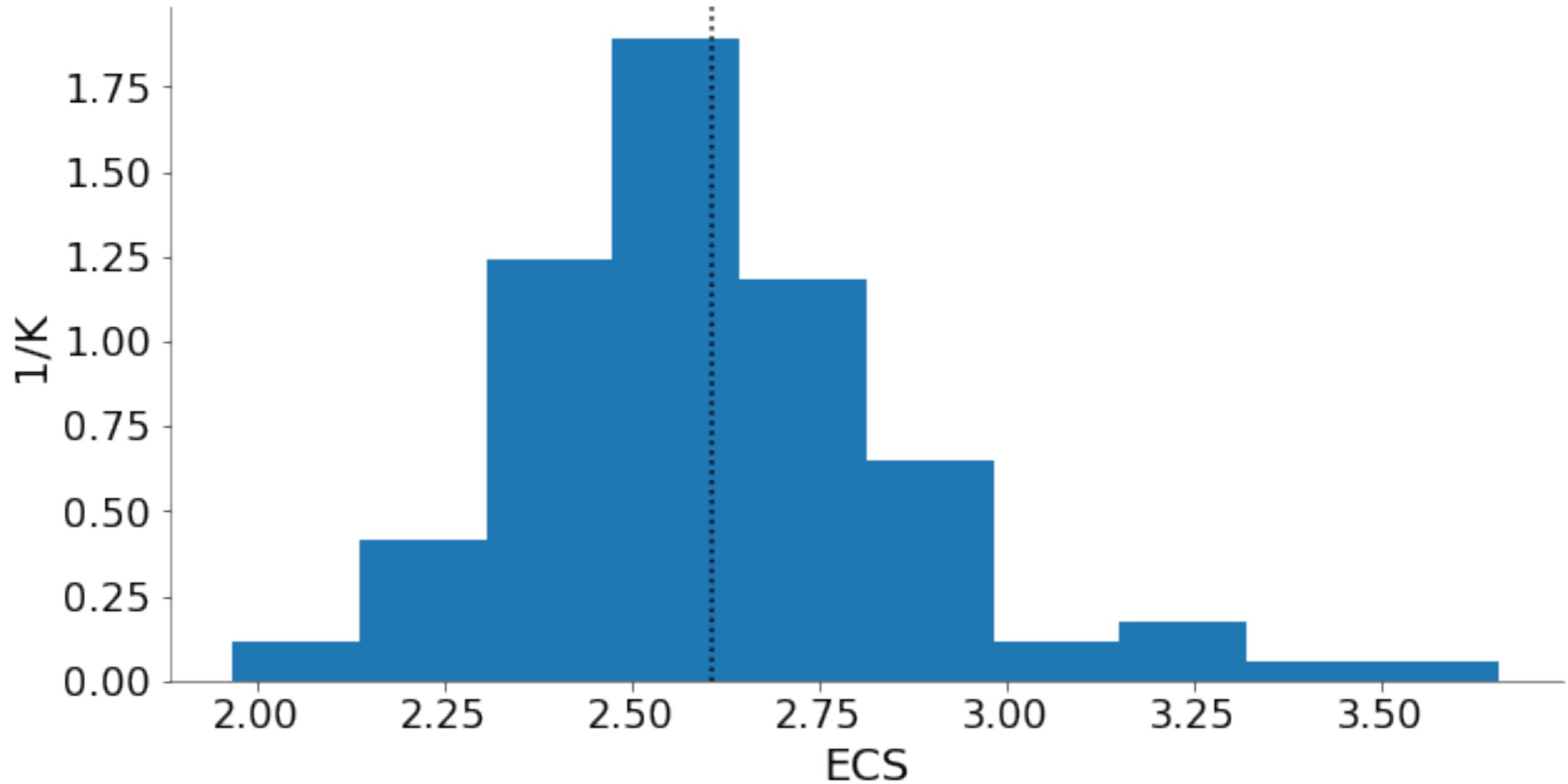


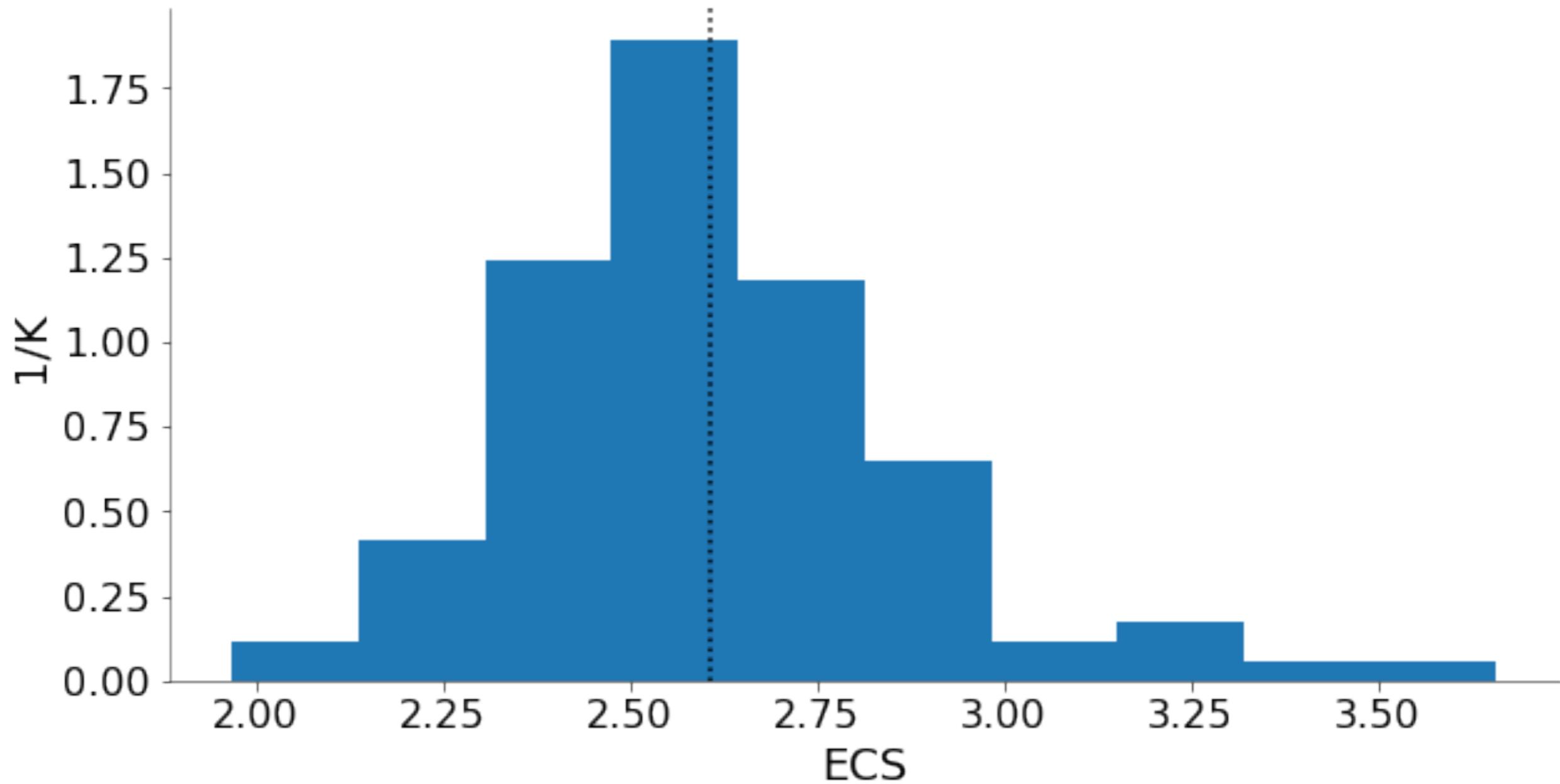


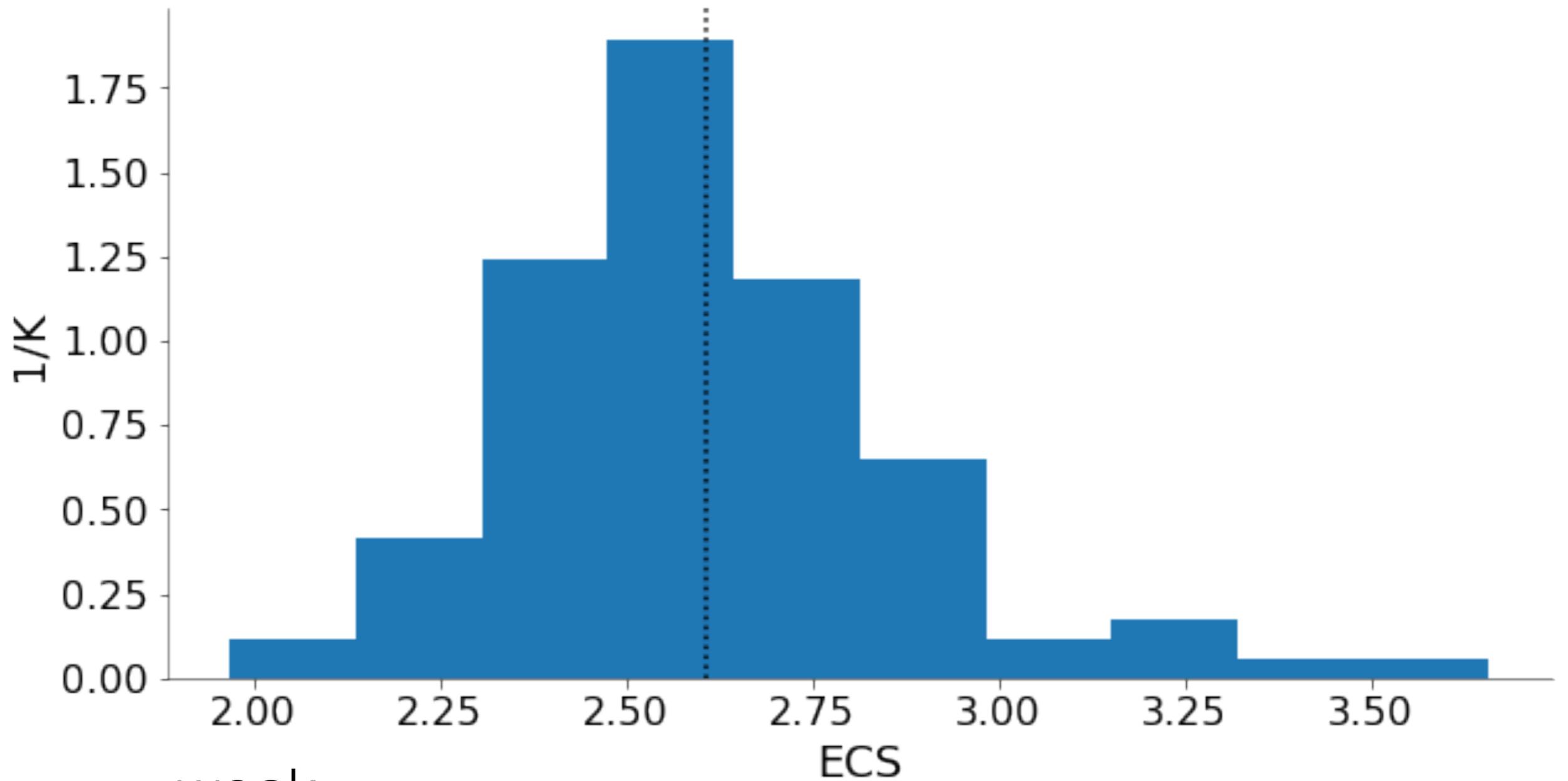
unforced pattern effect



$$ECS = - \frac{F_{2 \times CO_2}}{\lambda_{planck} + \lambda_{lapse\ rate} + \lambda_{\Delta RH} + \lambda_{albedo} + \lambda_{LW\ cloud} + \lambda_{SW\ cloud}}$$

