

# A new analysis framework to detect changes in internal variability under global warming

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# Does internal variability change under global warming?

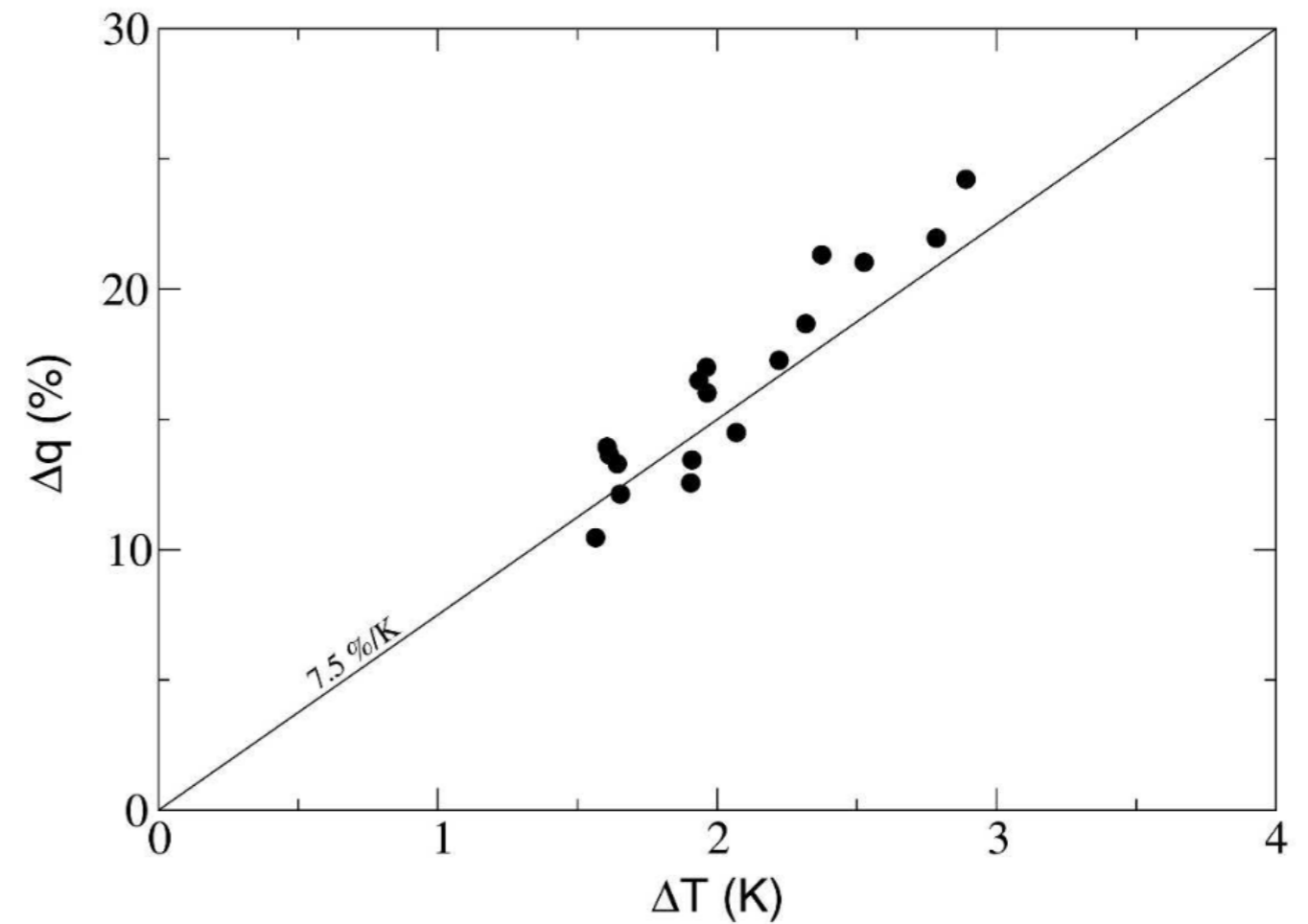
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Quantity with change in variability  
under global warming:

- precipitable water
- global mean, annual mean

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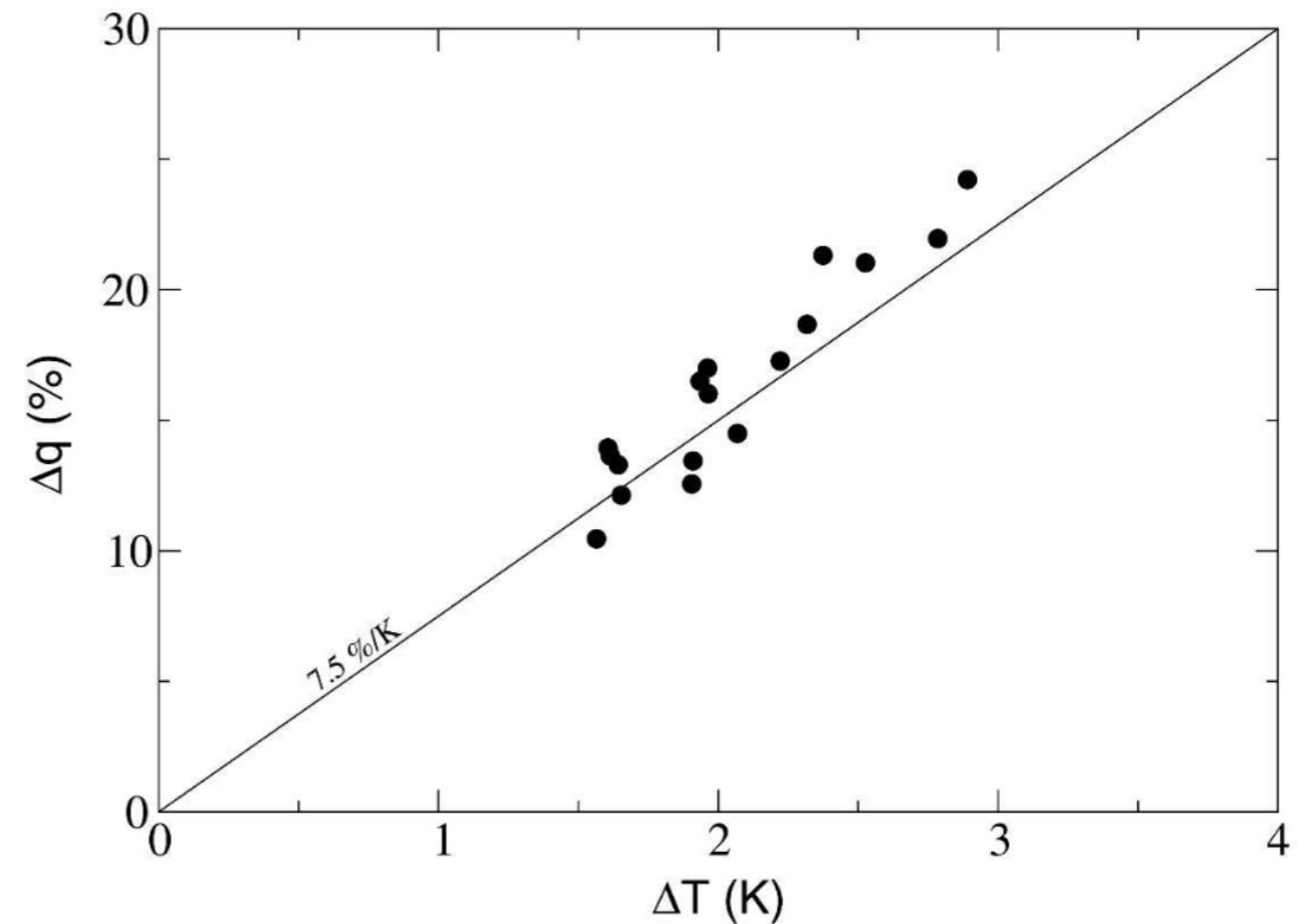
*Held and Soden, 2006*

## Quantity with change in variability under global warming:

- precipitable water
- global mean, annual mean

## Scenario:

- strong warming



*Held and Soden, 2006*

## Model:

- MPI-ESM-LR ( T63 / GR15 )

*[www.mpimet.mpg.de/en/grand-ensemble](http://www.mpimet.mpg.de/en/grand-ensemble)*

**Model:**

- MPI-ESM-LR ( T63 / GR15 )

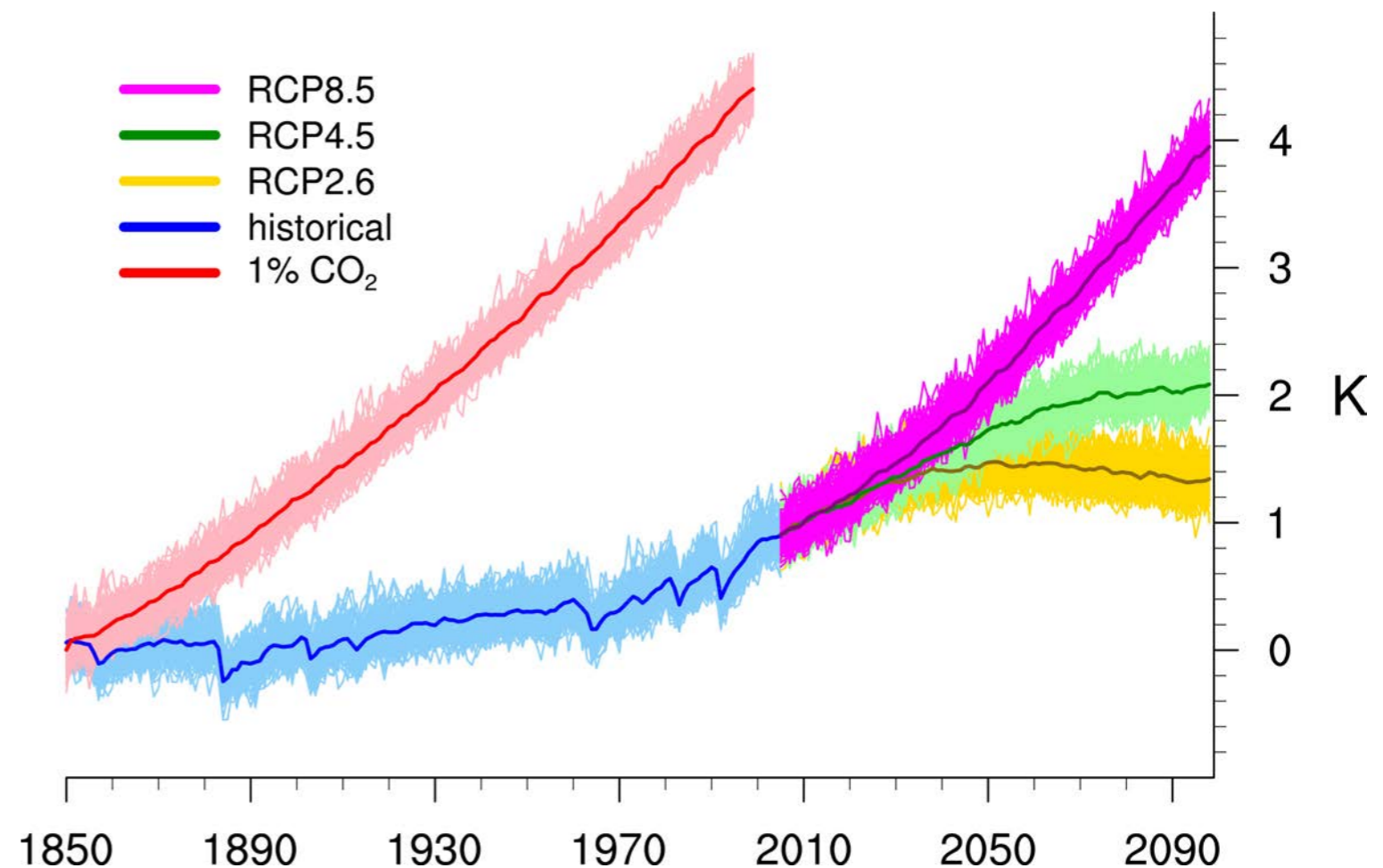
**Experiment:**

- 1% CO<sub>2</sub>

**Ensemble simulations:**

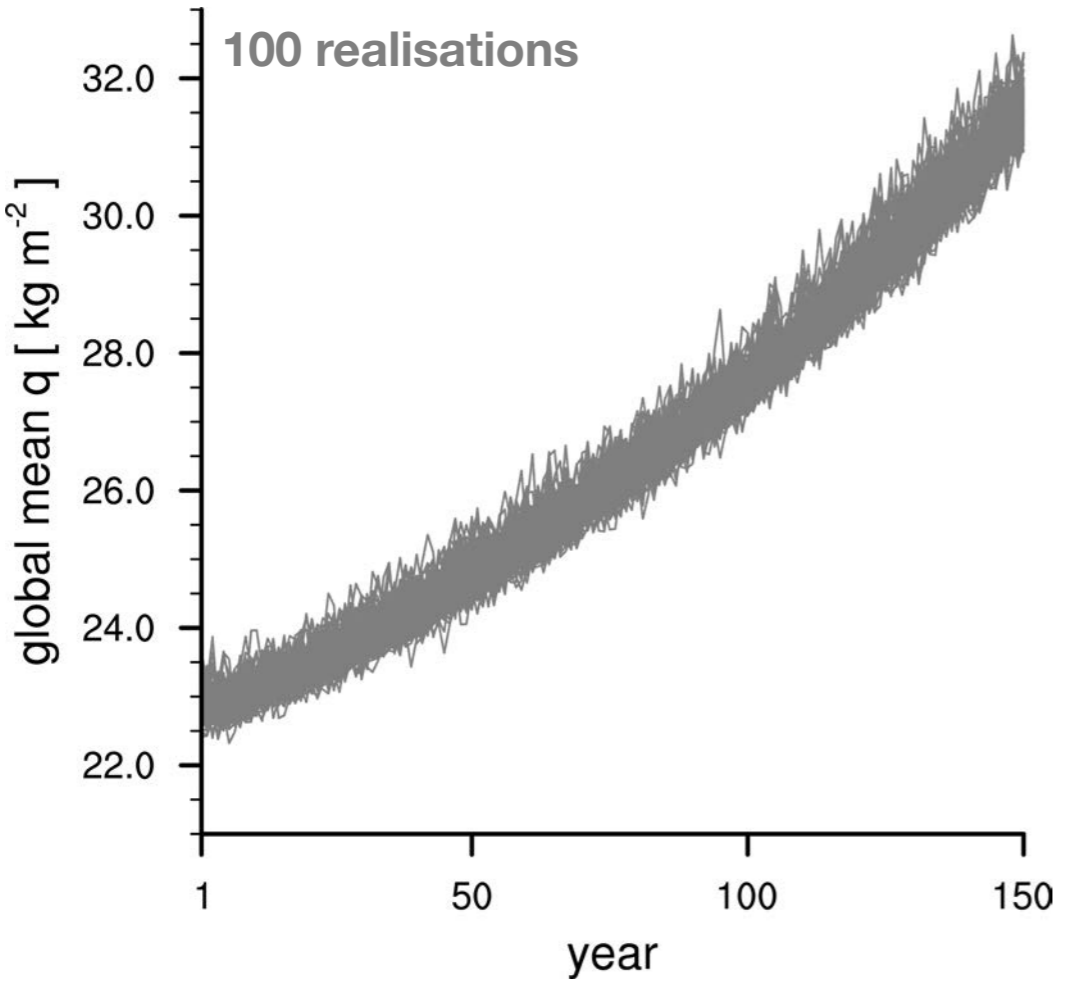
- 100 realisations / experiment
- different initial conditions (macro)