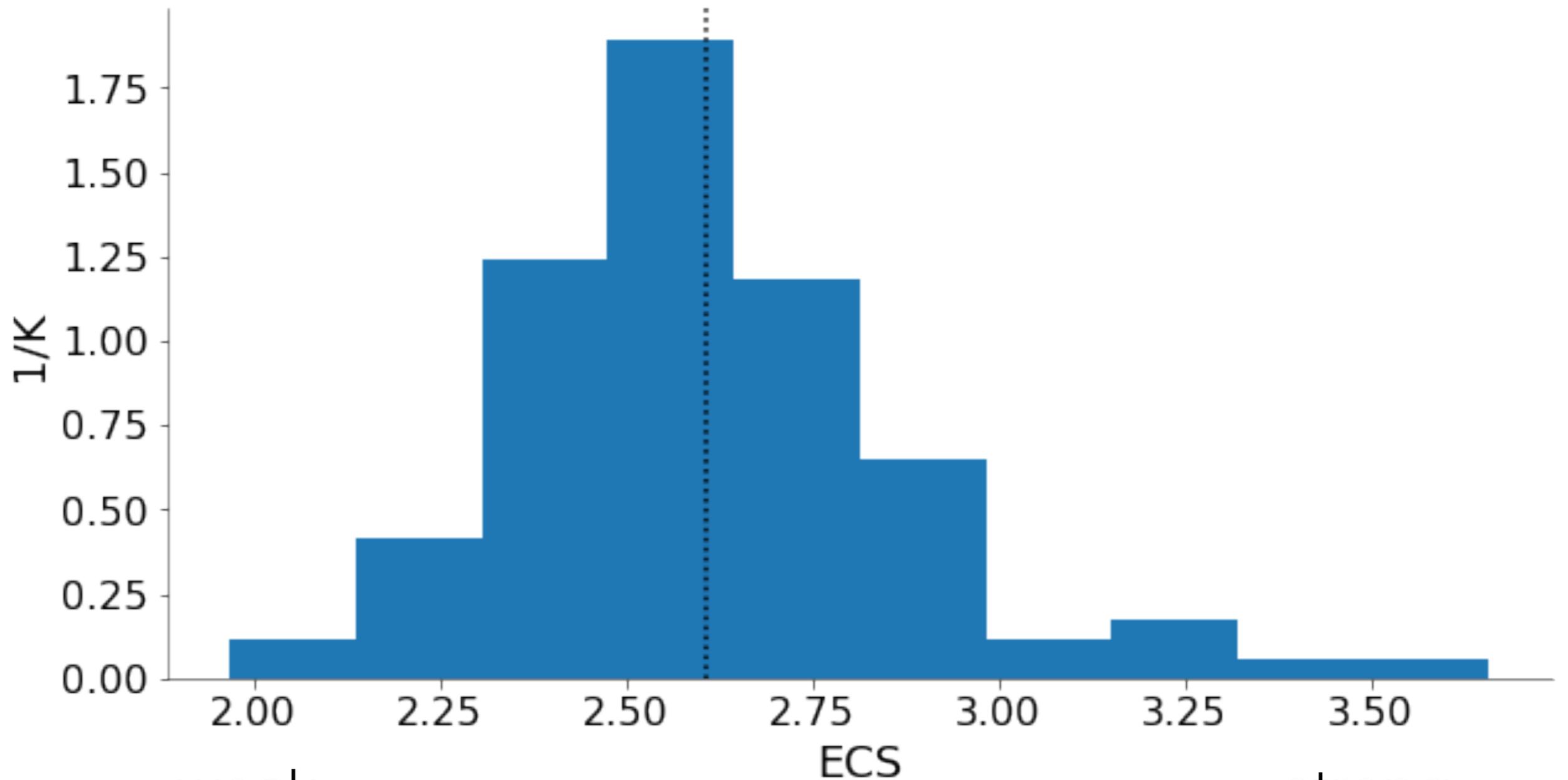






weak:  
surface albedo  
& SW cloud  
feedbacks

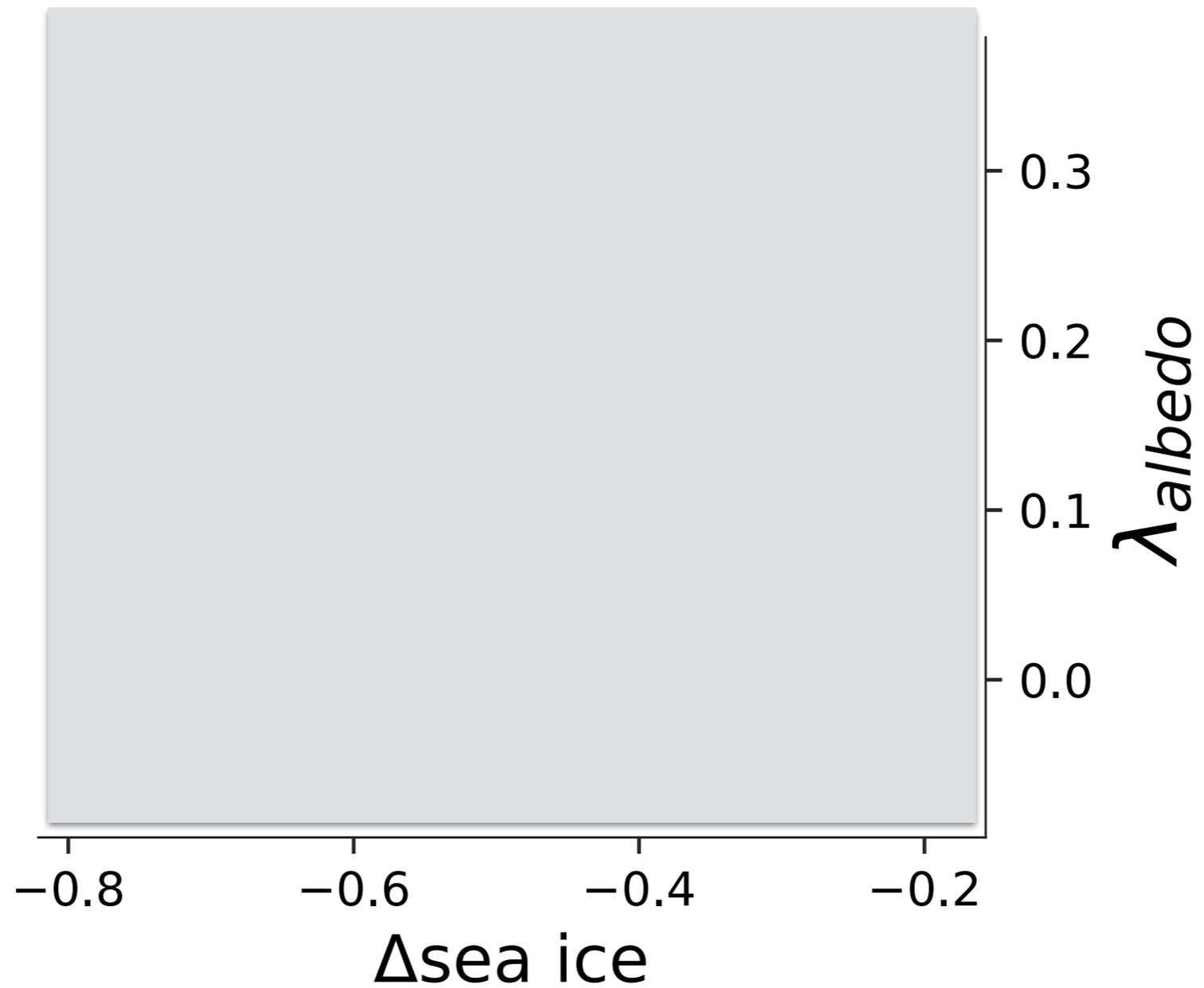




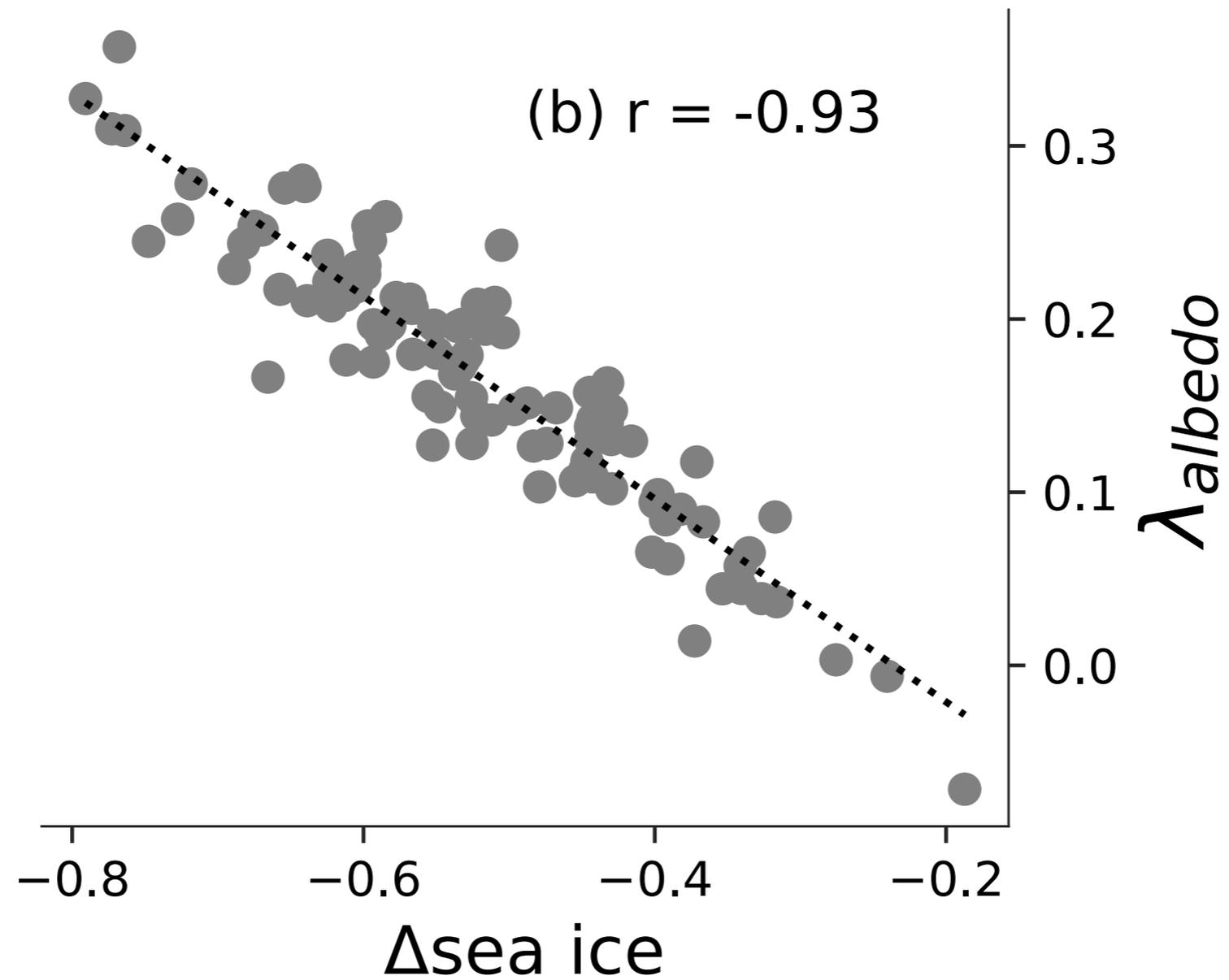
weak:  
 surface albedo  
 & SW cloud  
 feedbacks

strong:  
 surface albedo  
 & SW cloud  
 feedbacks

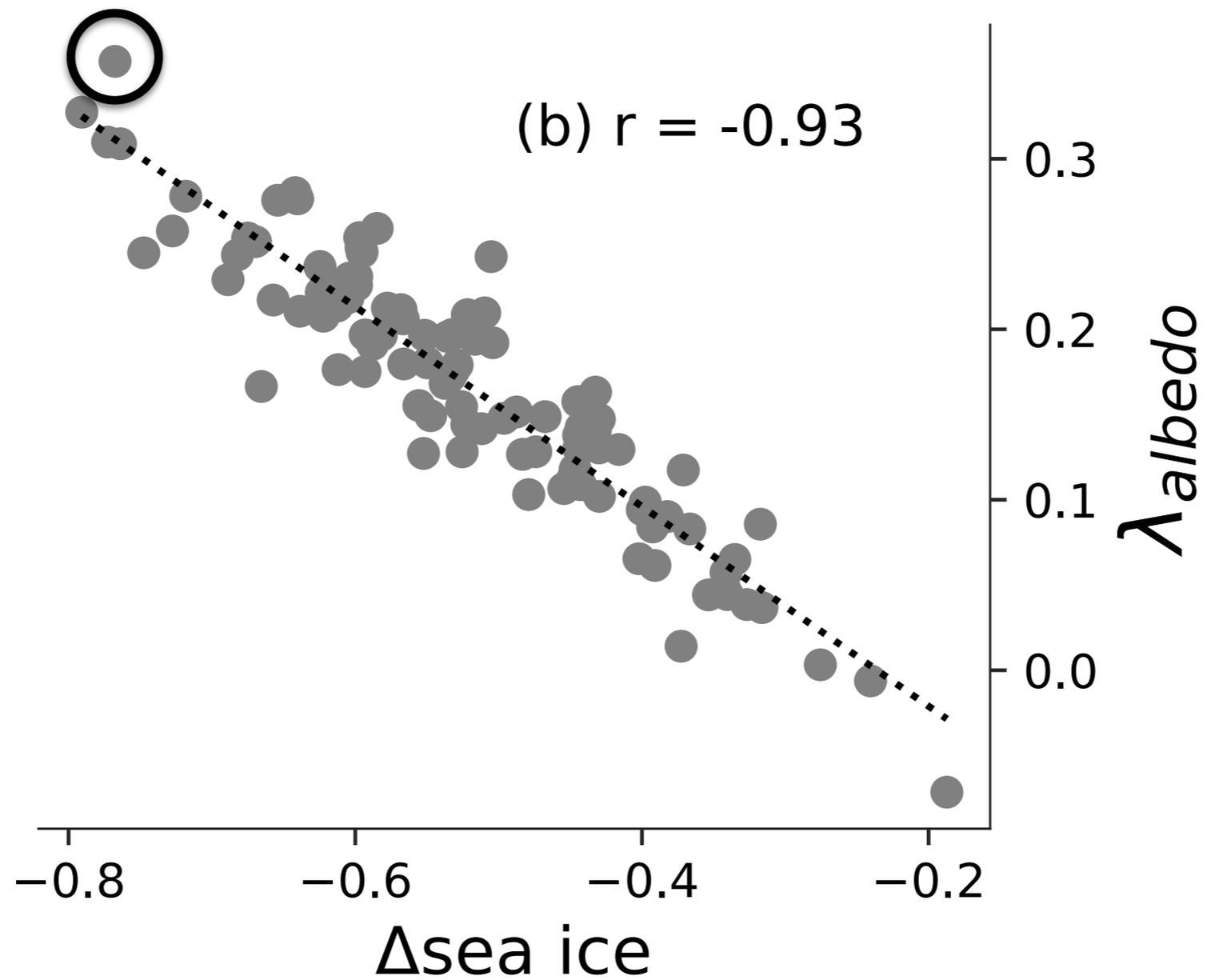




$\Delta\text{sea ice} = 1996\text{-}2005 \text{ sea ice minus } 1850\text{-}1859 \text{ sea ice}$

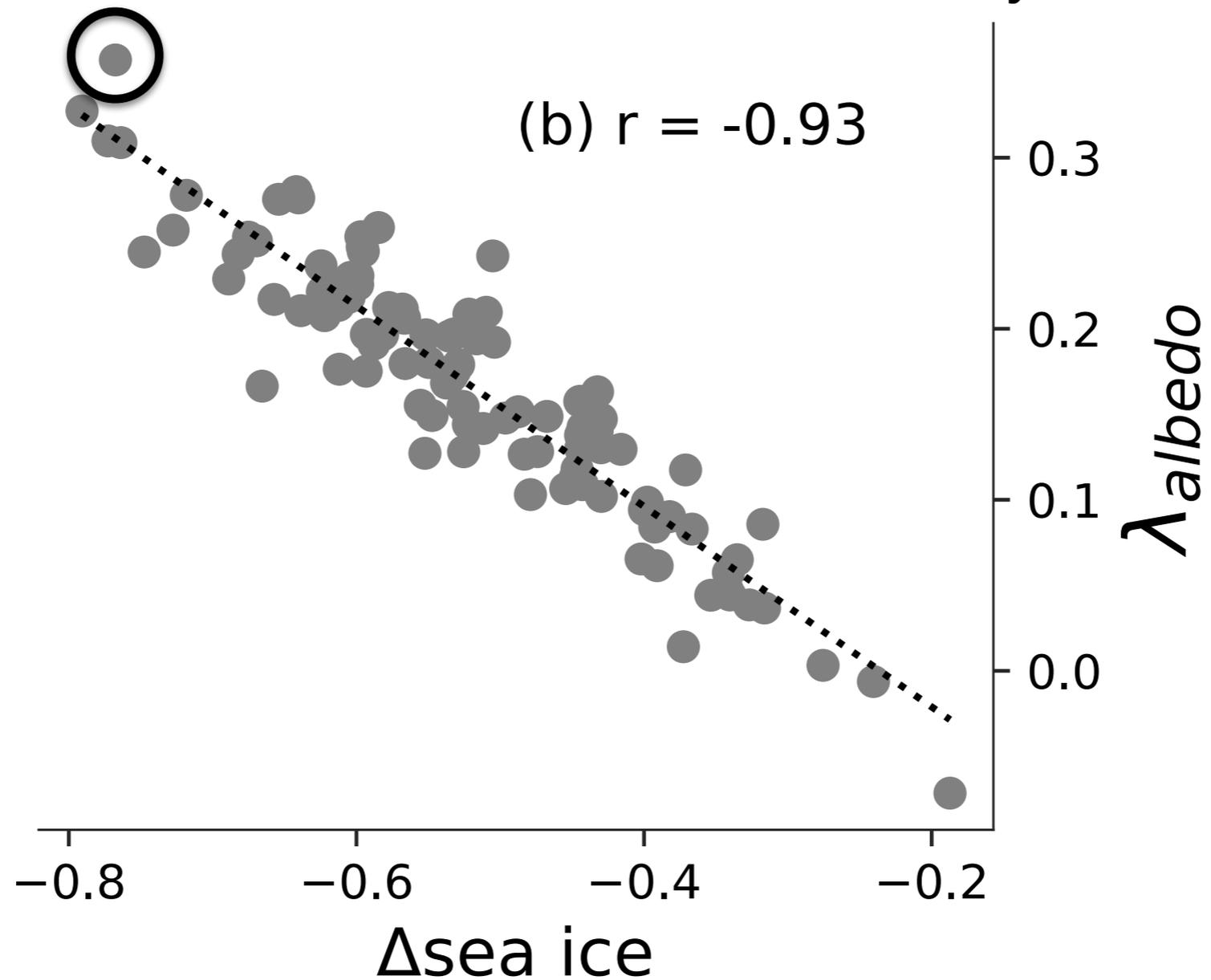


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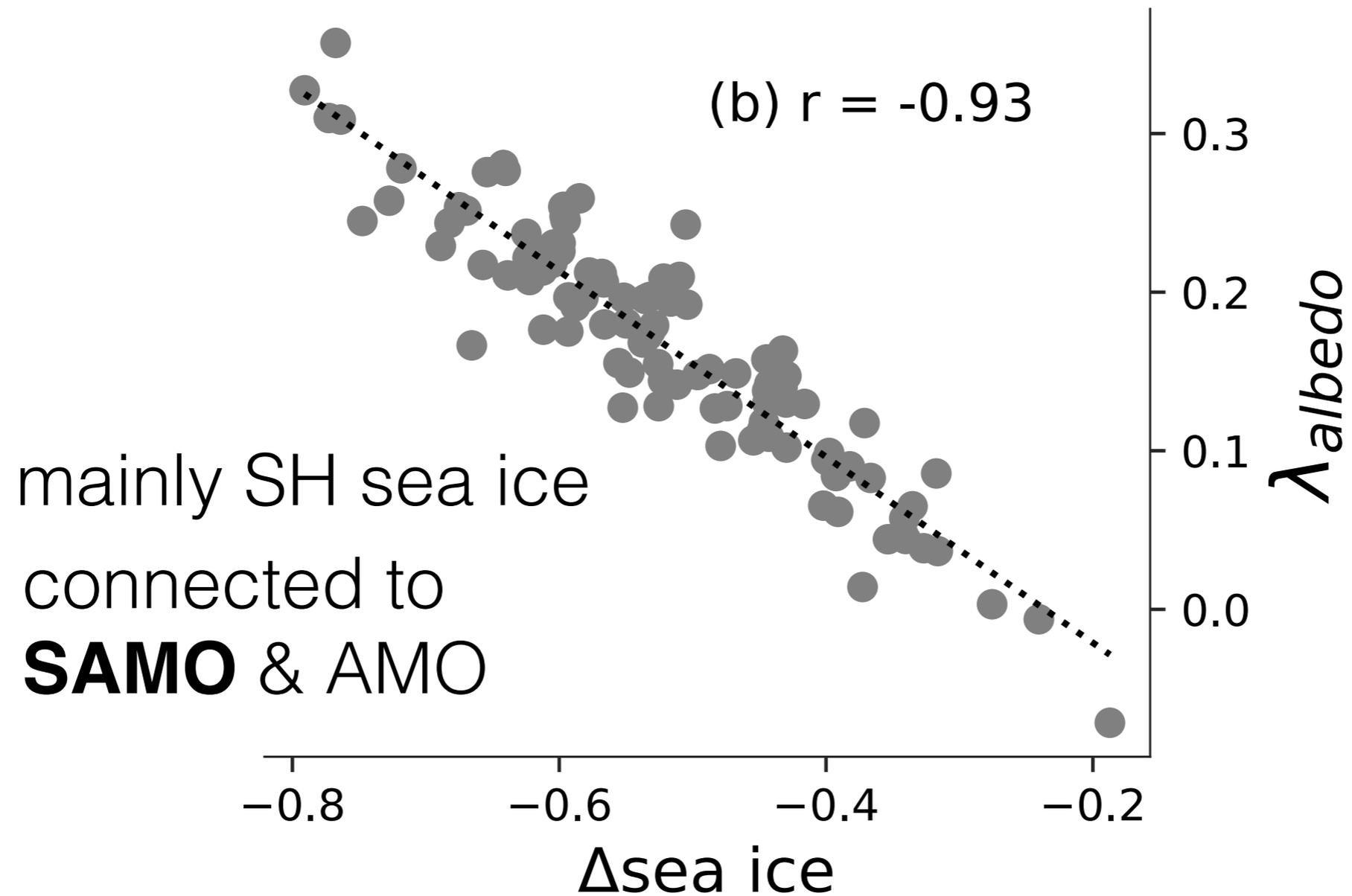


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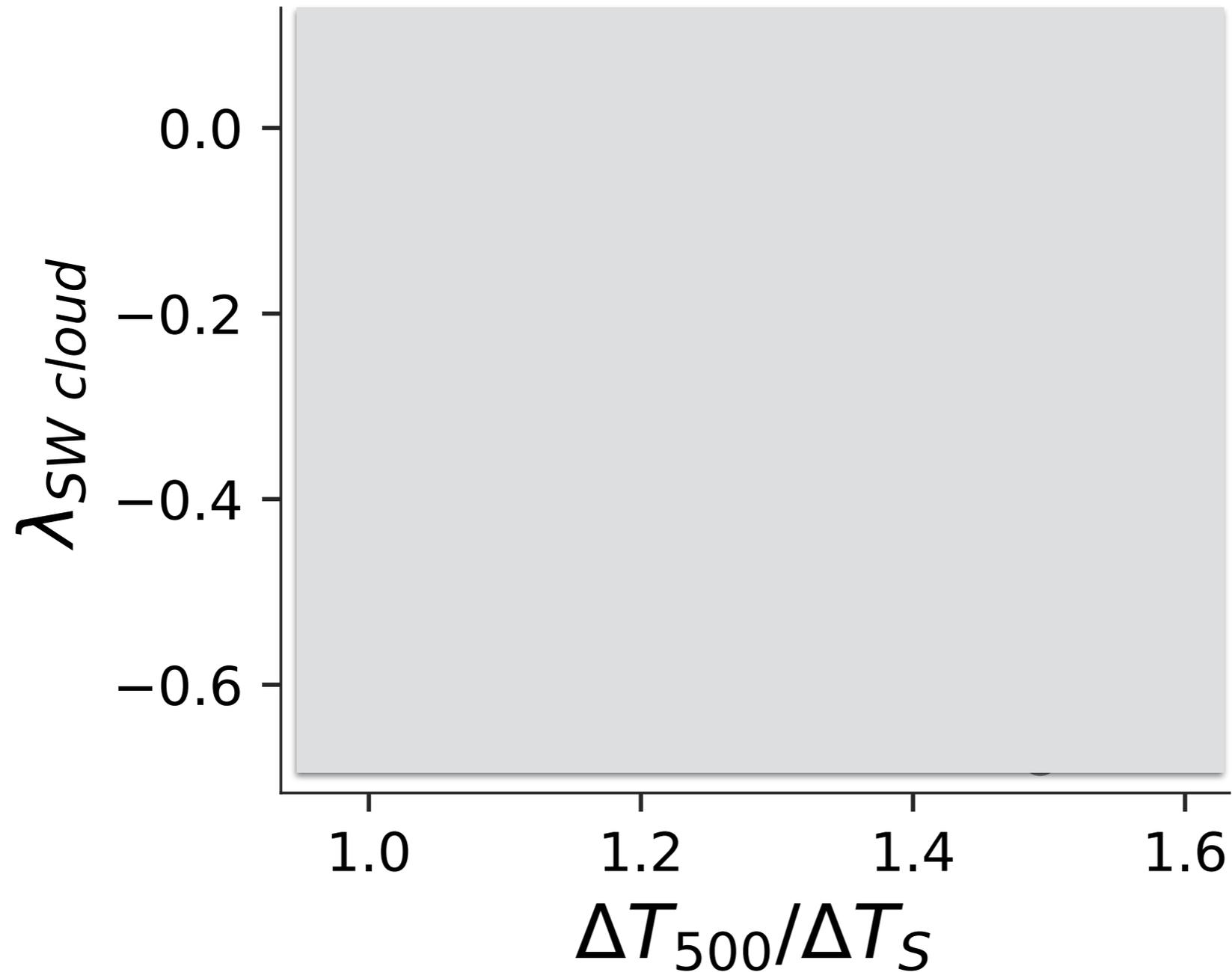
loss of sea ice is both  
forced & due to internal variability



$\Delta\text{sea ice} = 1996\text{-}2005 \text{ sea ice minus } 1850\text{-}1859 \text{ sea ice}$



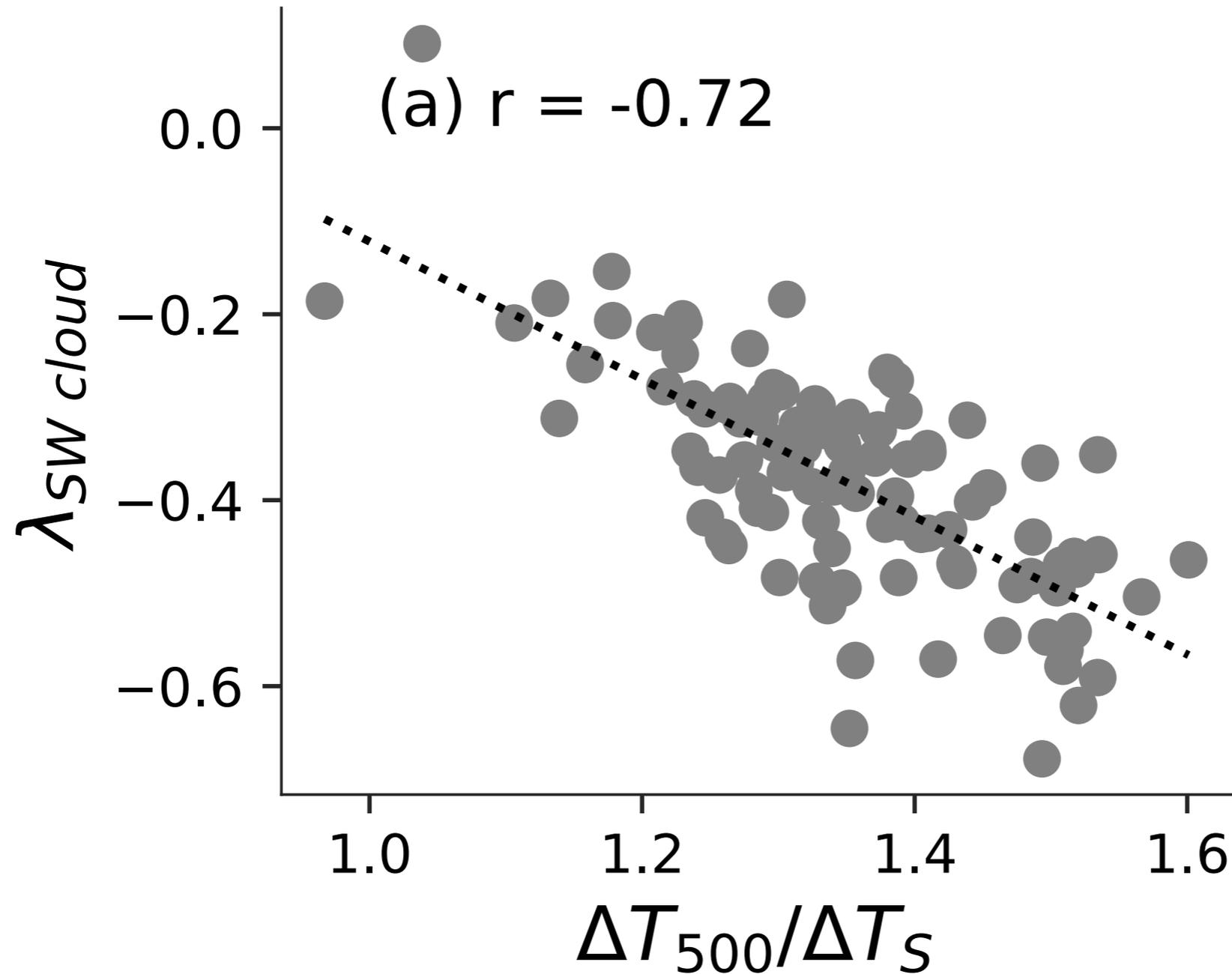
$\Delta$ sea ice = 1996-2005 sea ice minus 1850-1859 sea ice