GMST relative to  
1850-1900 mean



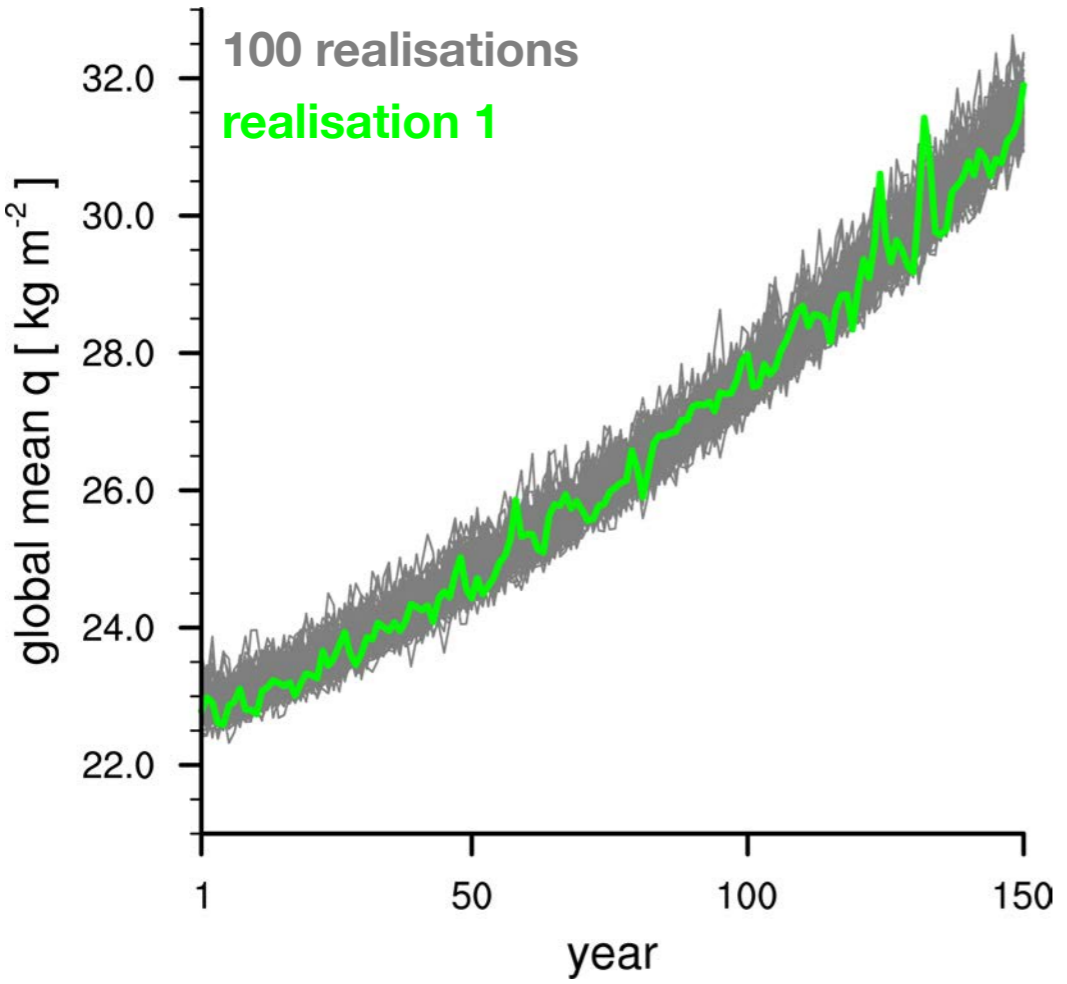
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global mean precipitable water

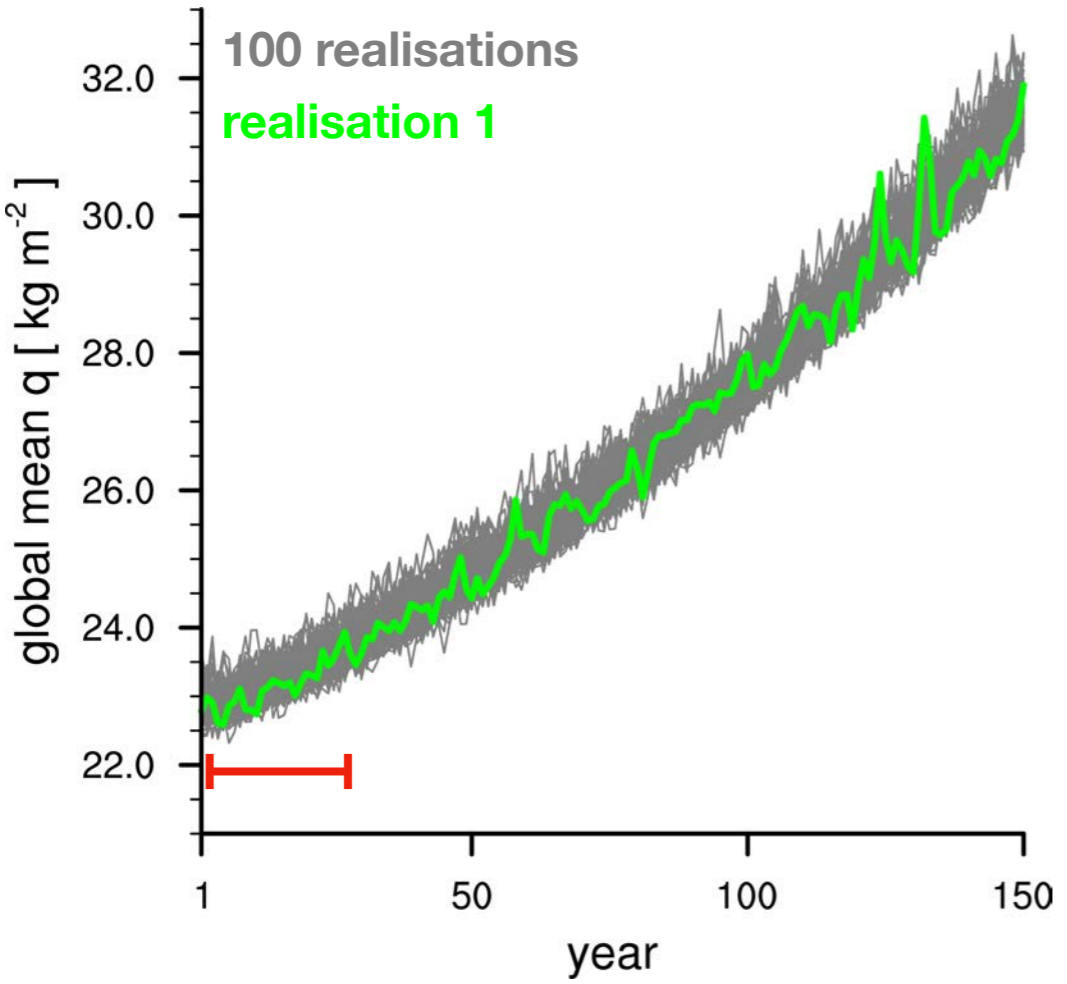




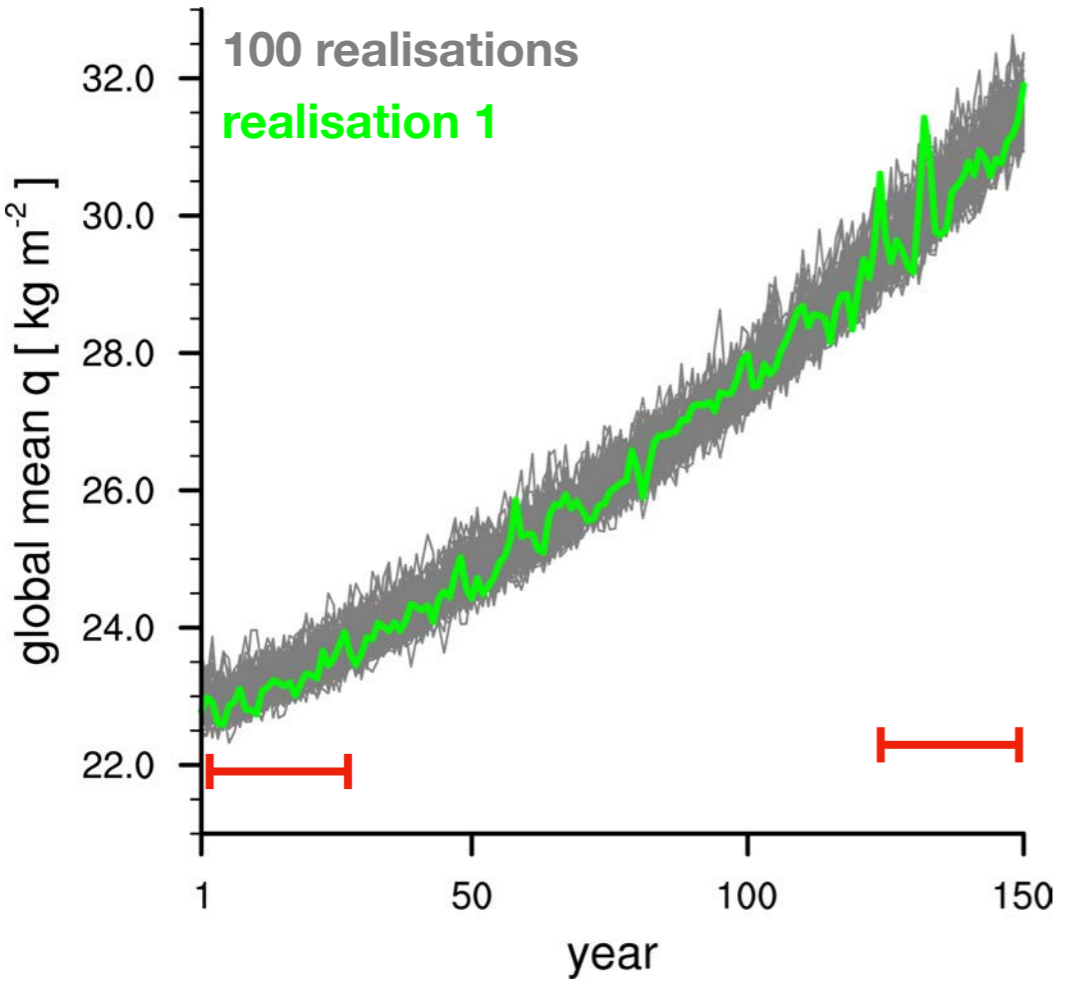
global mean precipitable water



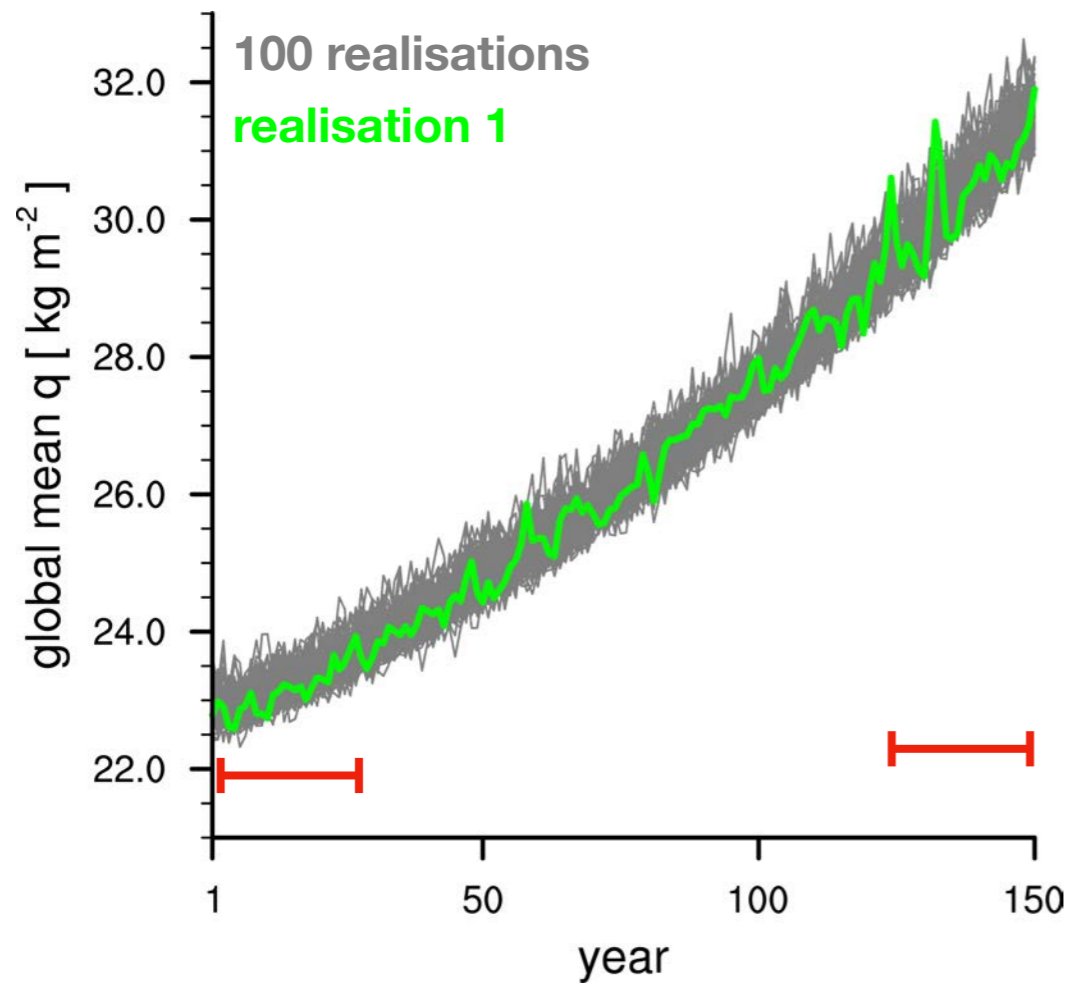
global mean precipitable water



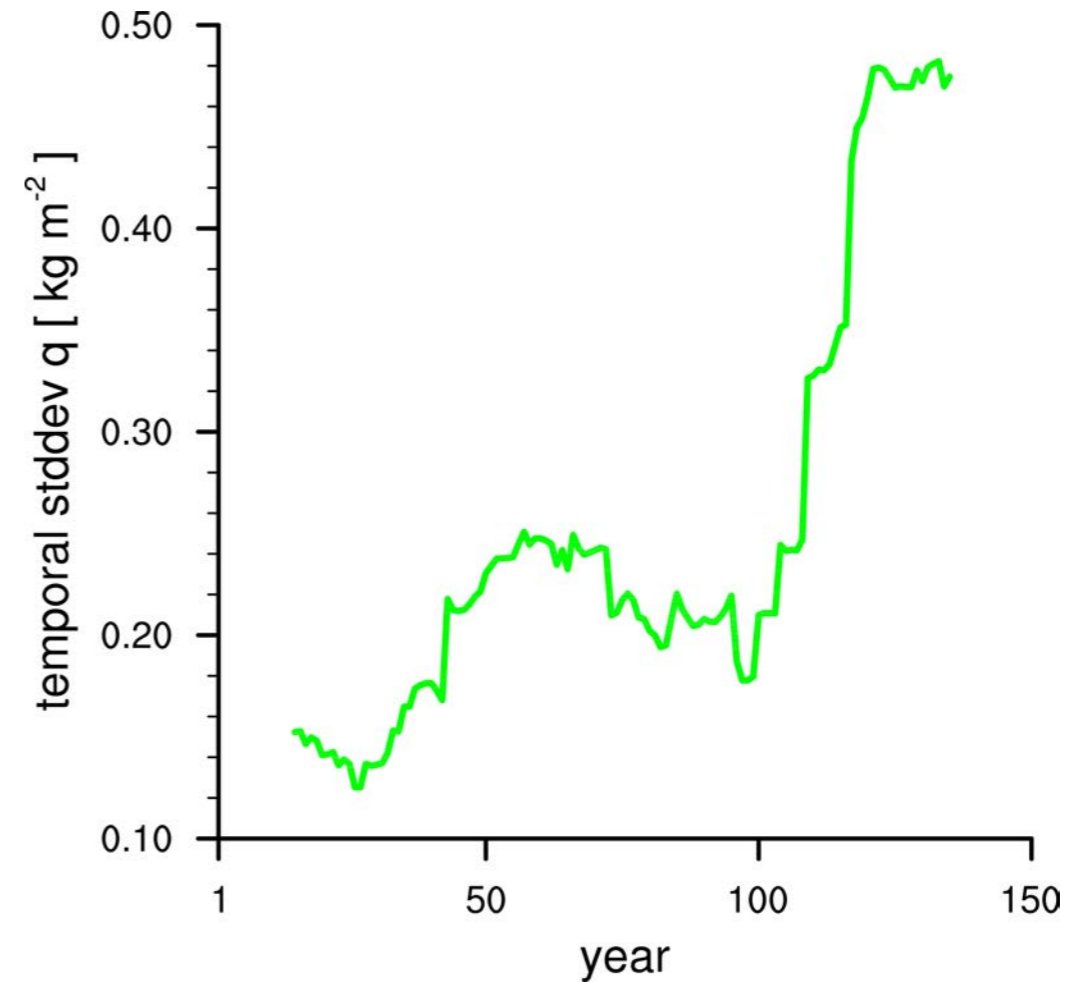
global mean precipitable water



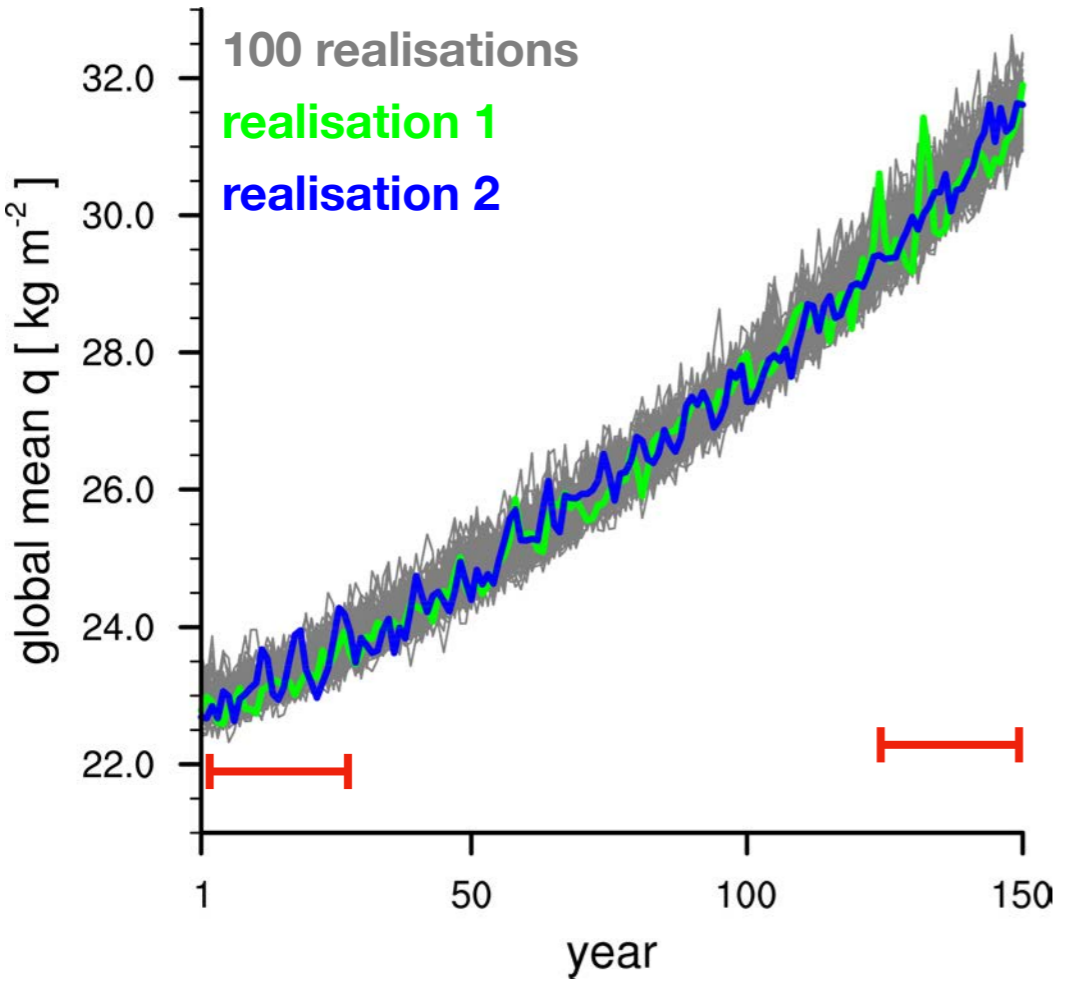
global mean precipitable water



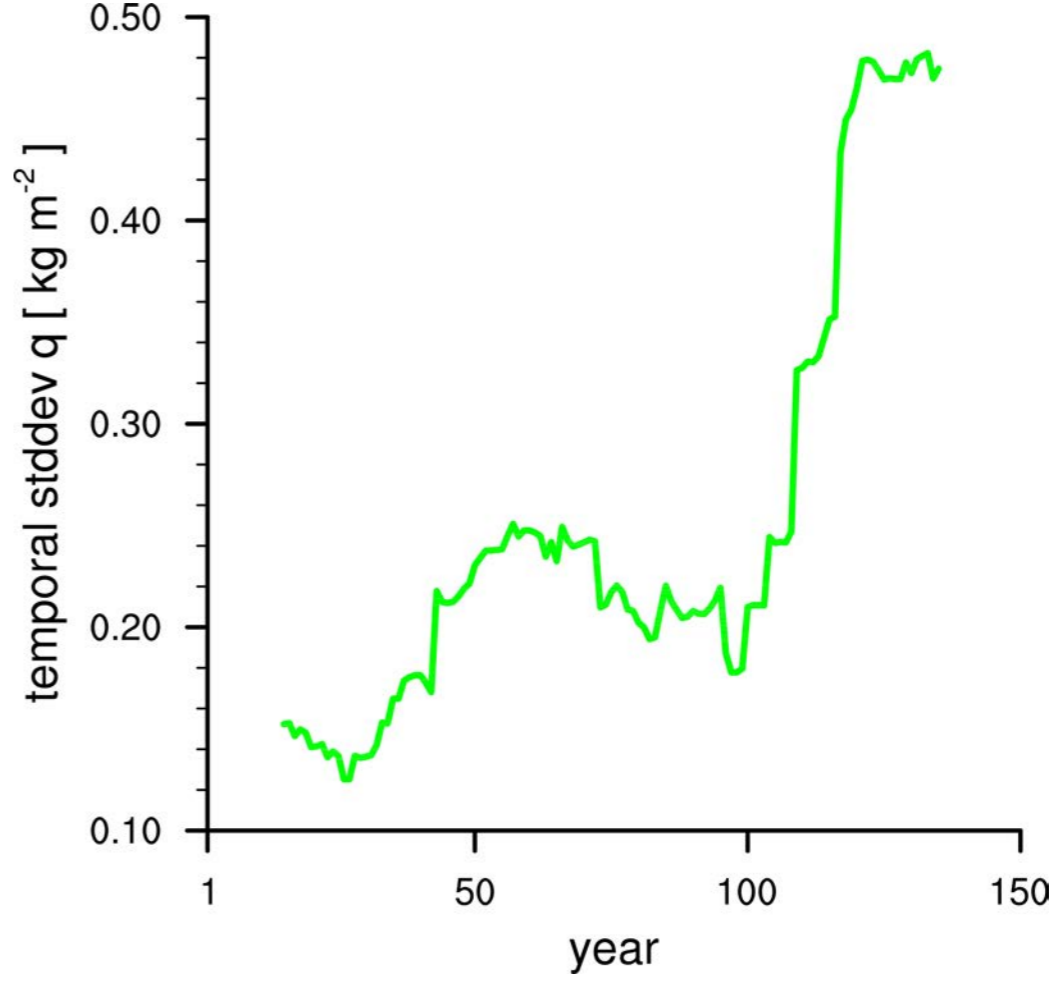