$\Delta T_{500}/\Delta T_S$  = tropical atmospheric warming per unit of global avg. surface warming

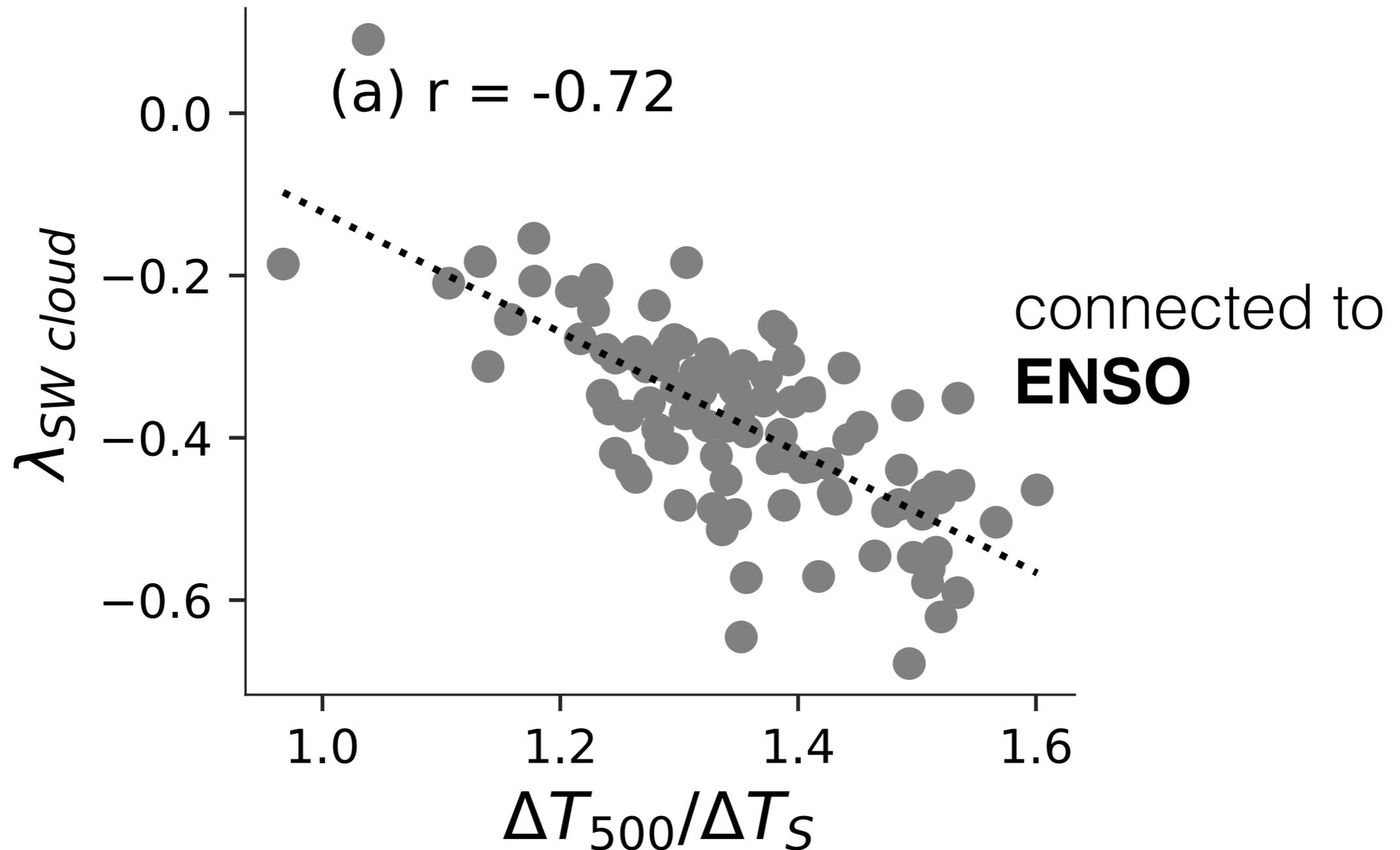
[see also: Zhou et al., 2016; Ceppi and Gregory, 2017, 2019; Andrews and Webb, 2018; Dessler et al., 2018]





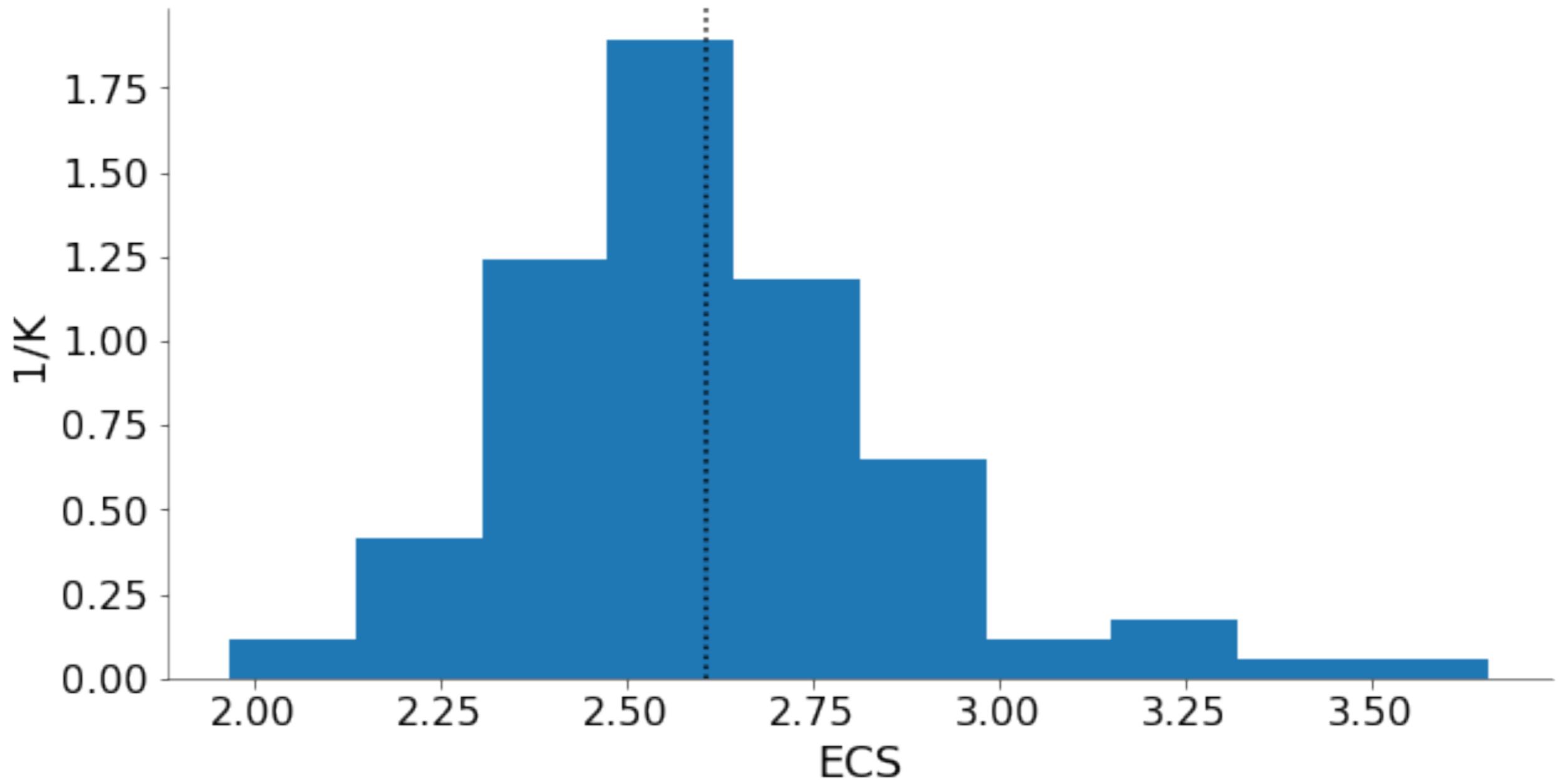
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less SH sea ice  
loss

more SH sea ice  
loss

more tropospheric  
warming

less tropospheric  
warming

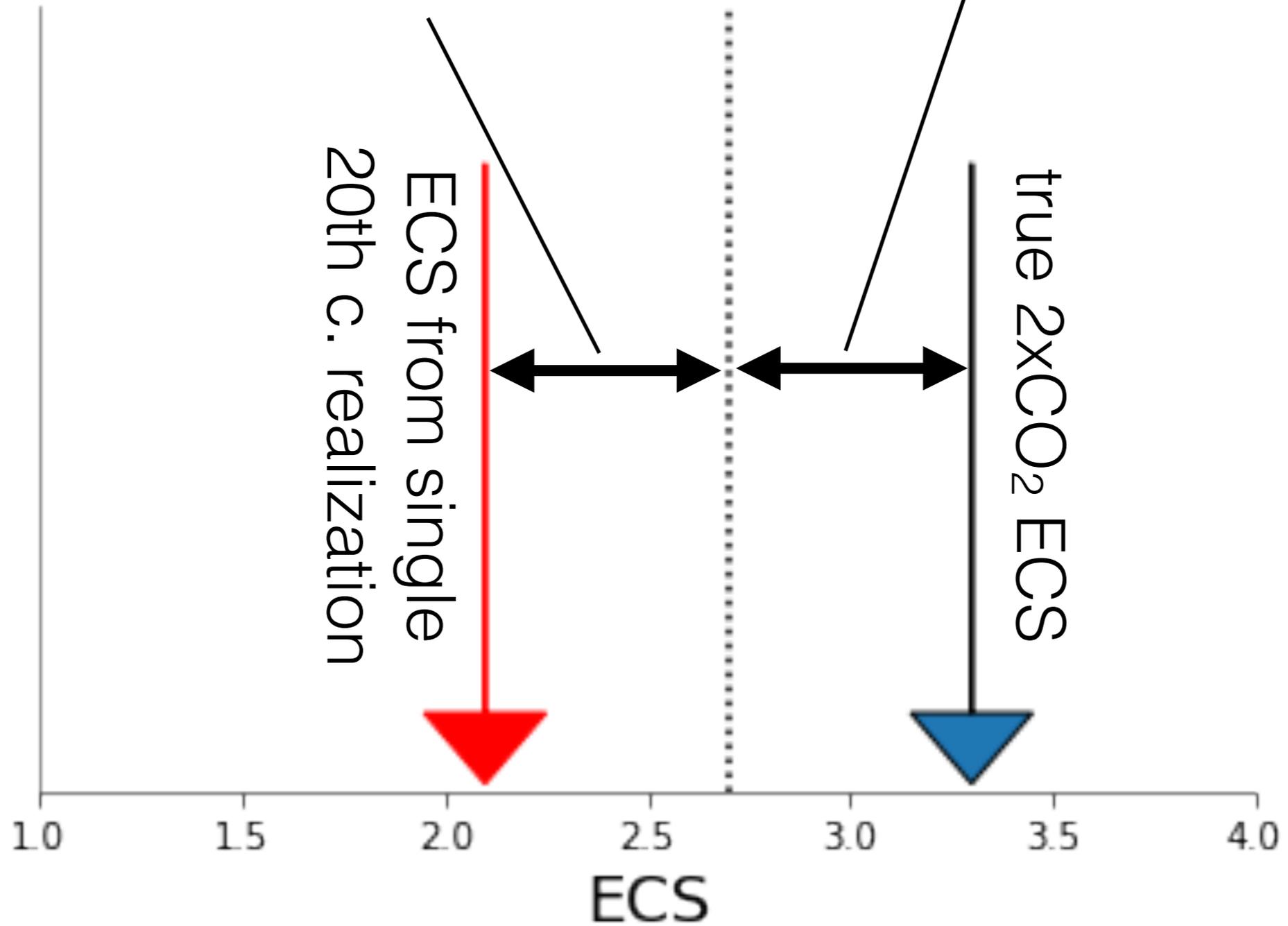


# unforced pattern effect

- ECS from a single trajectory will be  $\pm 0.3$  K (5-95%) from the ensemble average
- due primarily to unforced variability in SH sea ice and tropospheric warming
- some evidence ECS from historical record is low [Gregory and Andrews, 2016; Zhou et al., 2016; Marvel et al., 2018; Andrews et al., 2018]

“forced pattern effect”