temporal variability



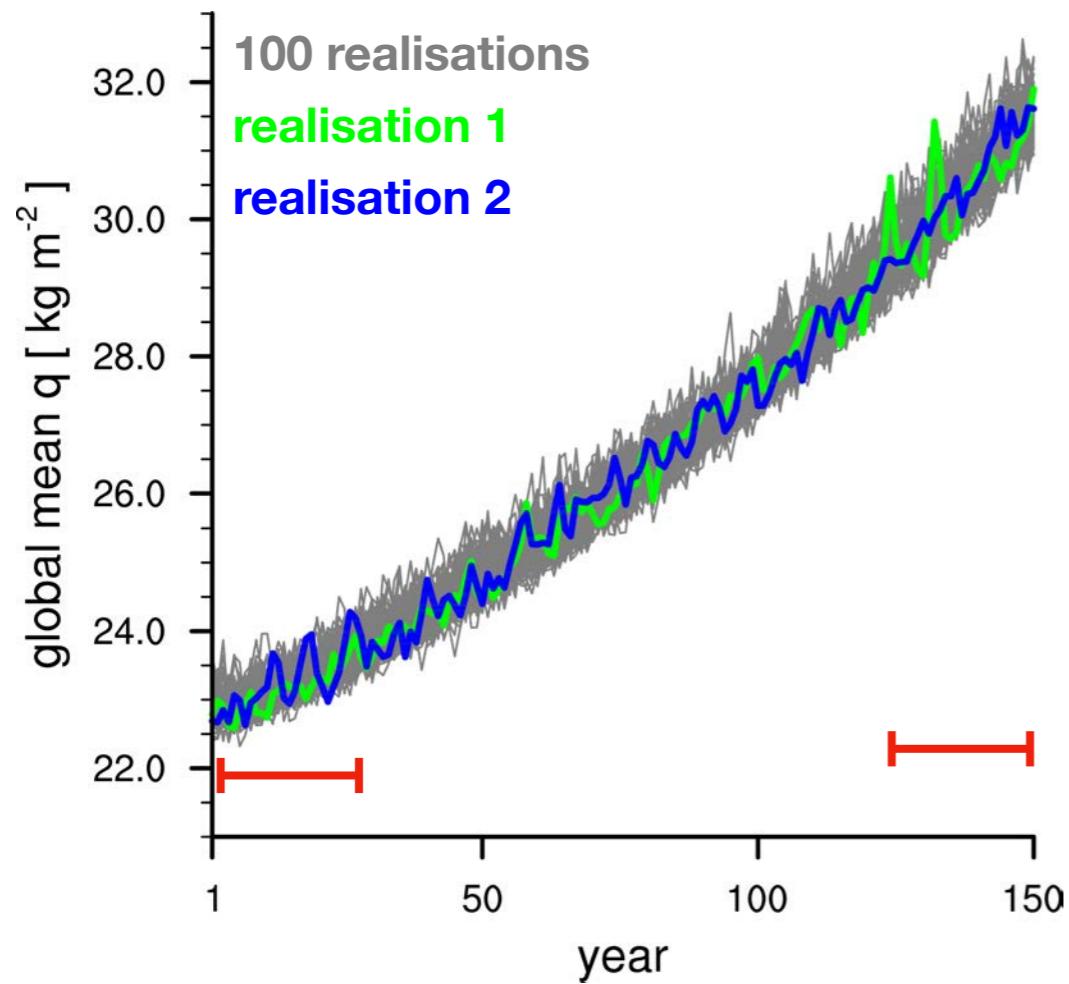
global mean precipitable water



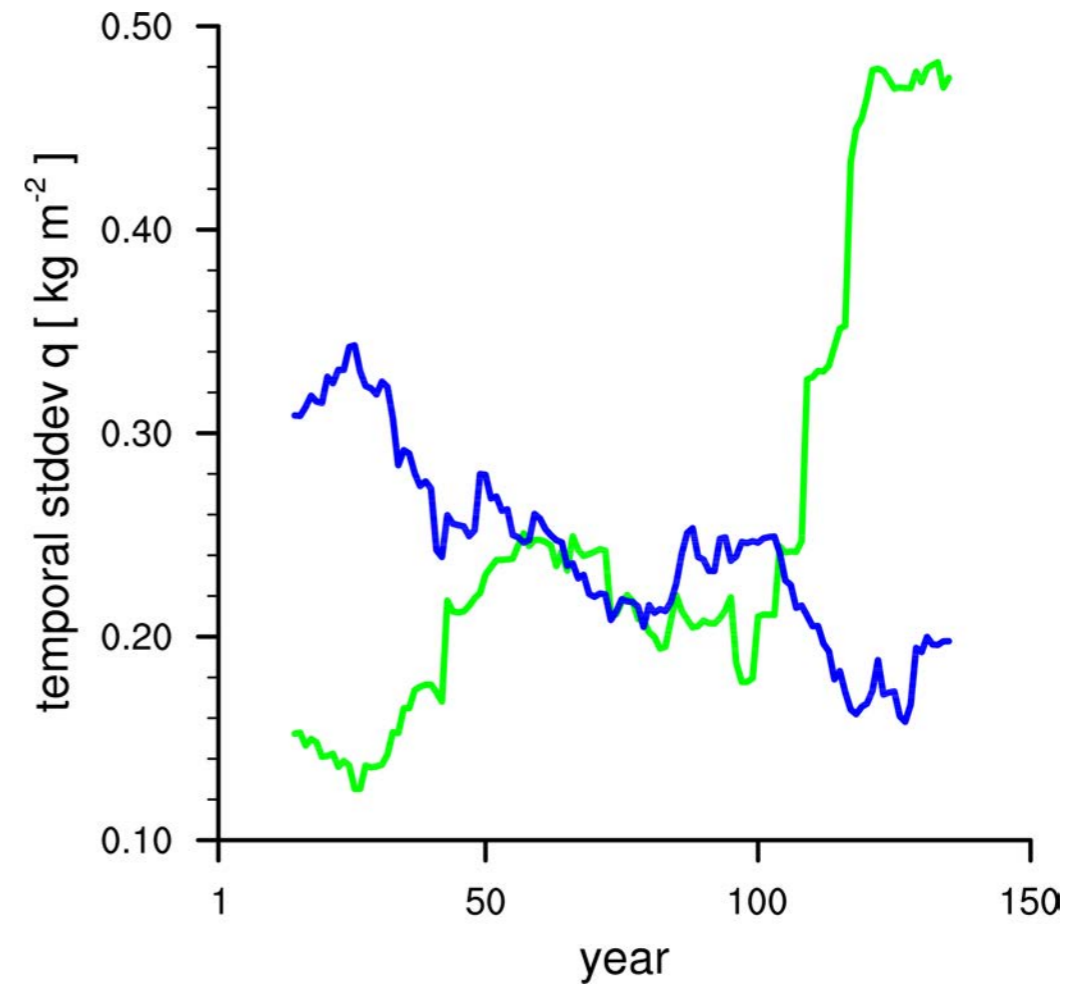
temporal variability



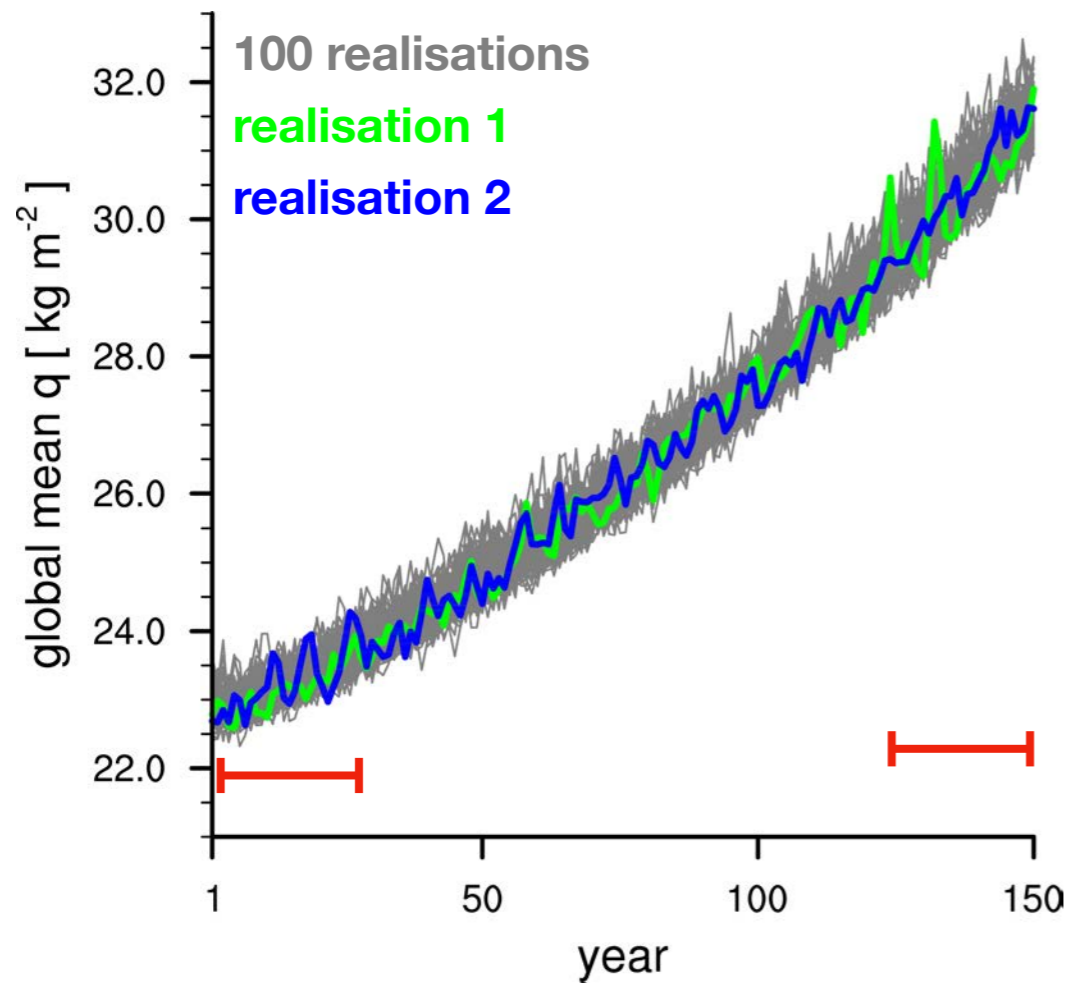
## global mean precipitable water



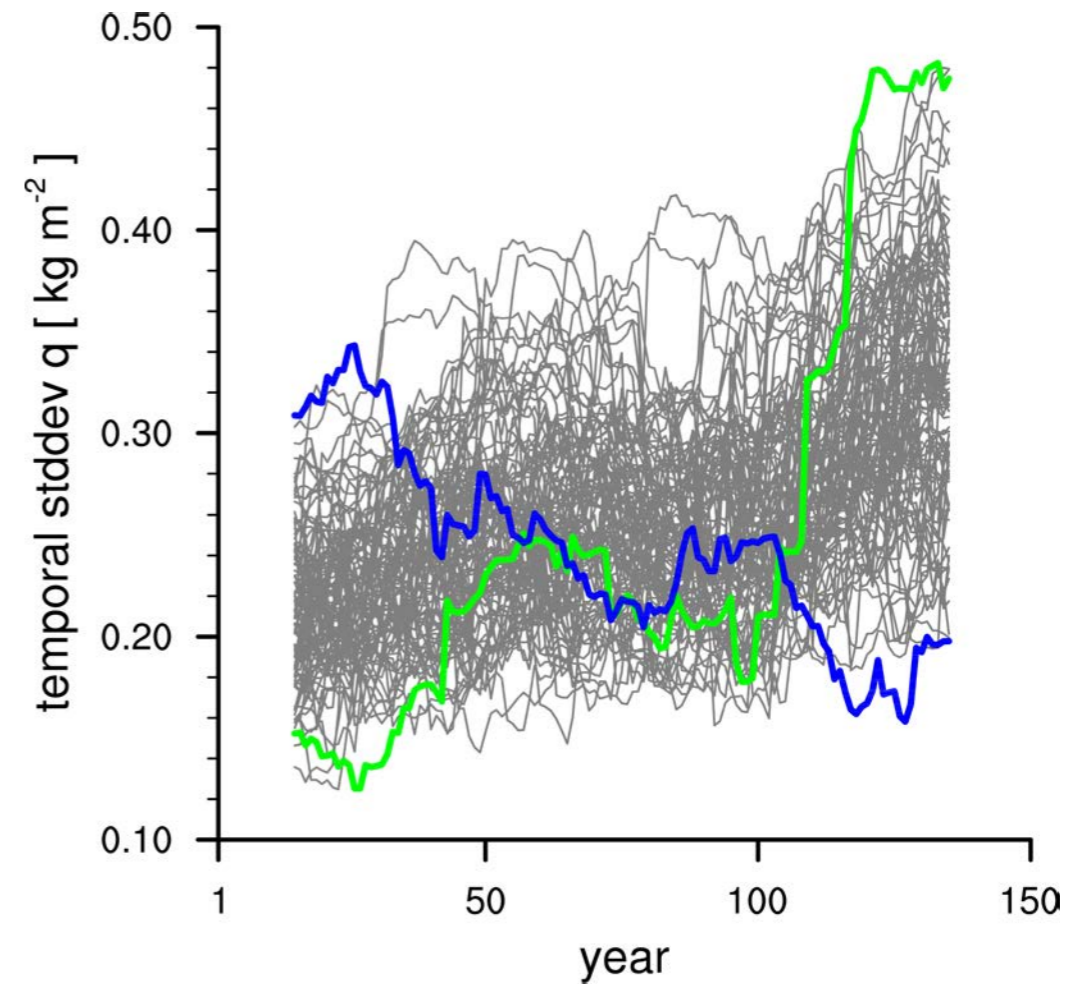
## temporal variability



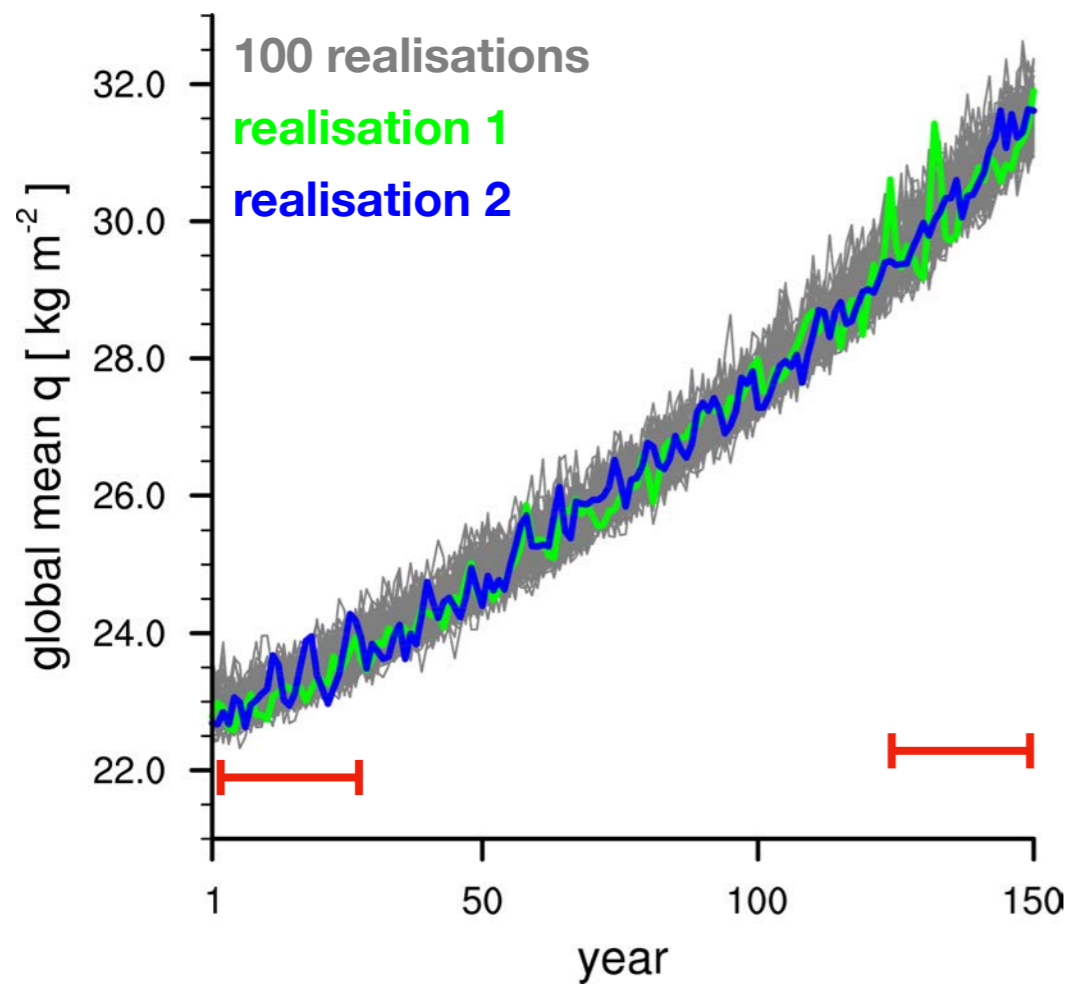
## global mean precipitable water



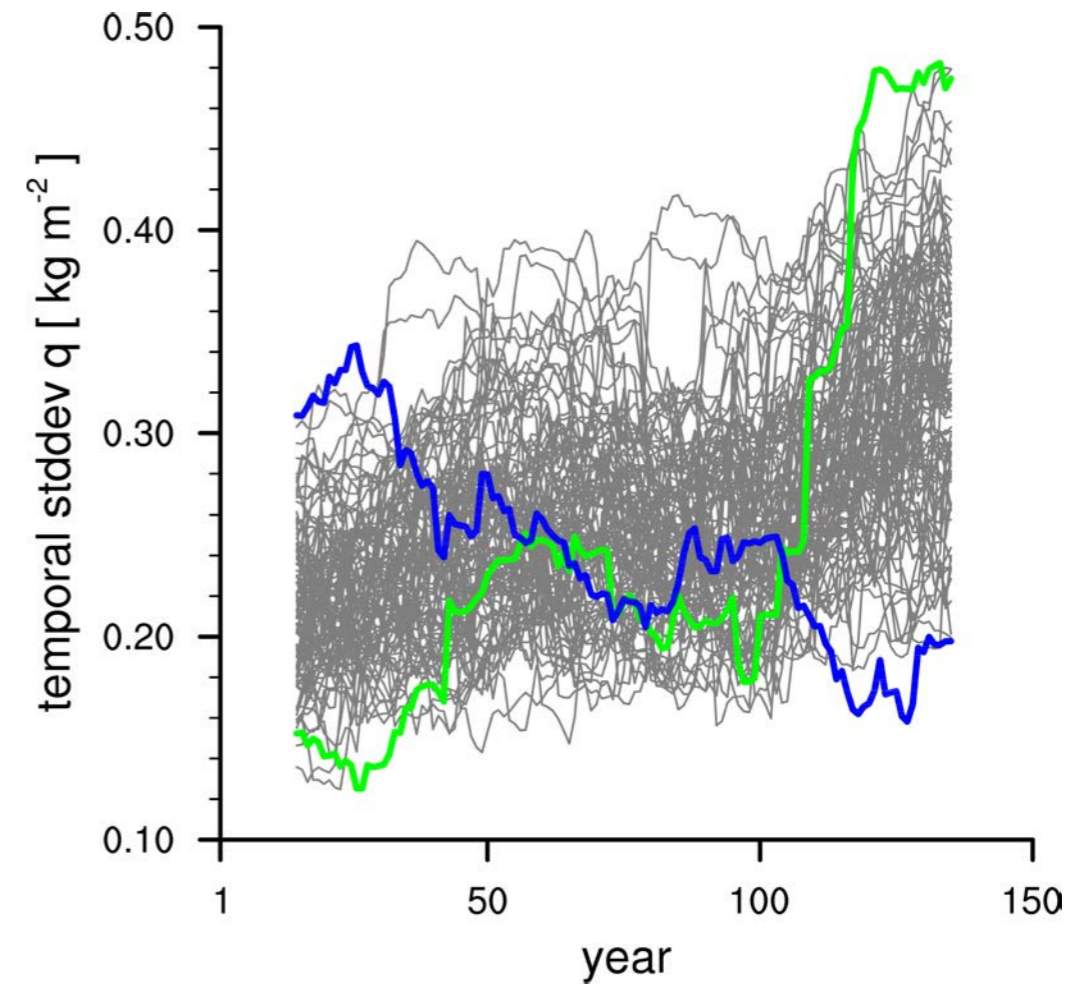
## temporal variability



## global mean precipitable water



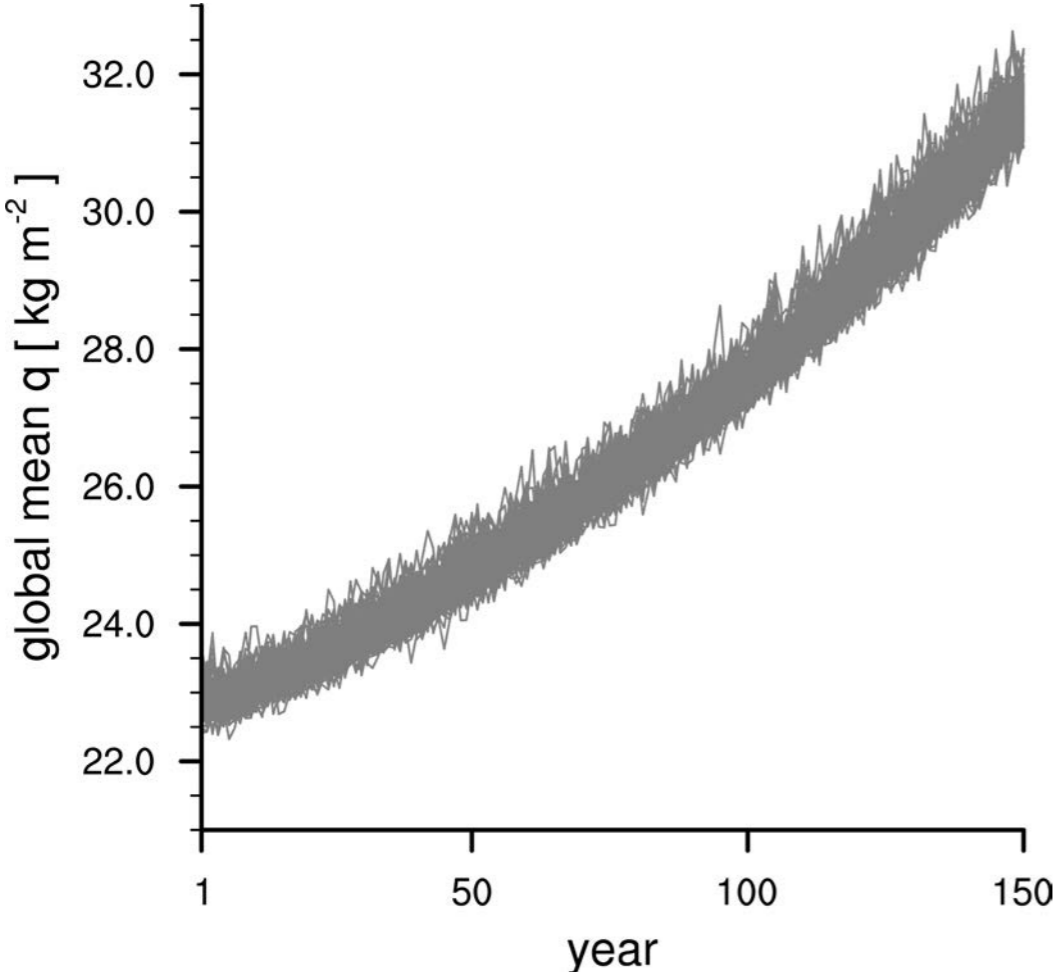
## temporal variability



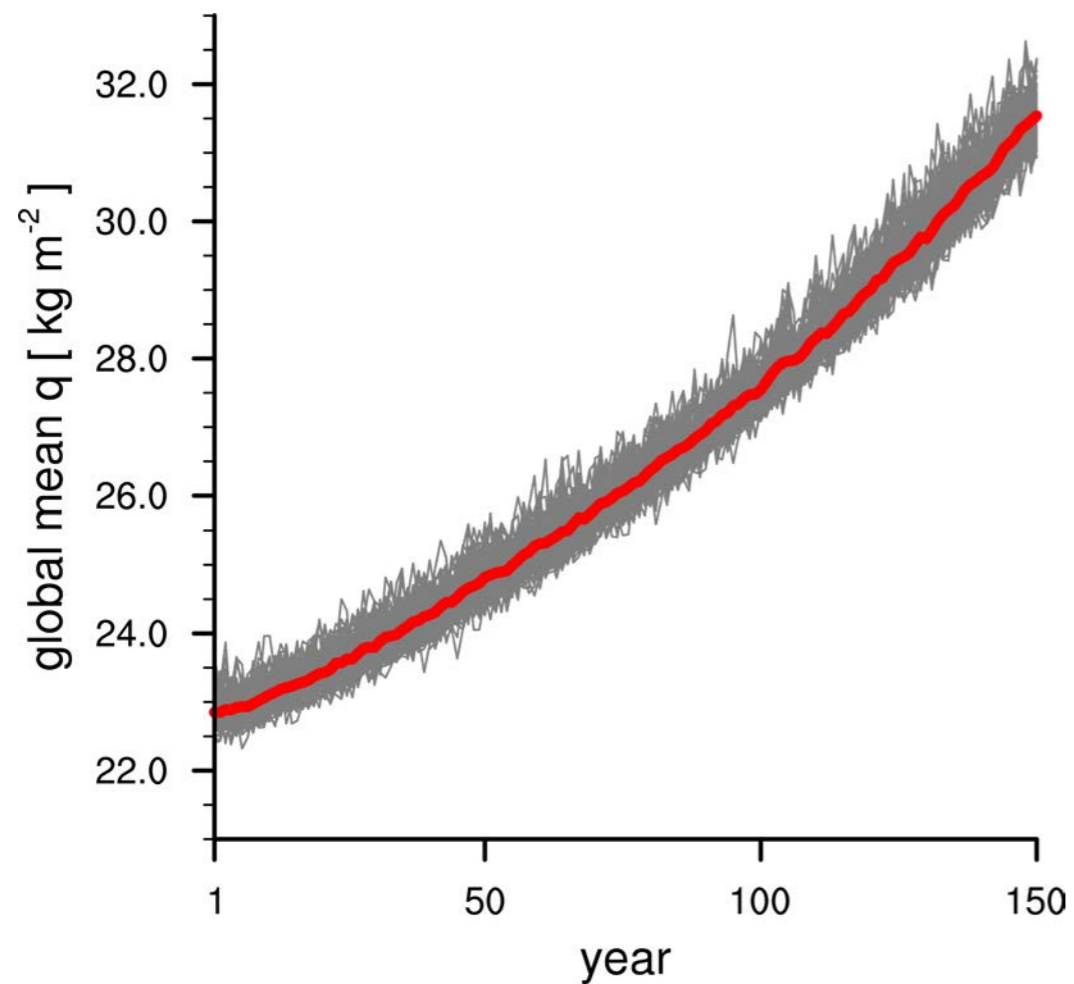
- Temporal variability does not provide a well-defined estimate of internal variability in a transient climate