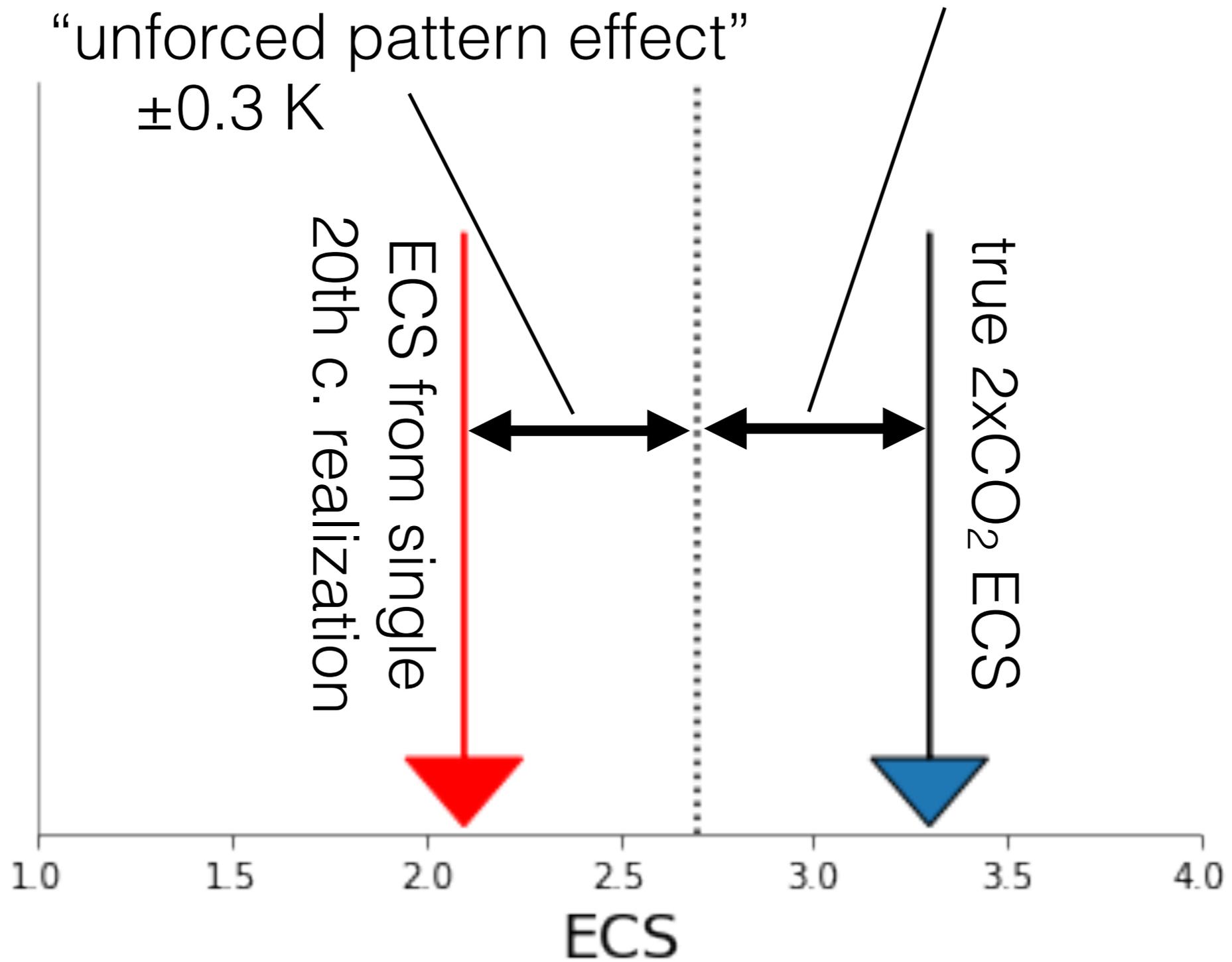
“unforced pattern effect”



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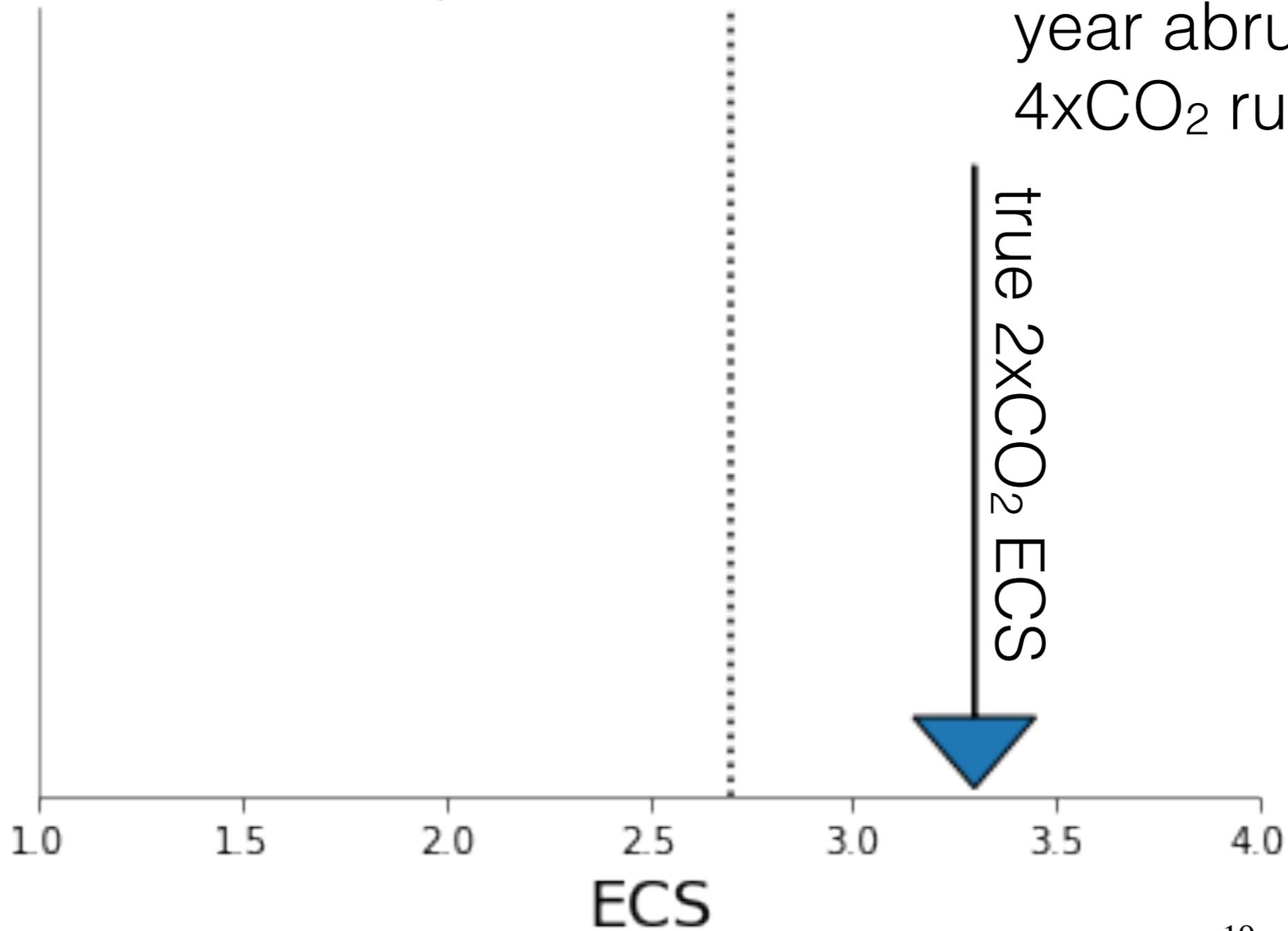
“unforced pattern effect”

$\pm 0.3$  K

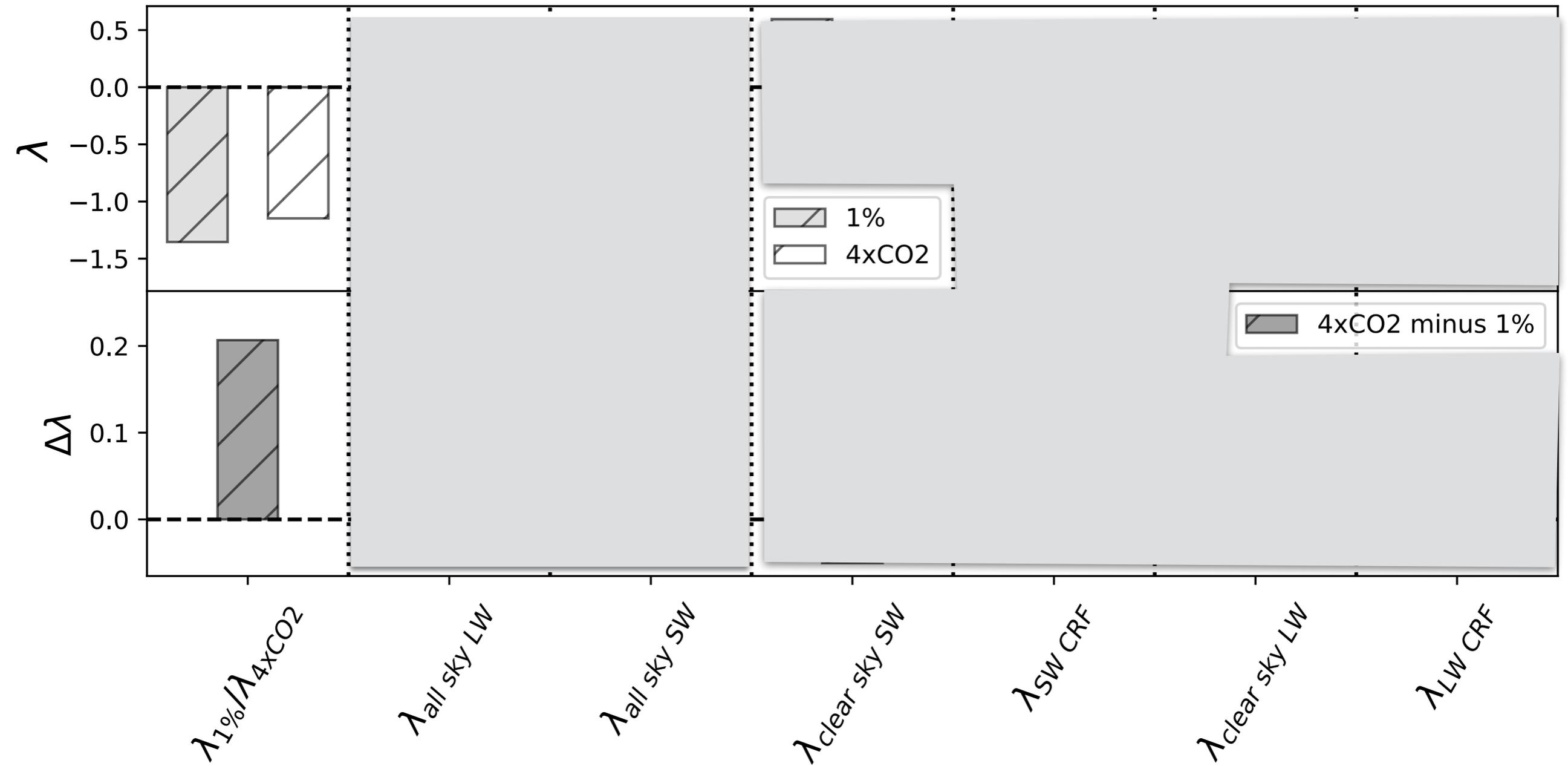


ensemble of 68  
150-year 1% runs

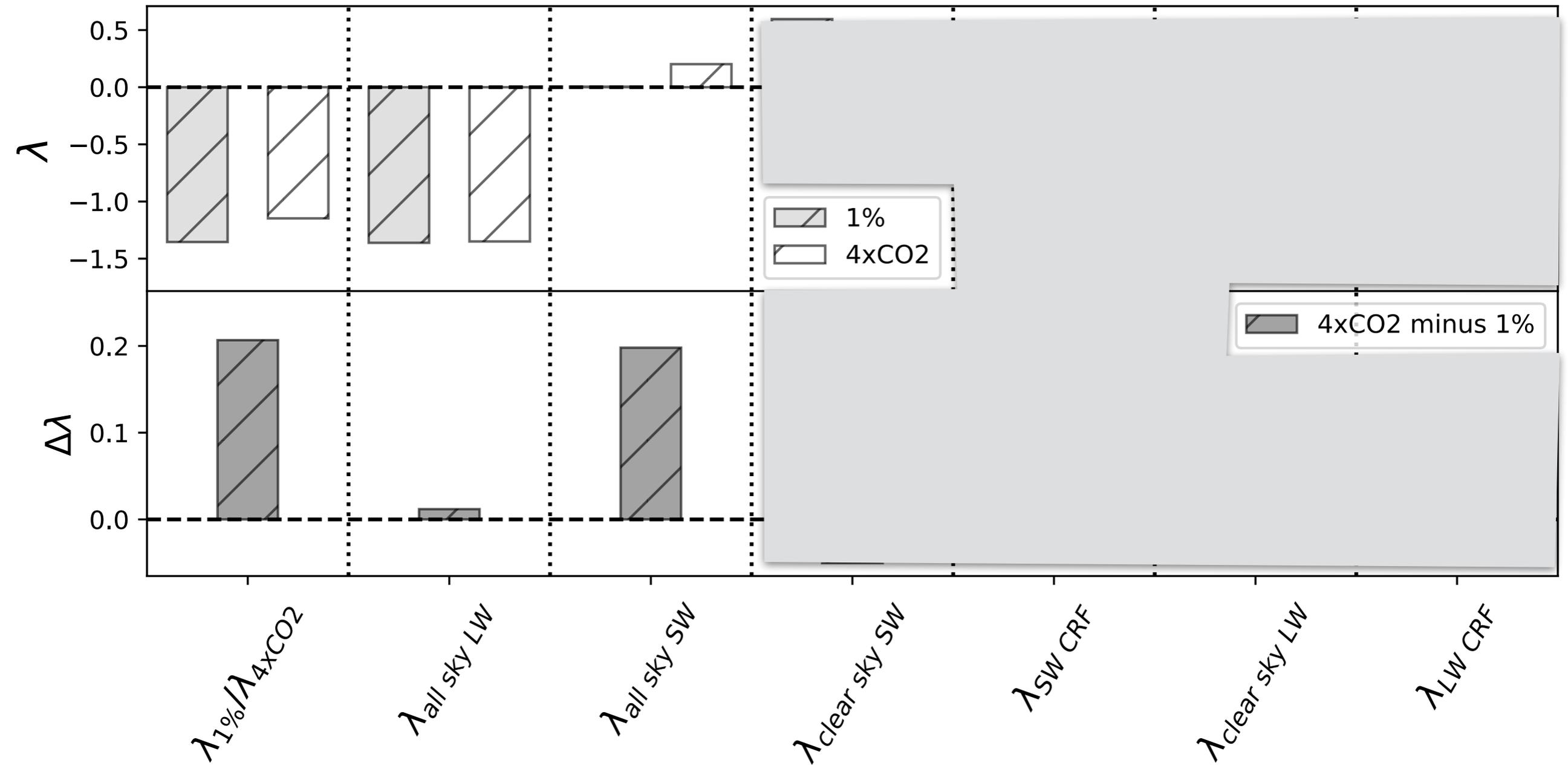
calculated  
from a 2600-  
year abrupt  
4xCO<sub>2</sub> run



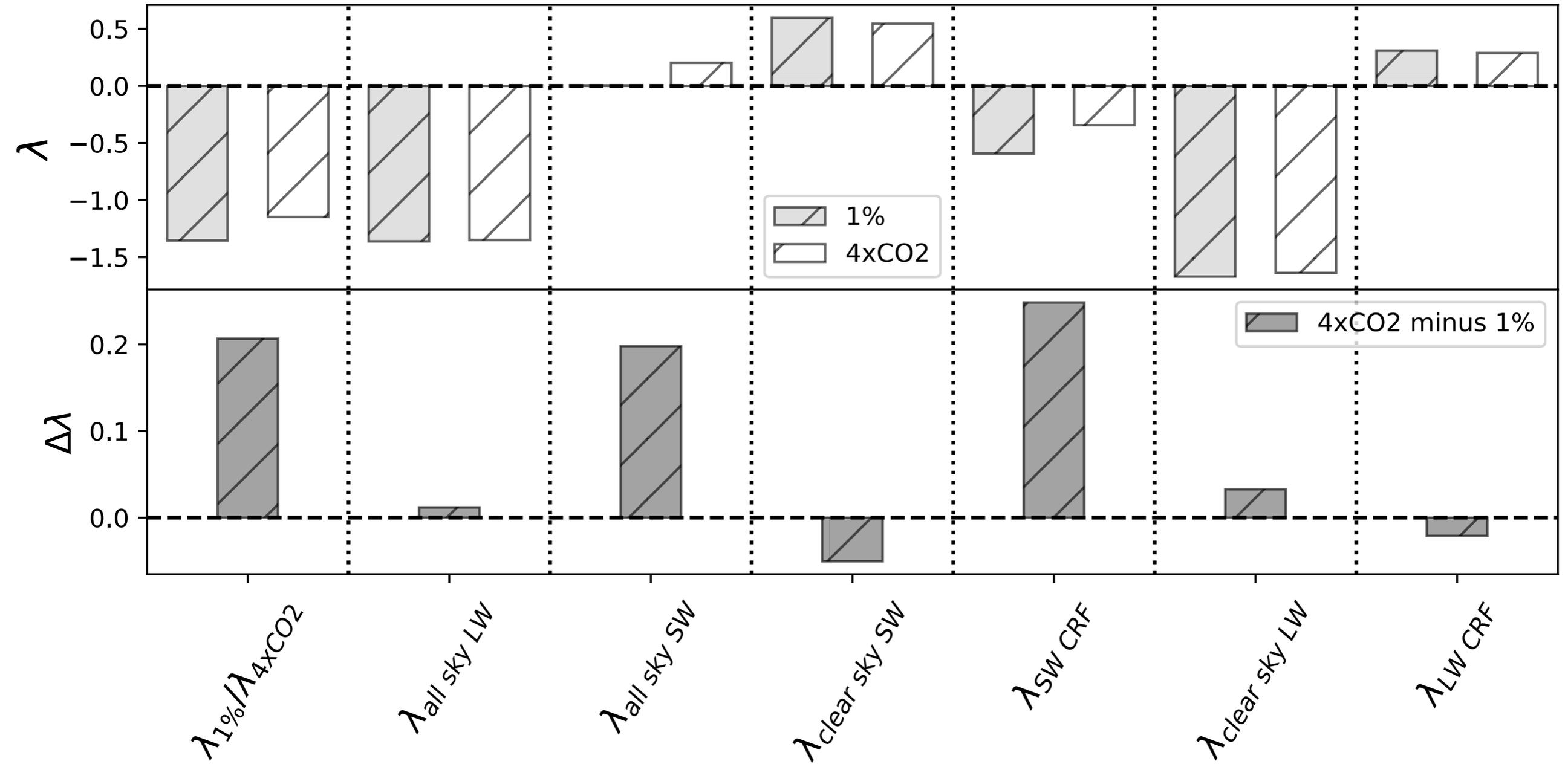
ensemble-average 1% & 4xCO2  $\lambda$



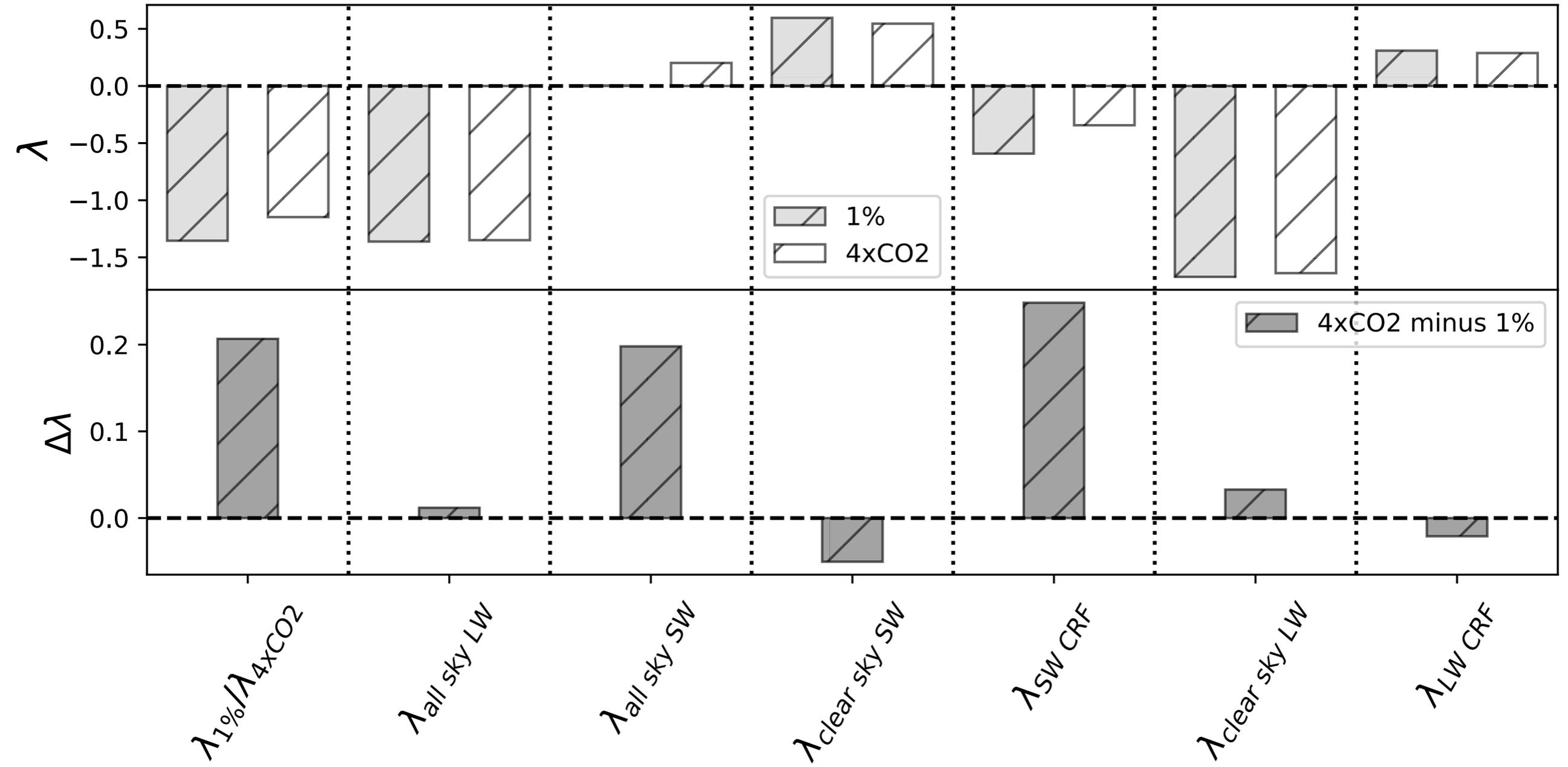
ensemble-average 1% & 4xCO2  $\lambda$



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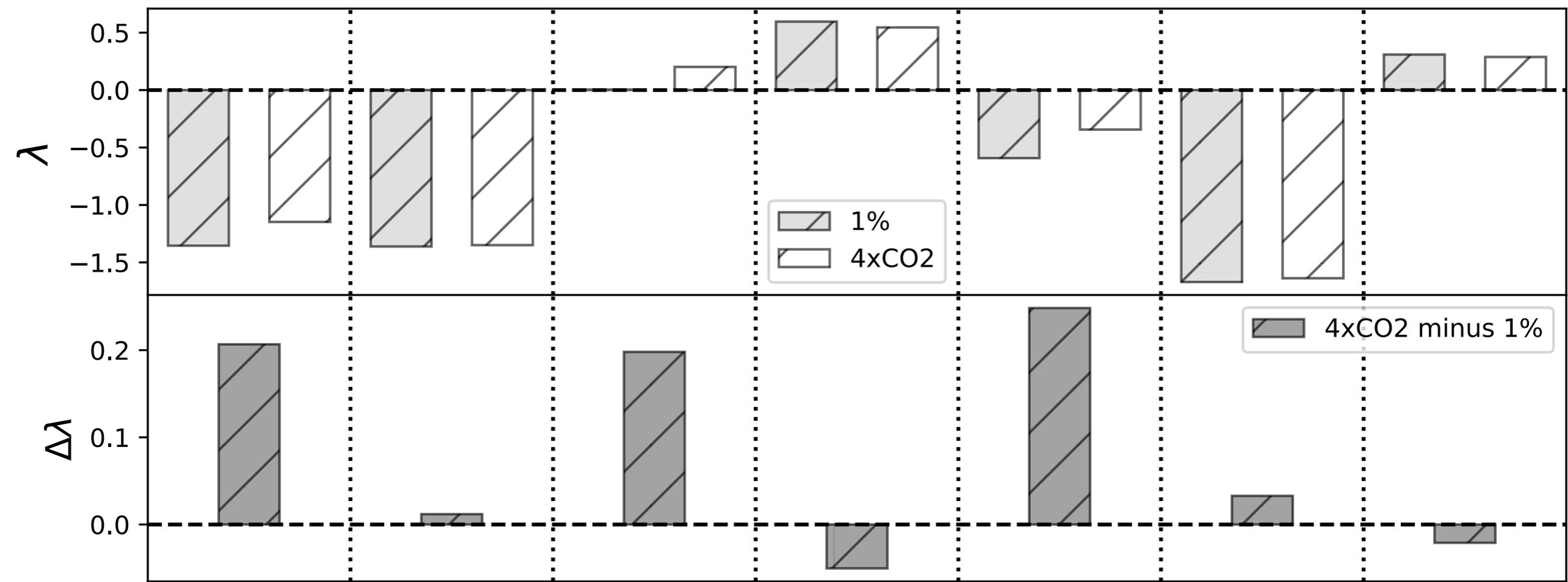
ensemble-average 1% & 4xCO2  $\lambda$



planck  
lapse rate  
water vapor



ensemble-average 1% & 4xCO2  $\lambda$

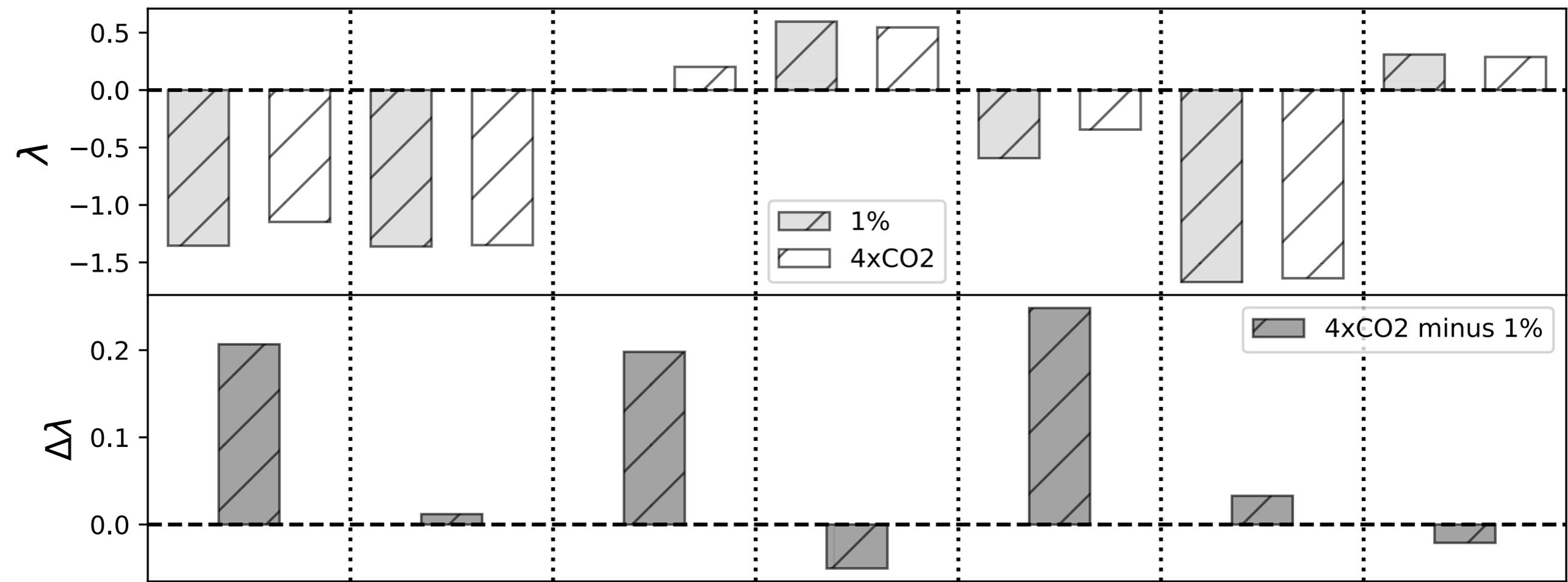


$\lambda_{1\%}/\lambda_{4xCO2}$        $\lambda_{all\ sky\ LW}$        $\lambda_{all\ sky\ SW}$        $\lambda_{clear\ sky\ SW}$        $\lambda_{SW\ CRF}$        $\lambda_{clear\ sky\ LW}$        $\lambda_{LW\ CRF}$