global mean precipitable water

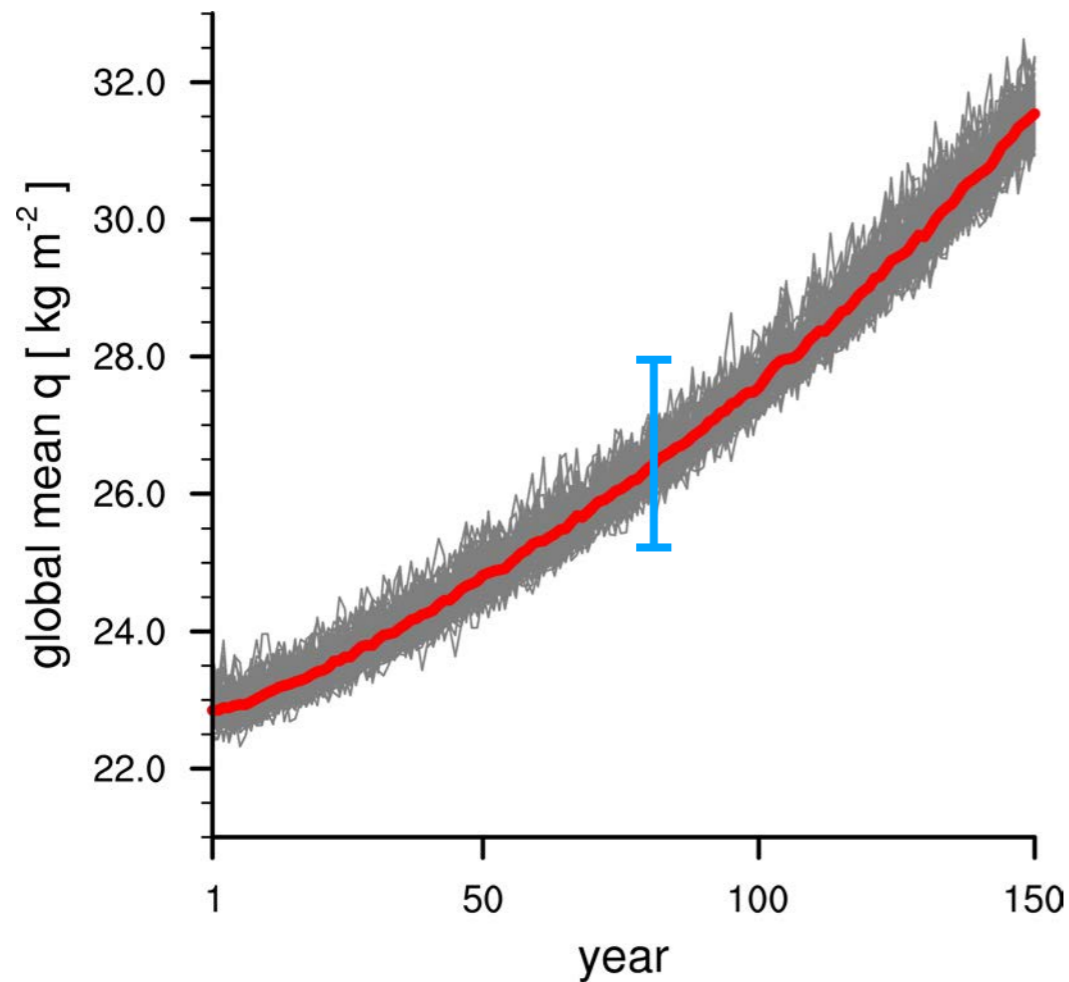


global mean precipitable water



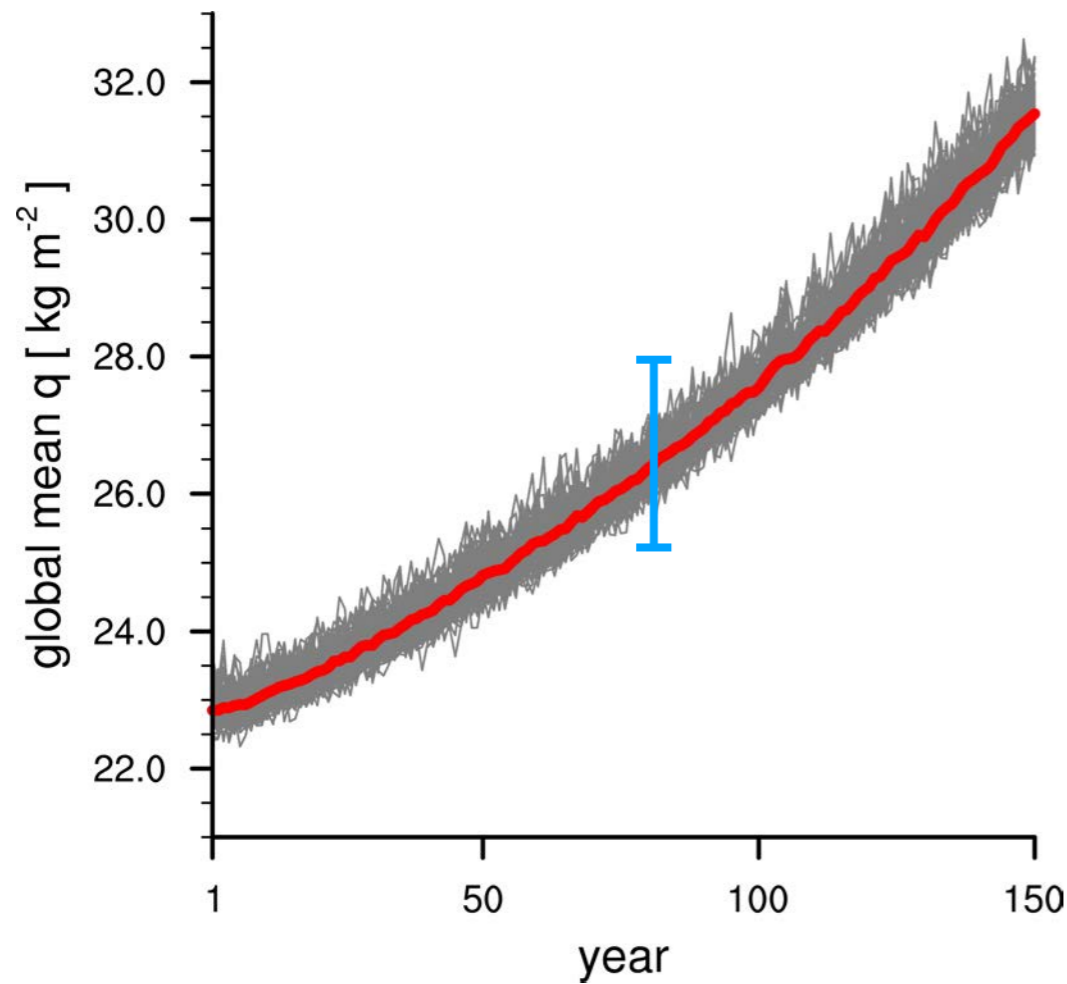
- ensemble mean = forced response

## global mean precipitable water

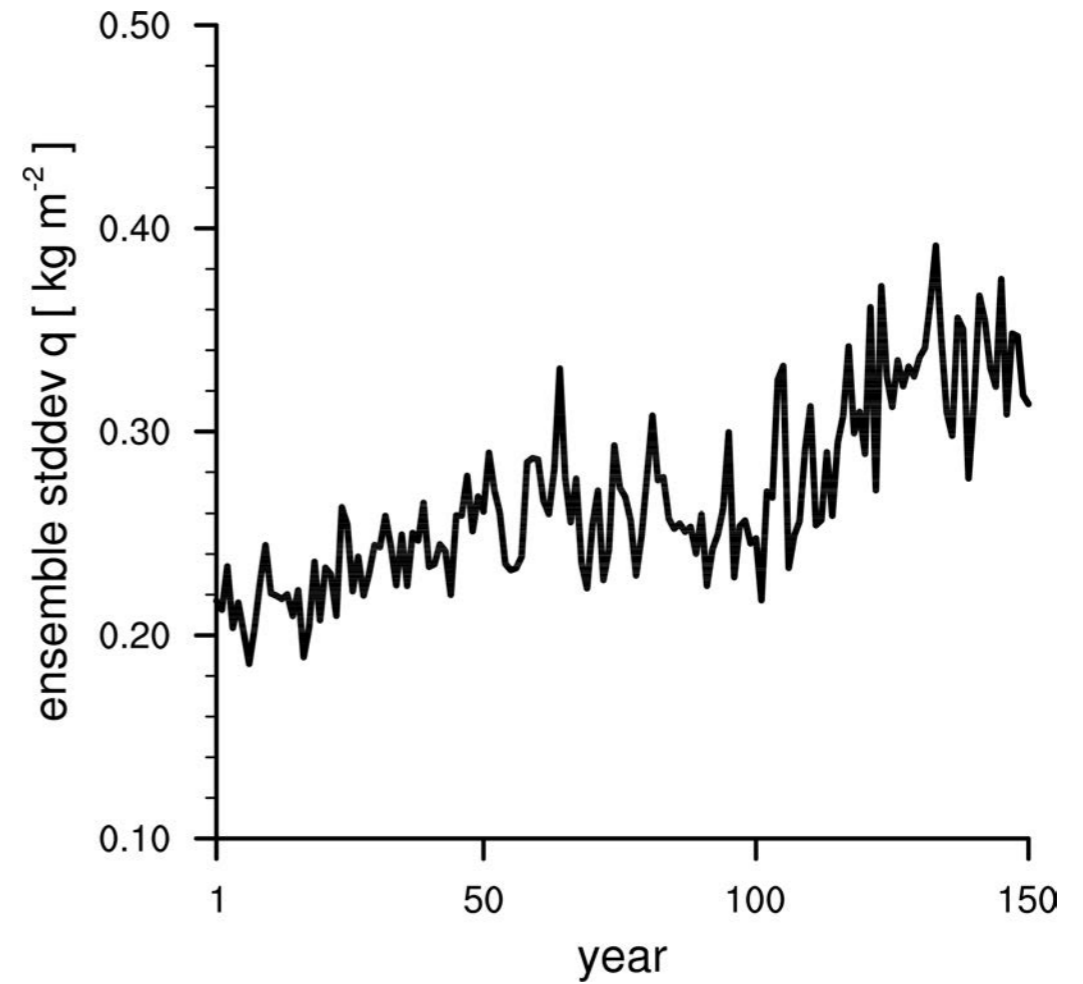


- ensemble mean = forced response
- ensemble spread = internal variability

global mean precipitable water

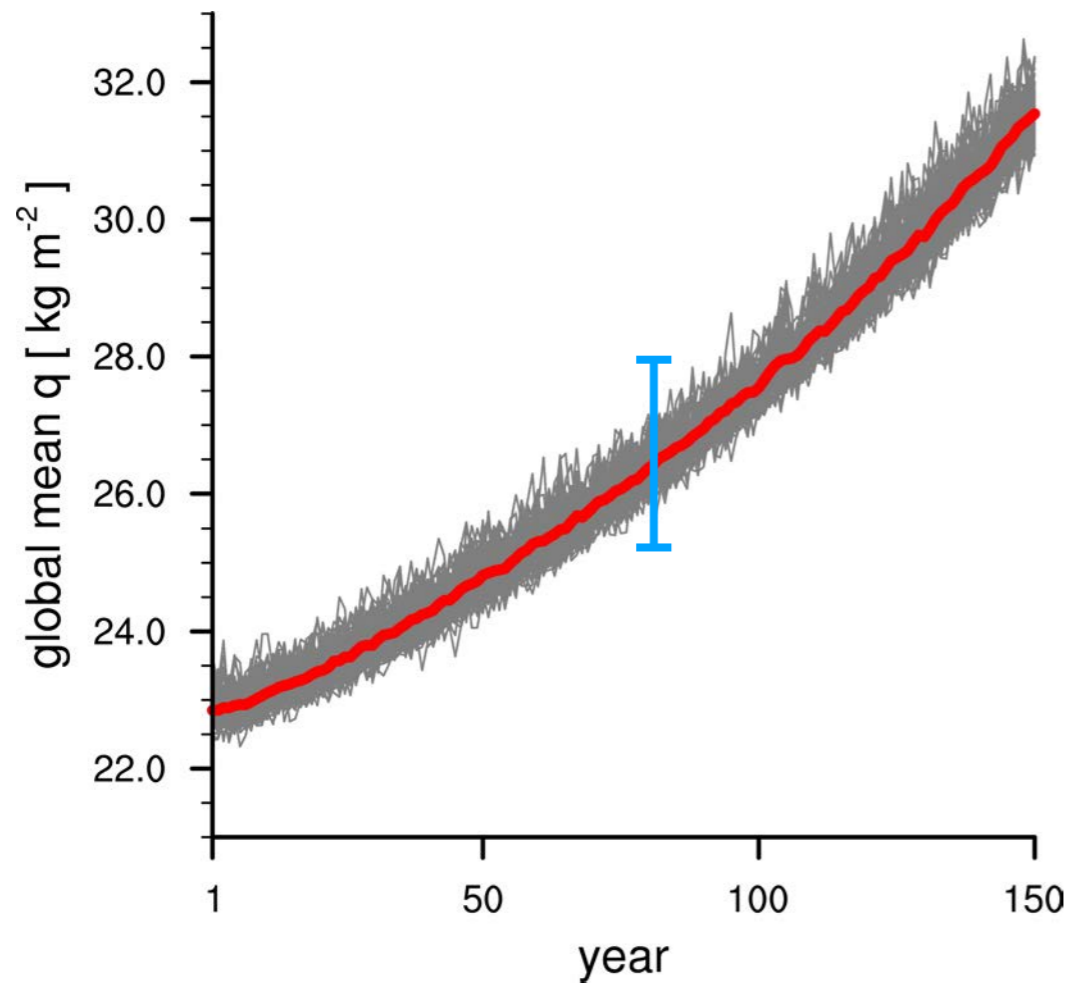


ensemble standard deviation

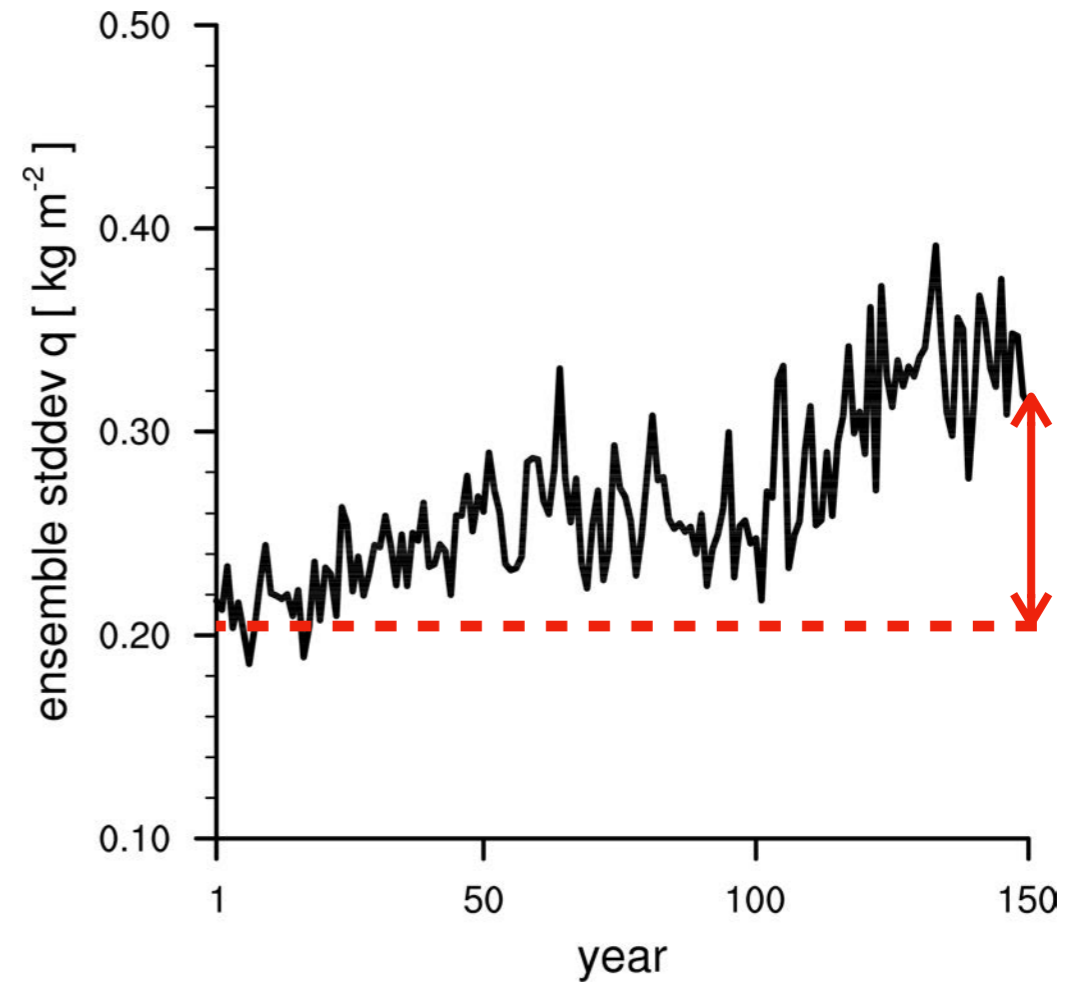


- ensemble mean = forced response
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global mean precipitable water

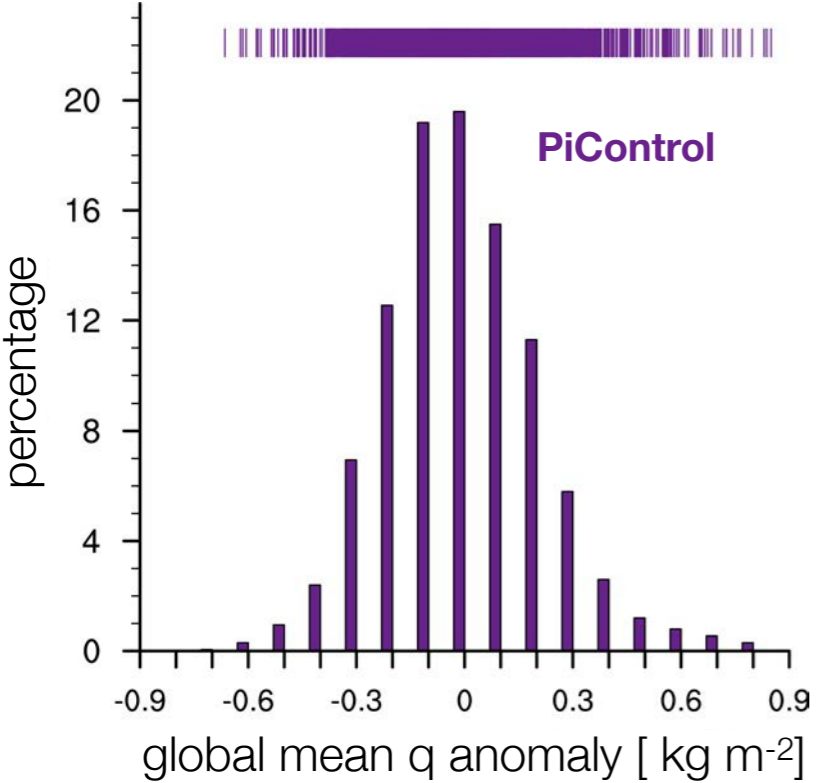


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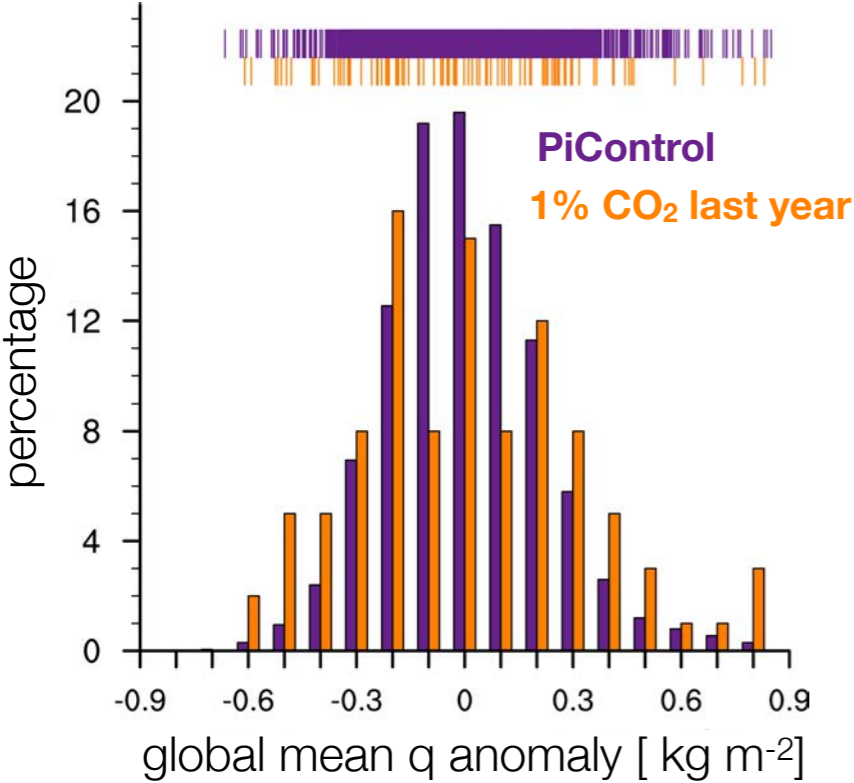


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PDF

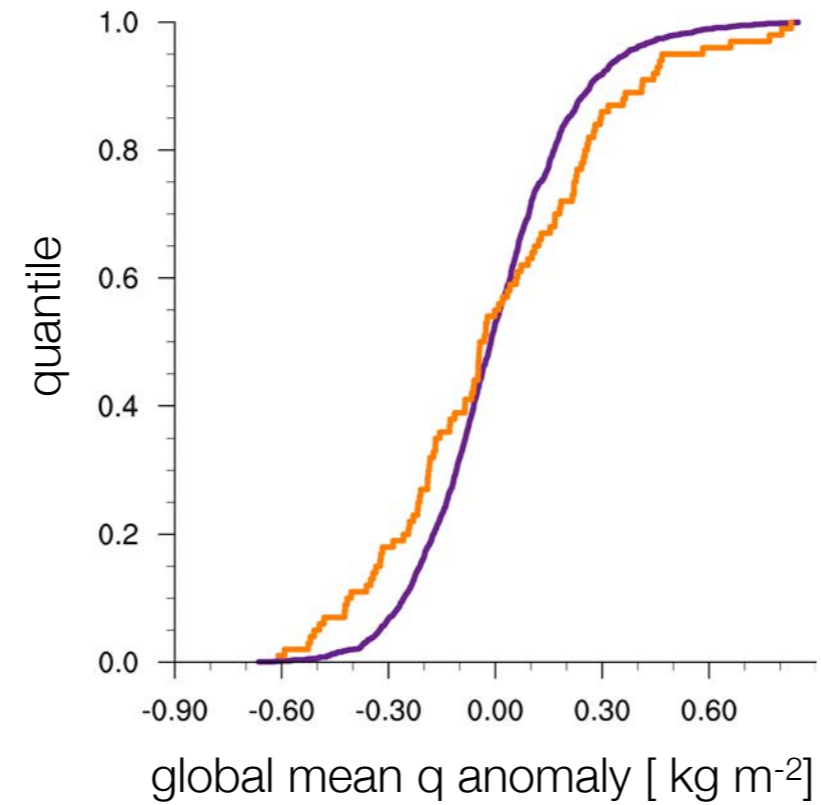
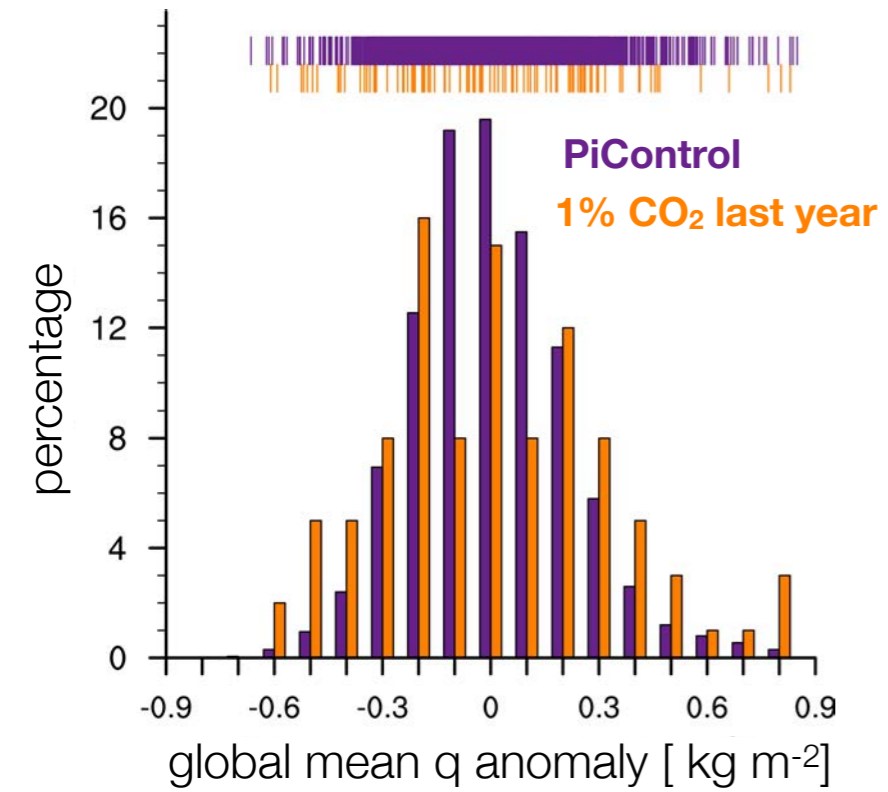