planck  
lapse rate    LW clouds  
water vapor



ensemble-average 1% & 4xCO2  $\lambda$



$\lambda_{1\%}/\lambda_{4xCO2}$

$\lambda_{all\ sky\ LW}$

$\lambda_{all\ sky\ SW}$

$\lambda_{clear\ sky\ SW}$

$\lambda_{SW\ CRF}$

$\lambda_{clear\ sky\ LW}$

$\lambda_{LW\ CRF}$

surface albedo

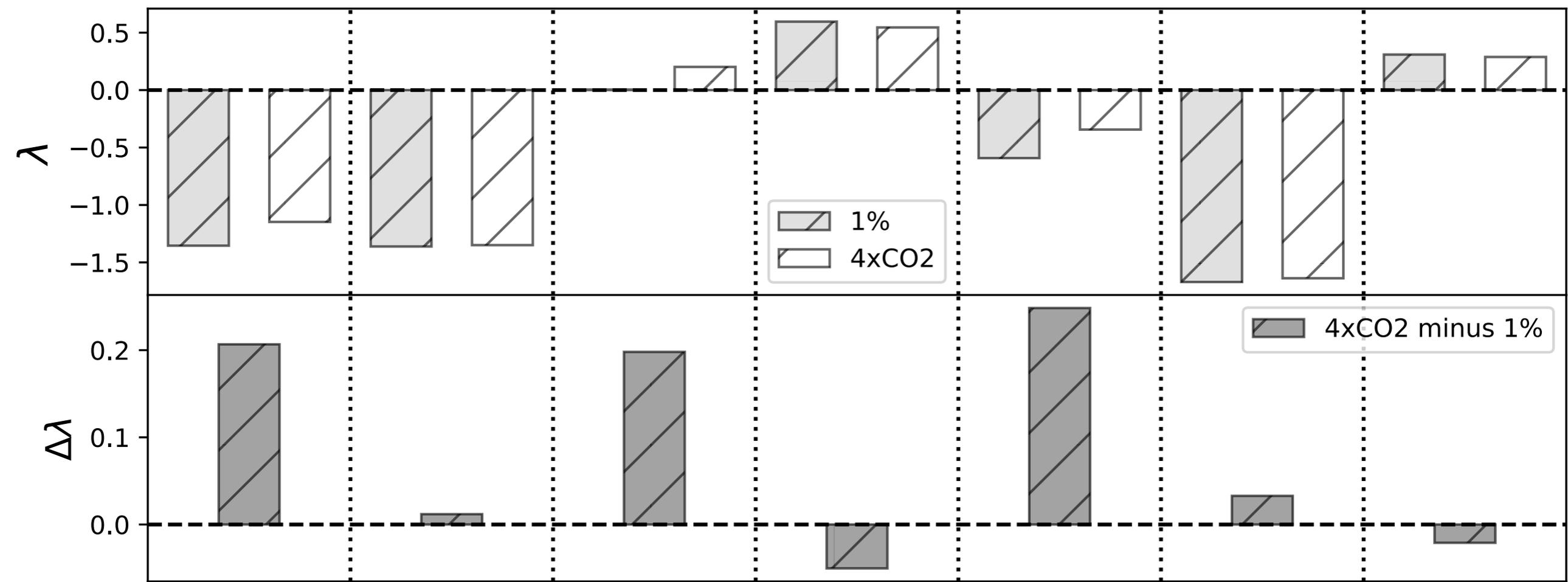
planck  
lapse rate  
water vapor

21

LW clouds



ensemble-average 1% & 4xCO2  $\lambda$



$\lambda_{1\%}/\lambda_{4xCO2}$

$\lambda_{all\ sky\ LW}$

$\lambda_{all\ sky\ SW}$

$\lambda_{clear\ sky\ SW}$

$\lambda_{SW\ CRF}$

$\lambda_{clear\ sky\ LW}$

$\lambda_{LW\ CRF}$

surface albedo

SW clouds

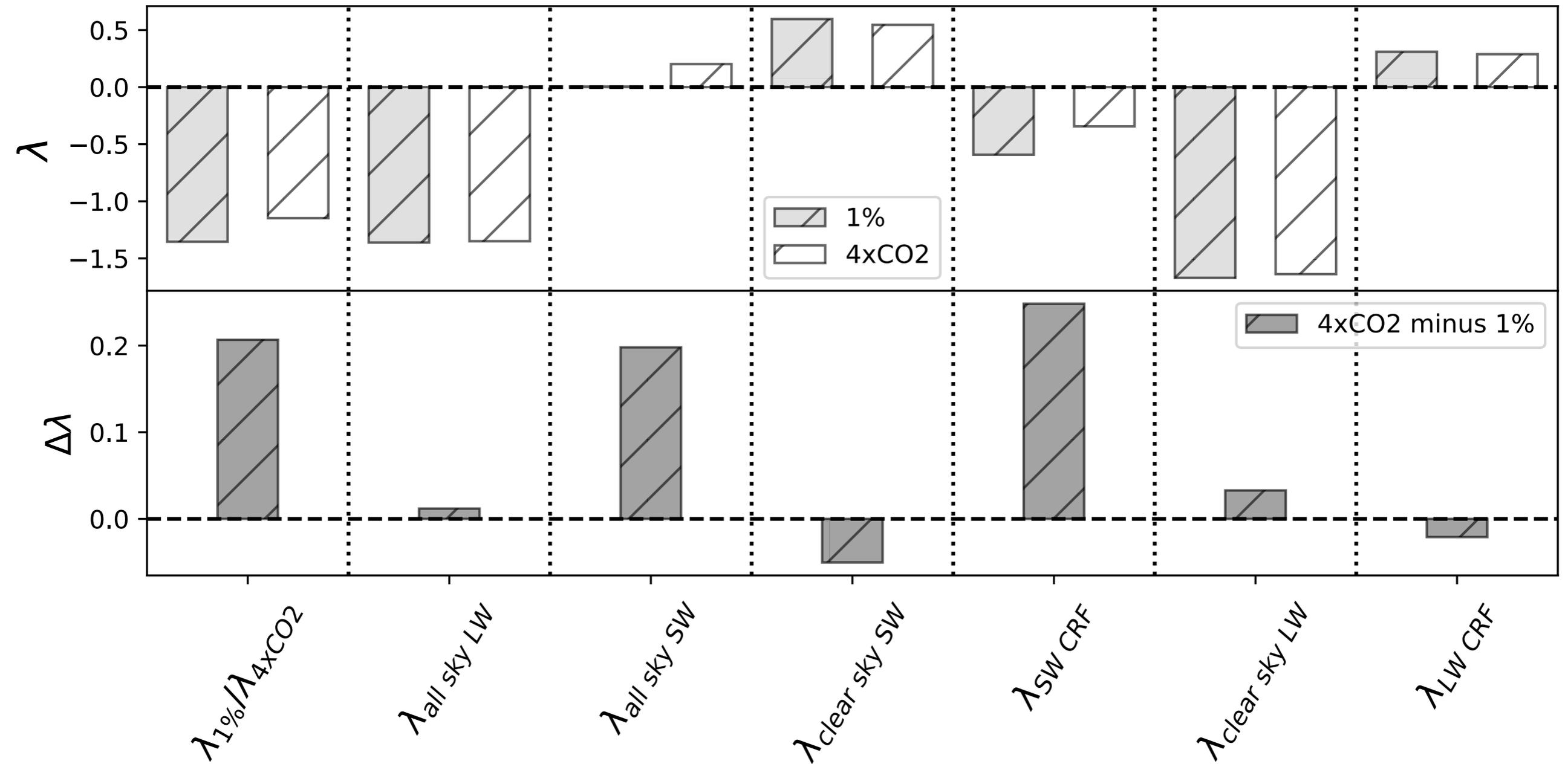
lapse rate water vapor

LW clouds

planck



ensemble-average 1% & 4xCO2  $\lambda$

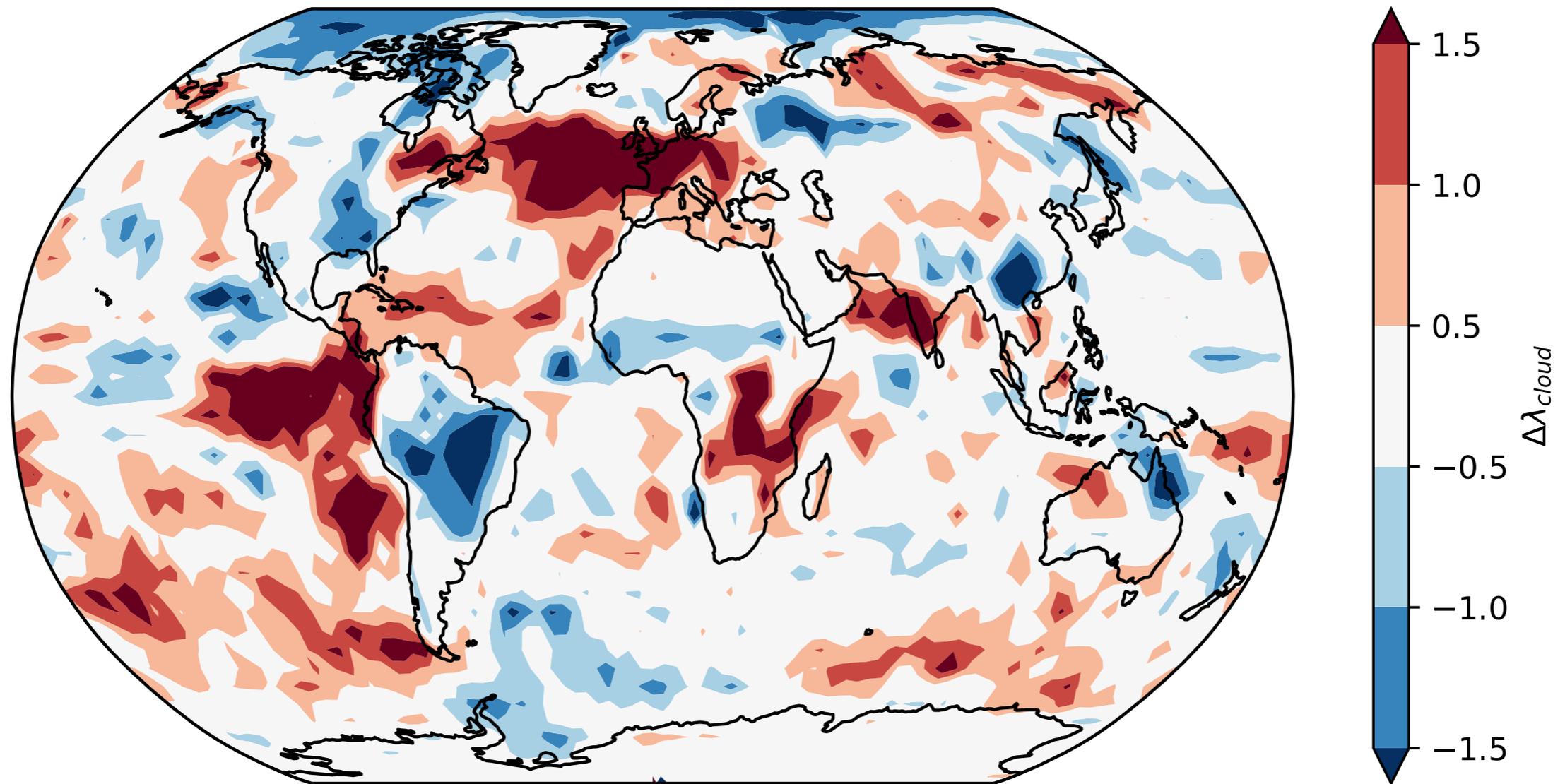


# forced pattern effect: low clouds

Senior and Mitchell, 2000; Ceppi and Gregory, 2017;  
 Andrews et al., 2018



net cloud feedback from 4xCO2 minus  
ensemble average from 1% ensemble



see also: Senior and Mitchell, 2000; Ceppi and Gregory, 2017;  
Andrews et al., 2018

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- Gregory method for  $4\times\text{CO}_2$  feedbacks is problematic

# summary

- forced pattern effect  $\approx$  **+0.2 K** (true ECS > historical ECS; due to changes in clouds in regions of delayed warming)
- unforced pattern effect  $\approx$   **$\pm 0.3$  K** (variability in sea ice & tropospheric temperatures)