## PDF



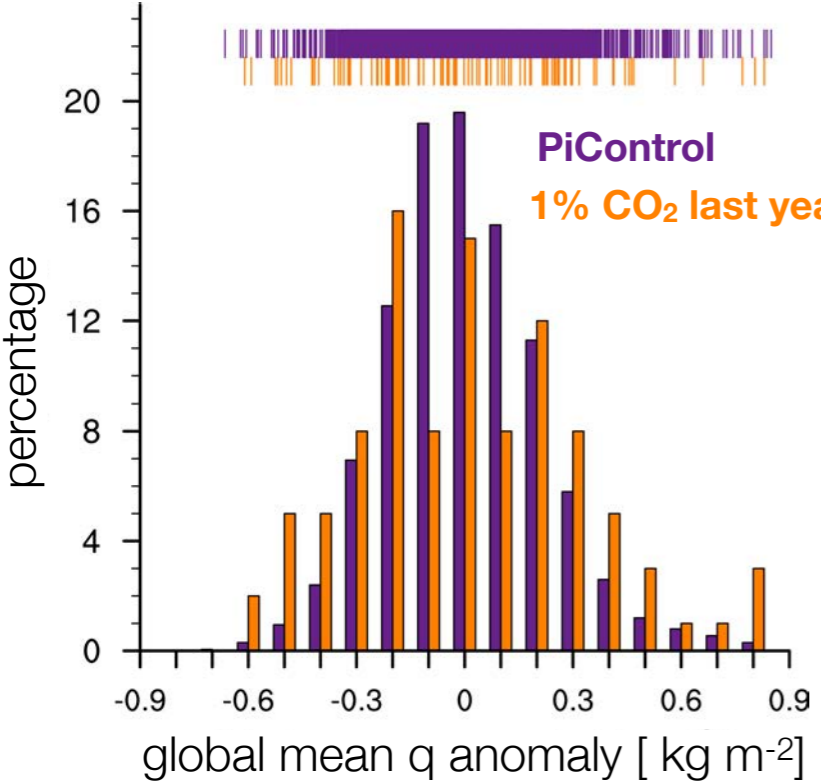
PDF

CDF

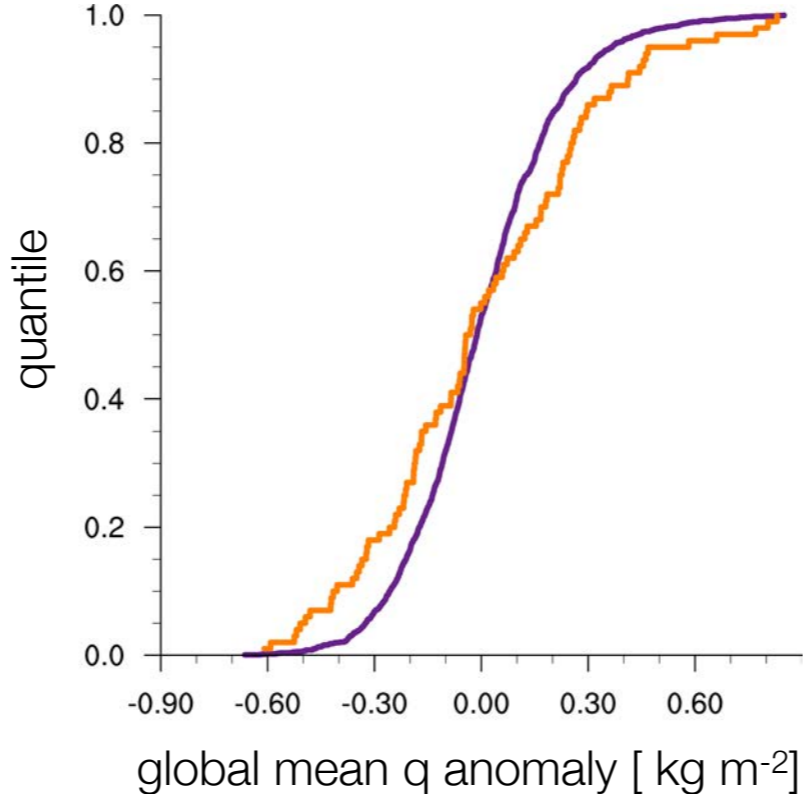




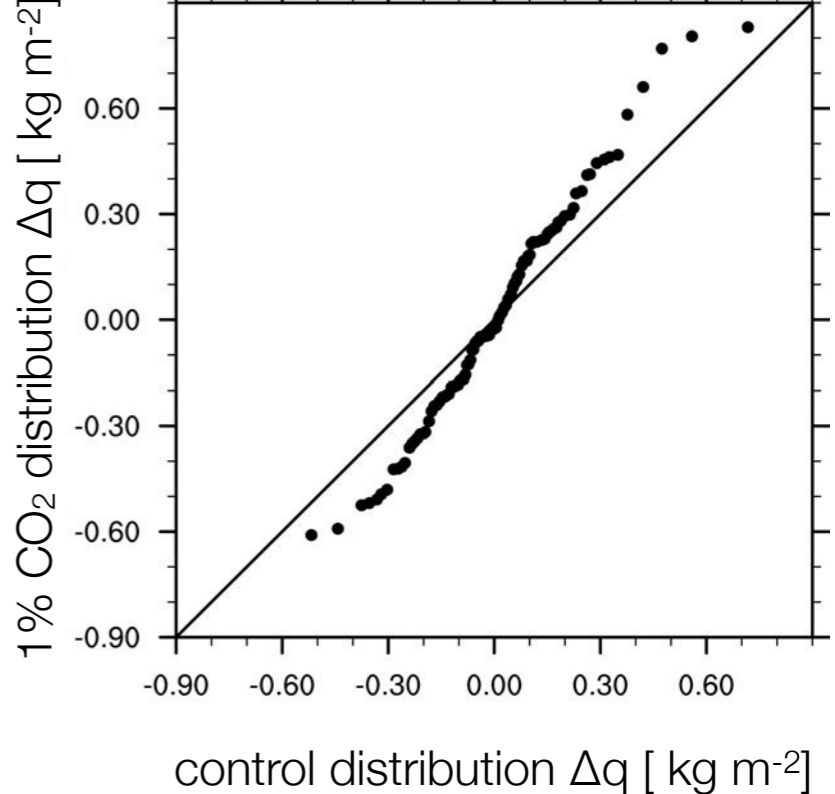
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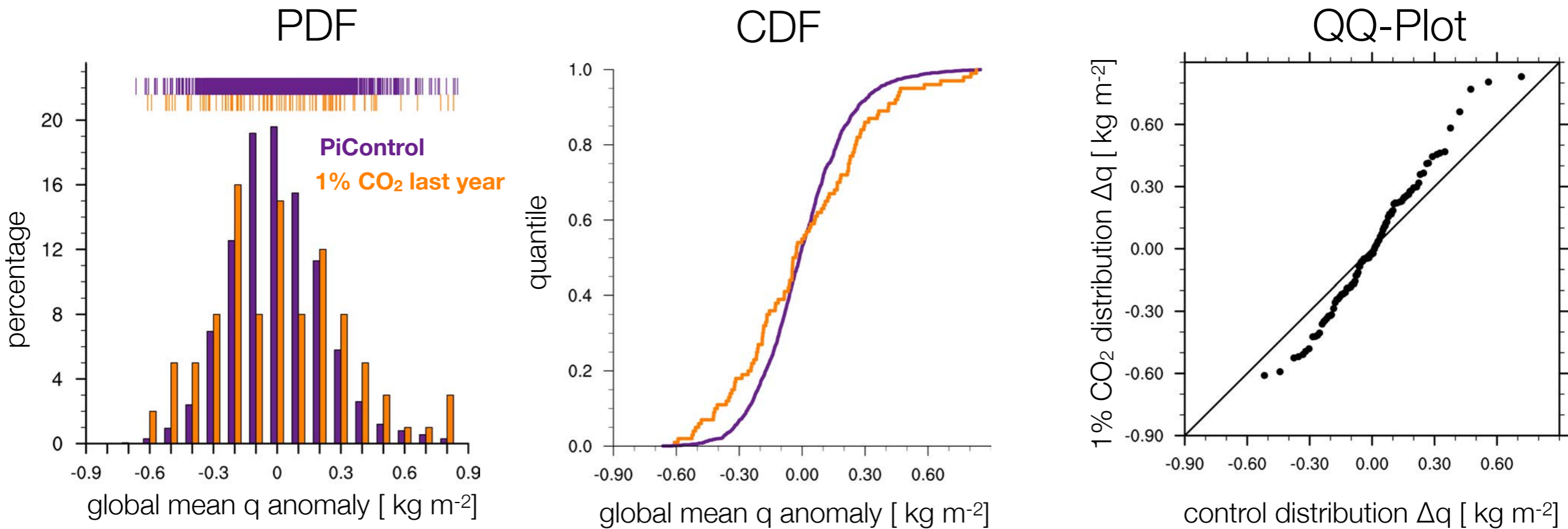


### CDF

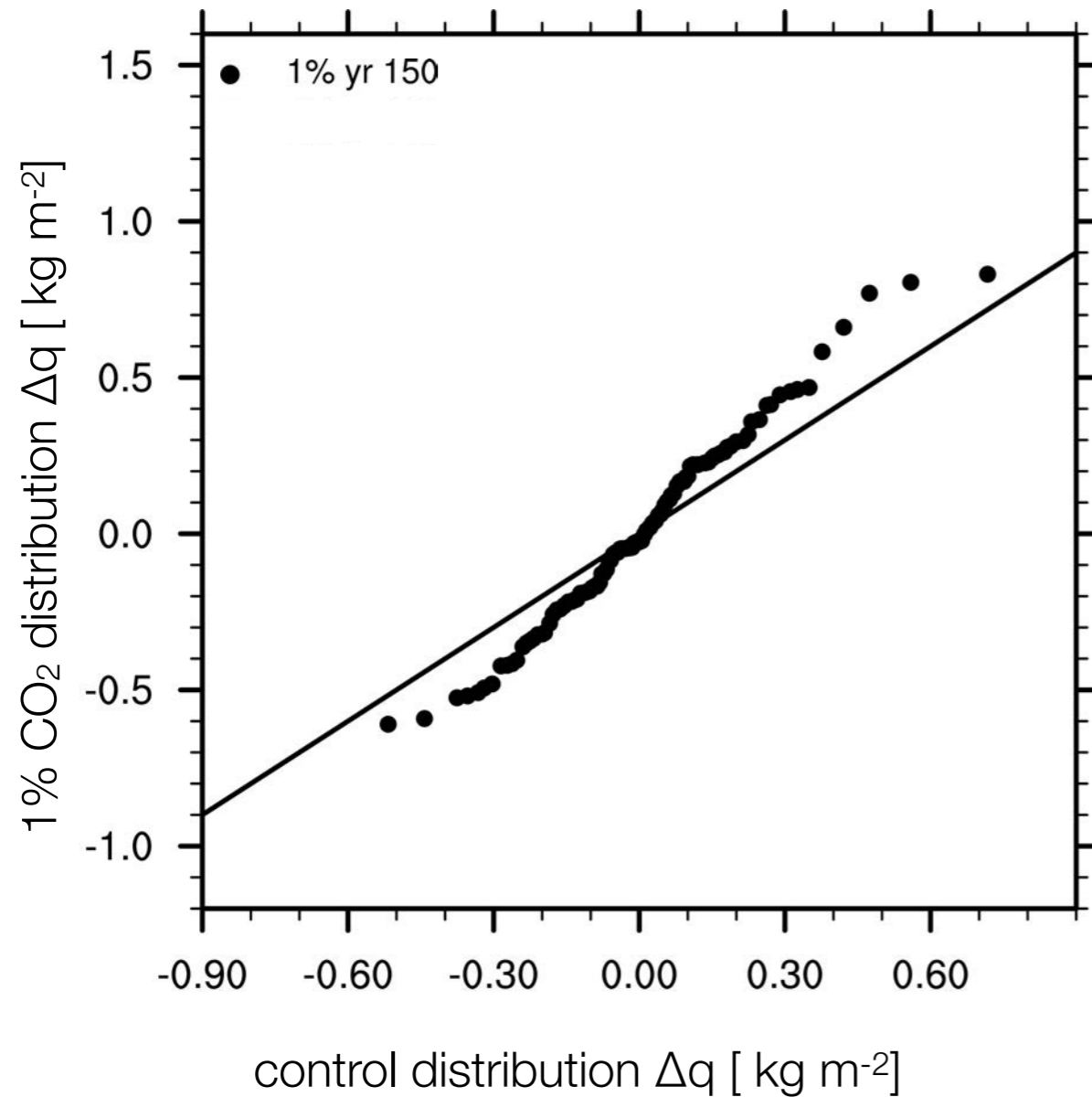


### QQ-Plot



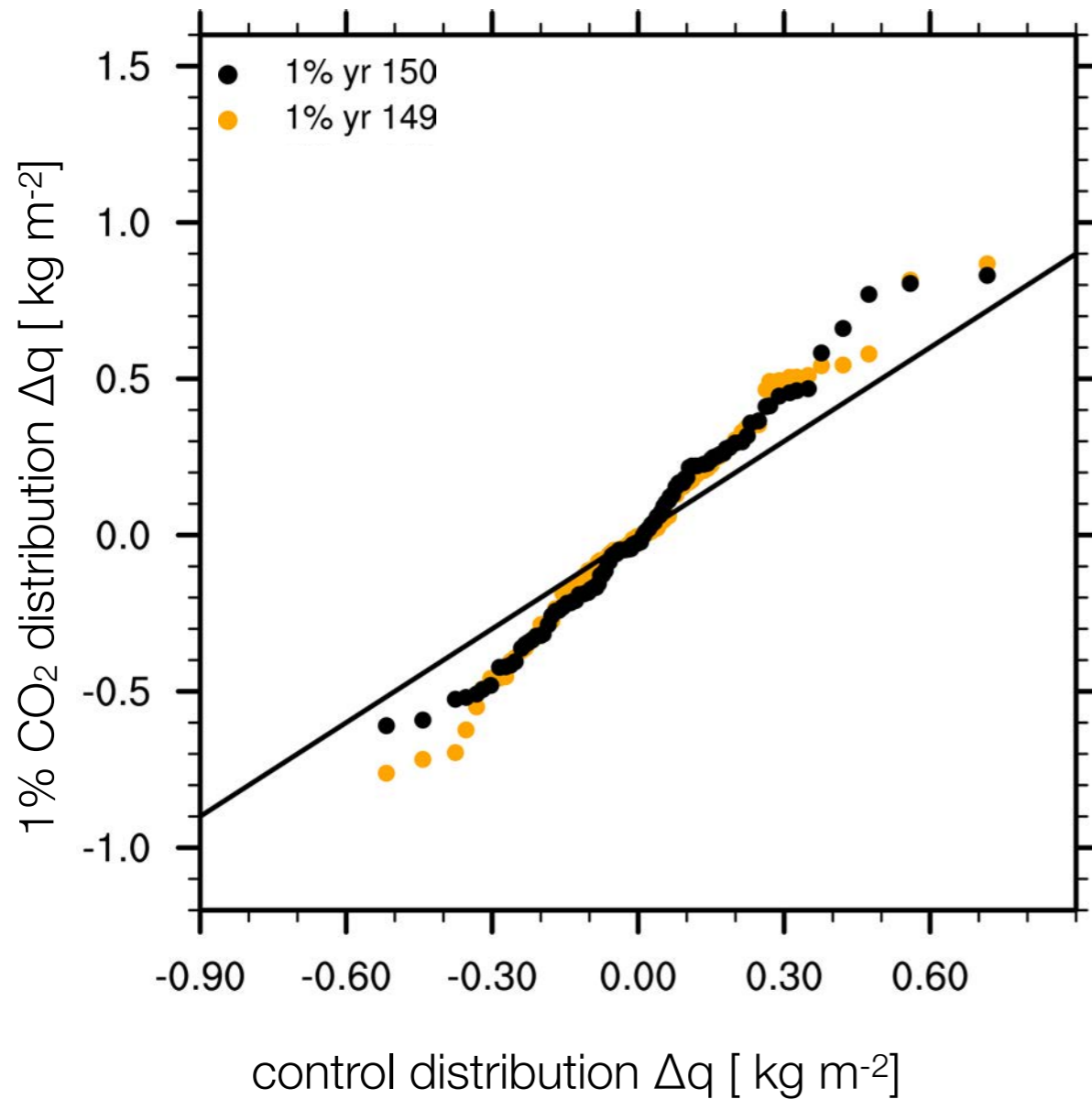


- QQ-plot indicates a widening of the distribution  
 -> increasing internal variability under strong warming