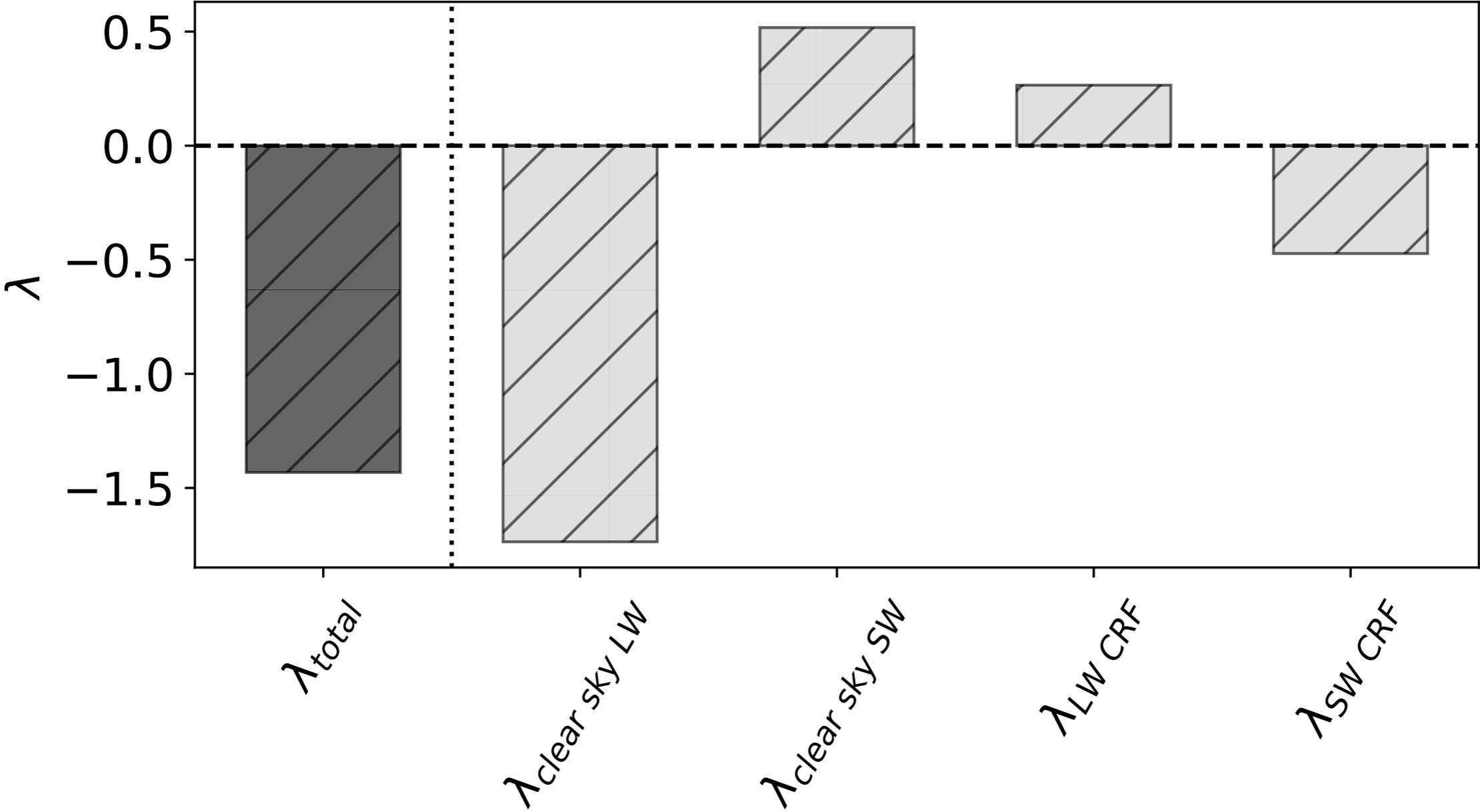
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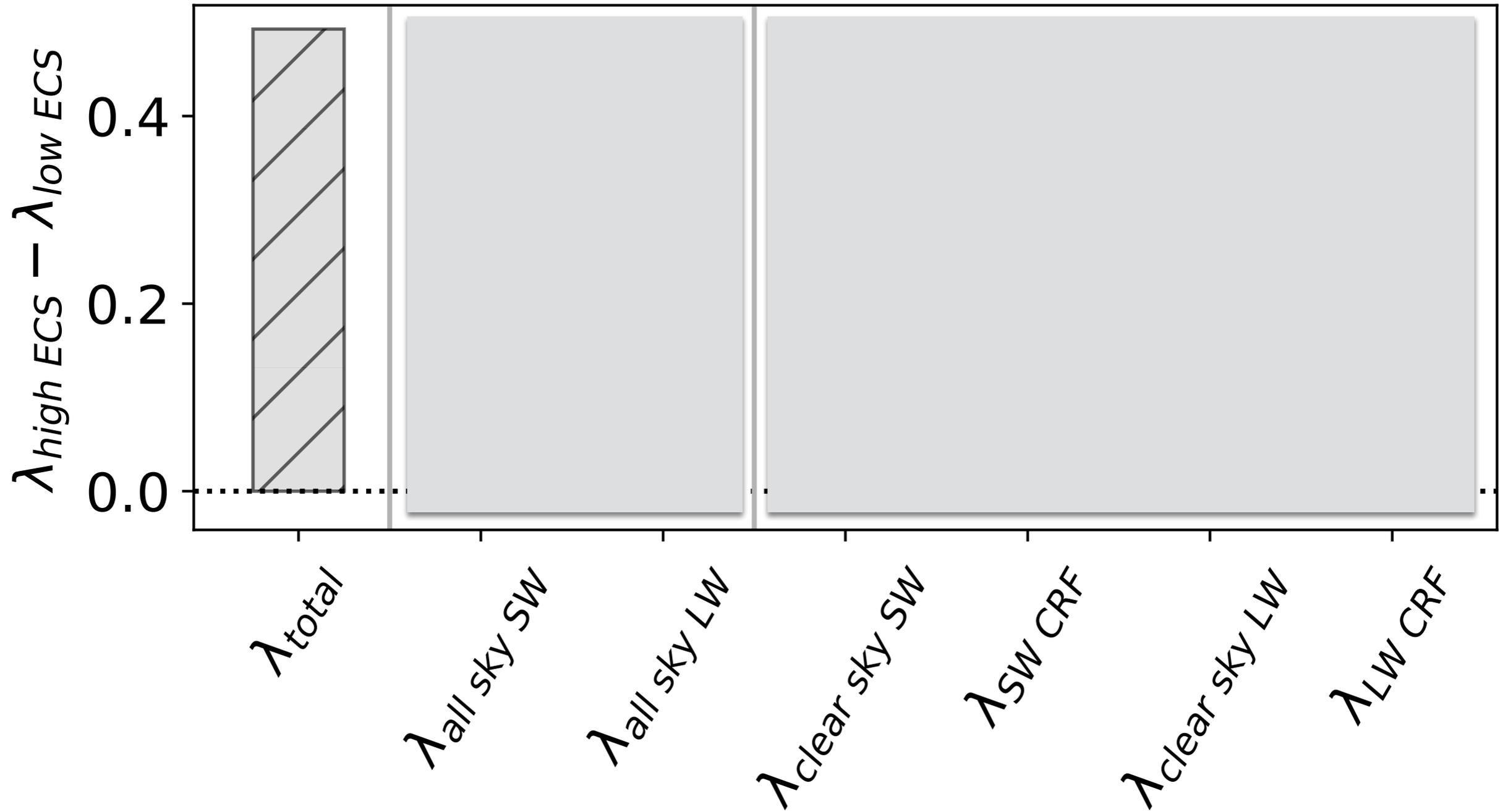
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- this is a single-model study
- This work was supported by NSF grant AGS-1661861 to Texas A&M. Thanks to MPI for providing access to the Grand Ensemble

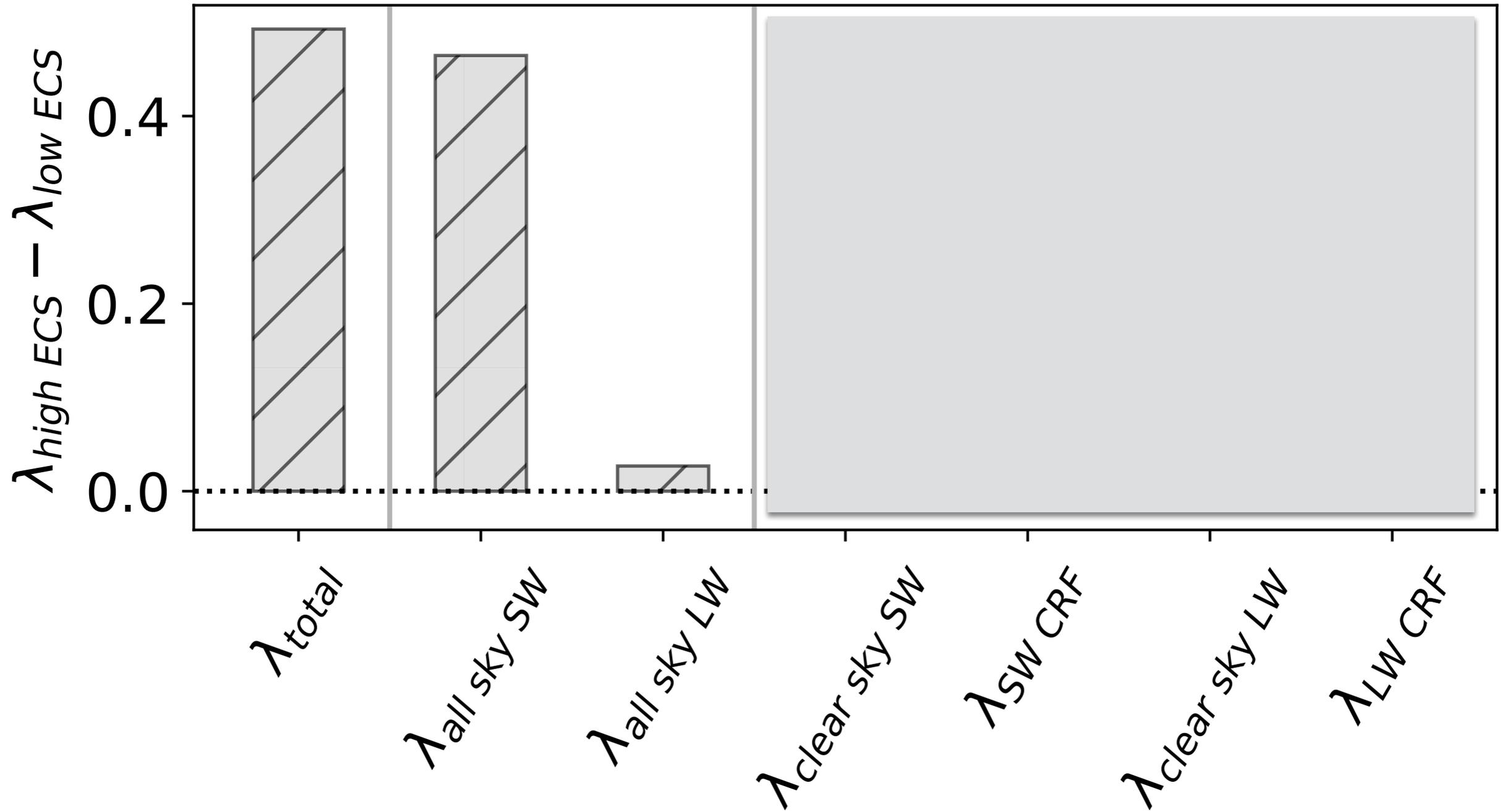
# ensemble average $\lambda$



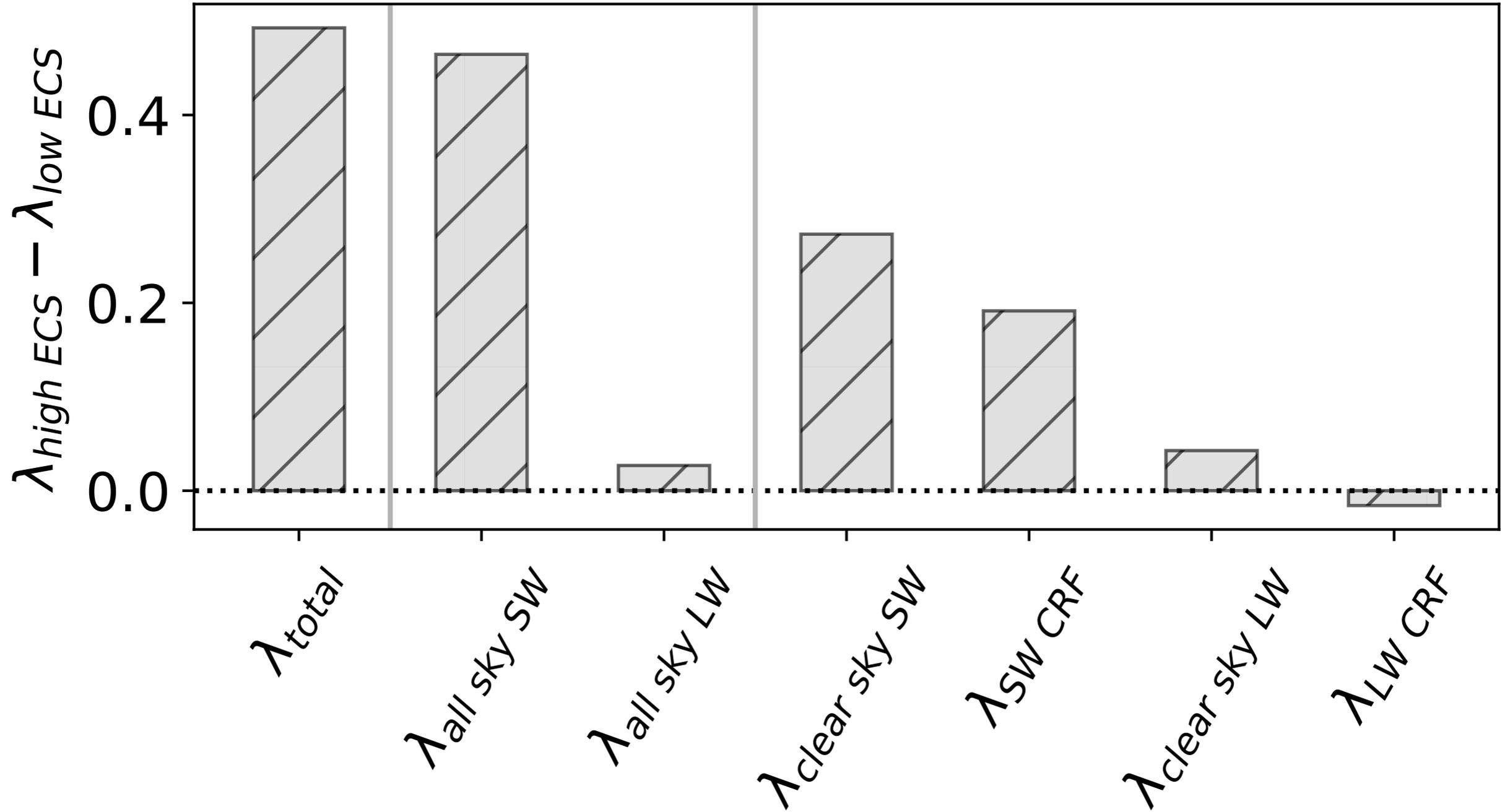
# $\Delta\lambda$ , high ECS minus low ECS



# $\Delta\lambda$ , high ECS minus low ECS



# $\Delta\lambda$ , high ECS minus low ECS



$$\lambda_{hist} = a \Delta(\text{sea ice}) + b \left( \frac{\Delta T_{500}}{\Delta T_S} \right)$$