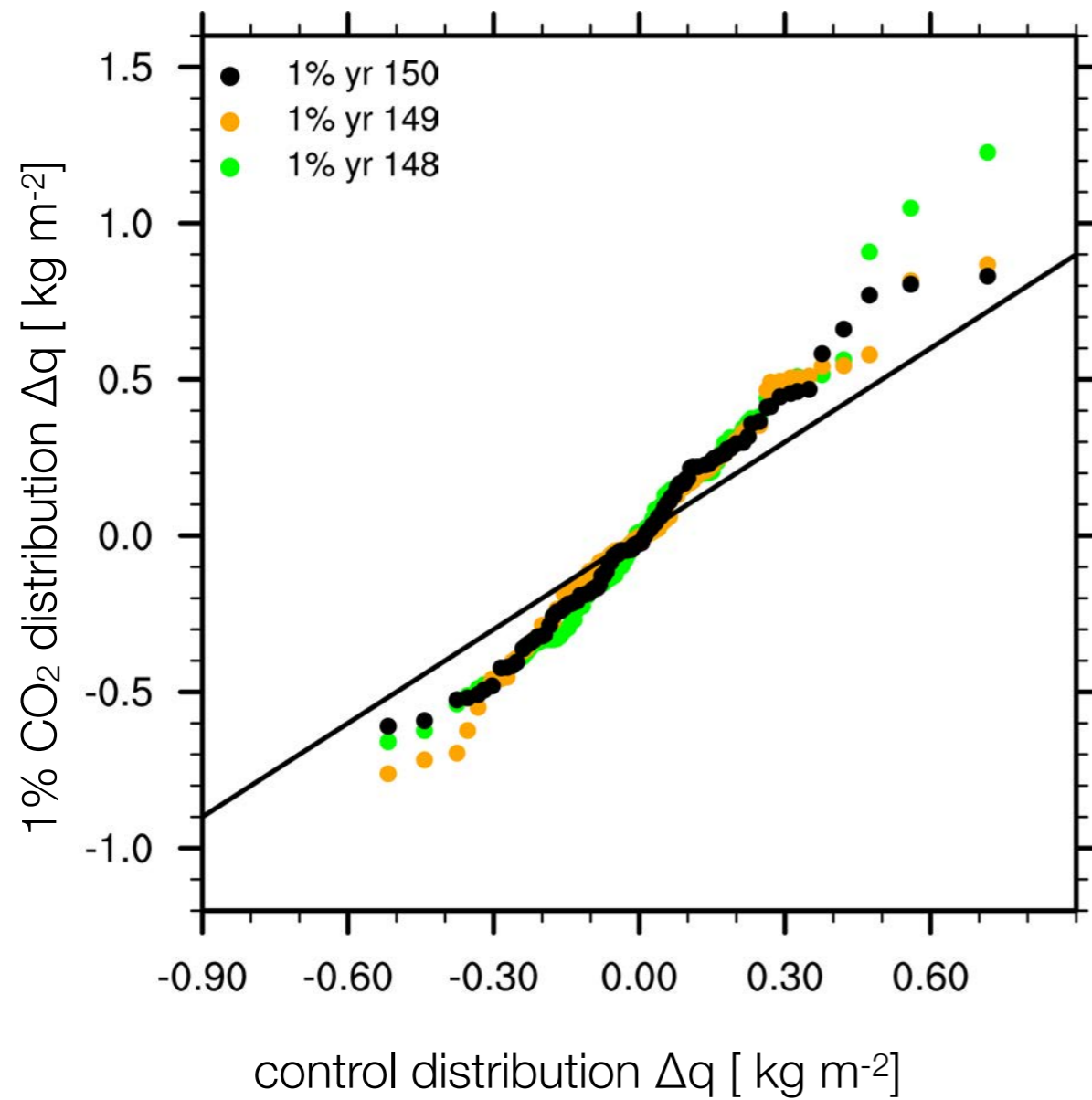
Are these changes robust?

- compare last five years



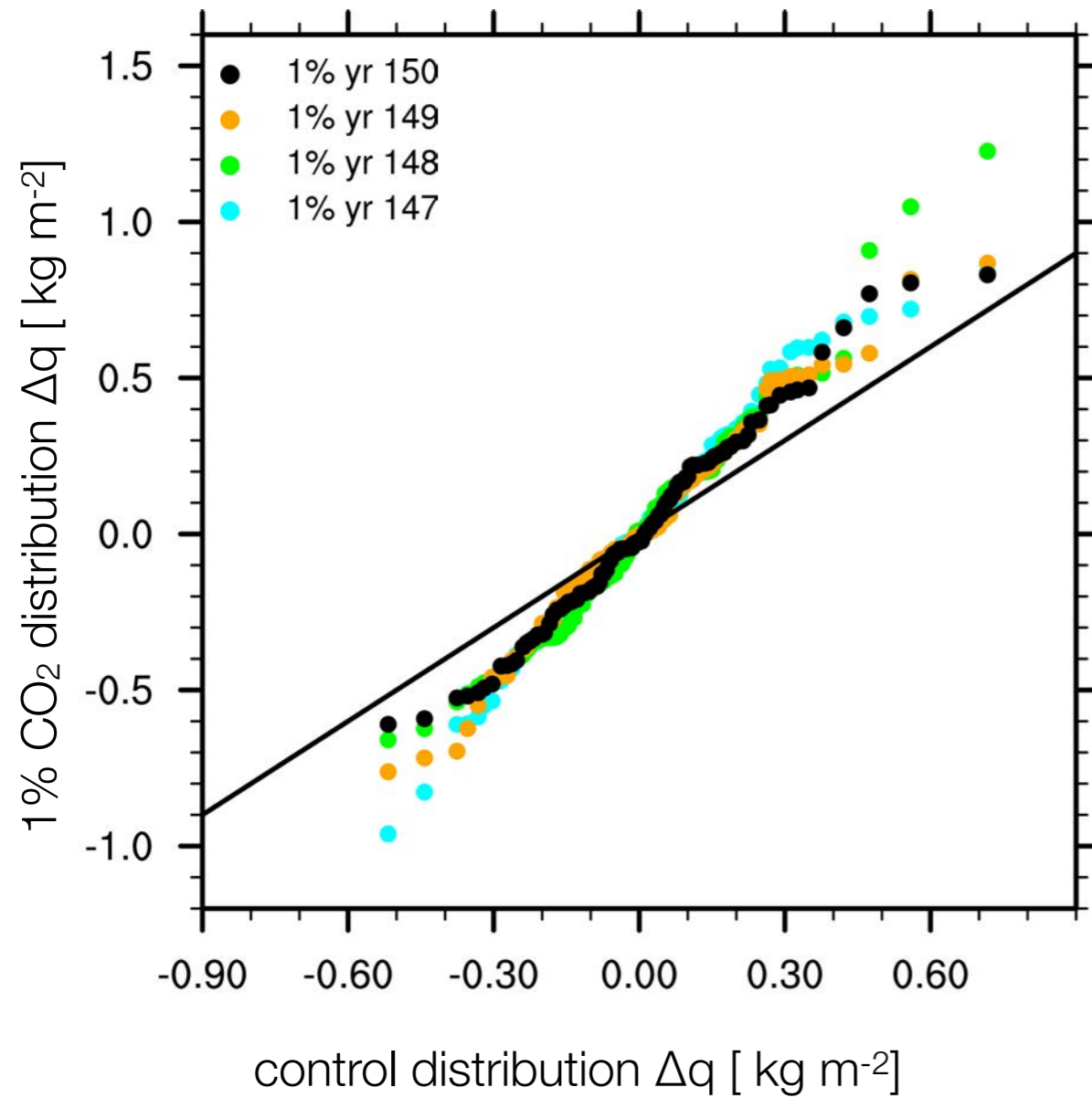
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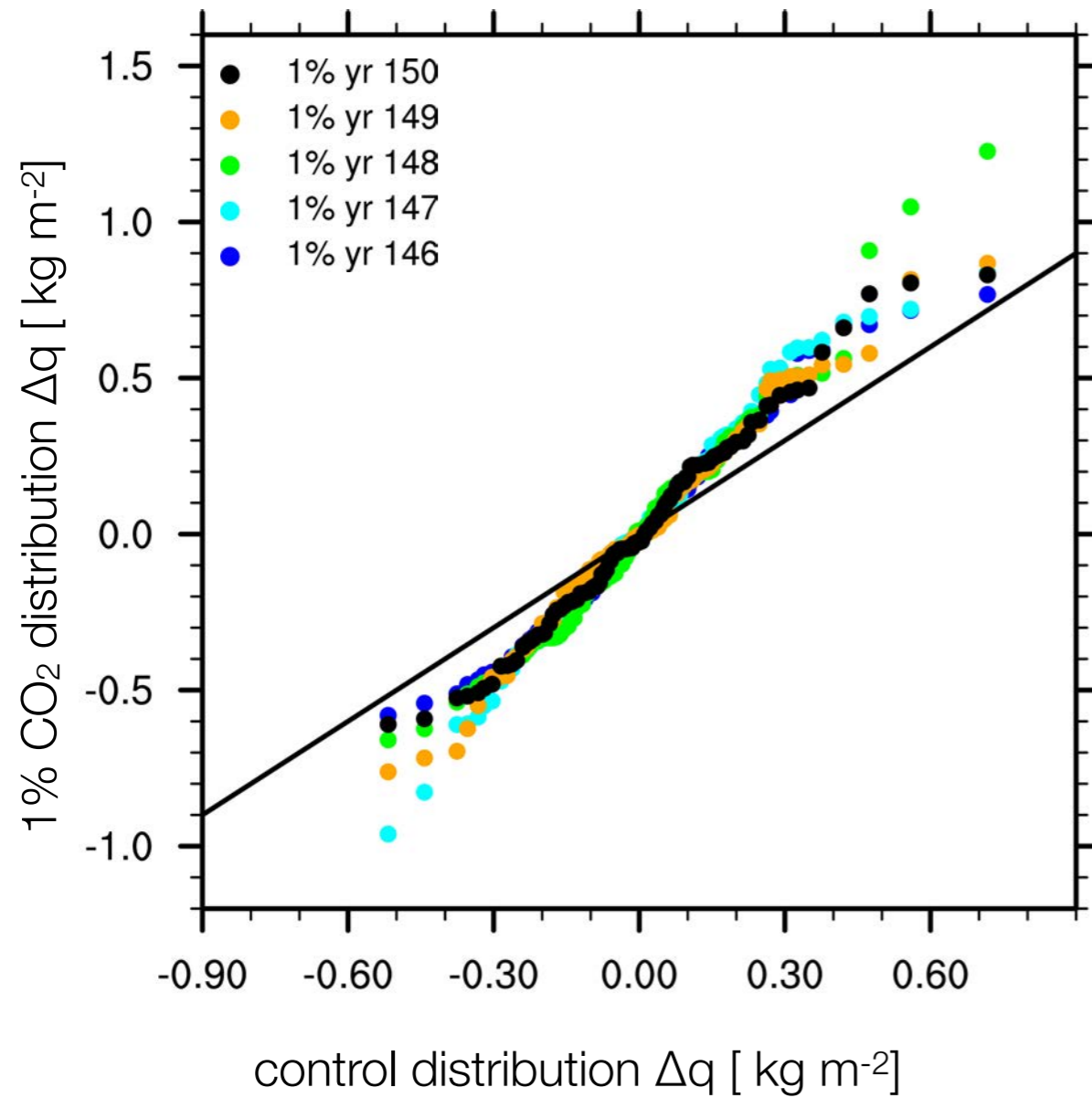
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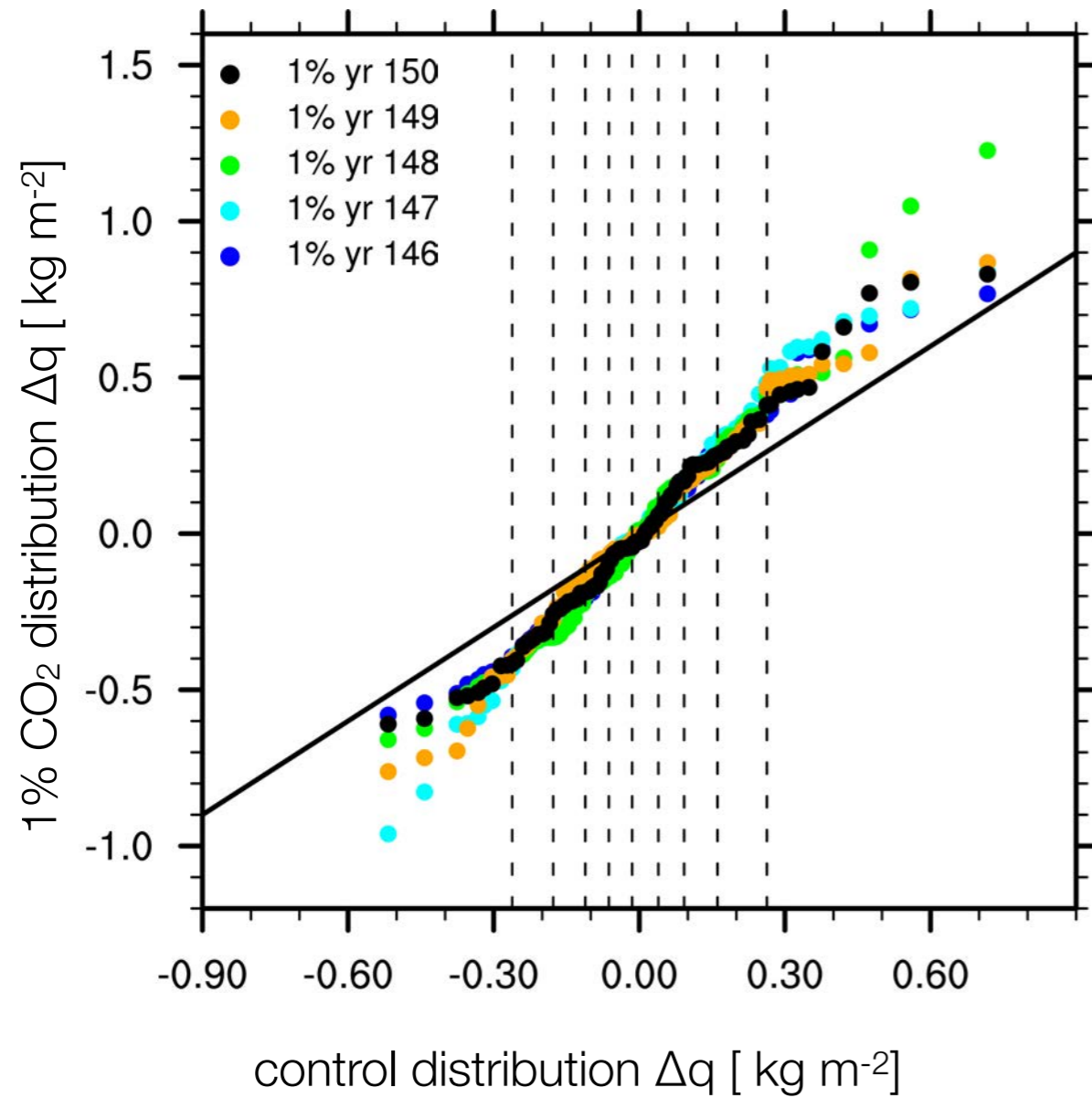
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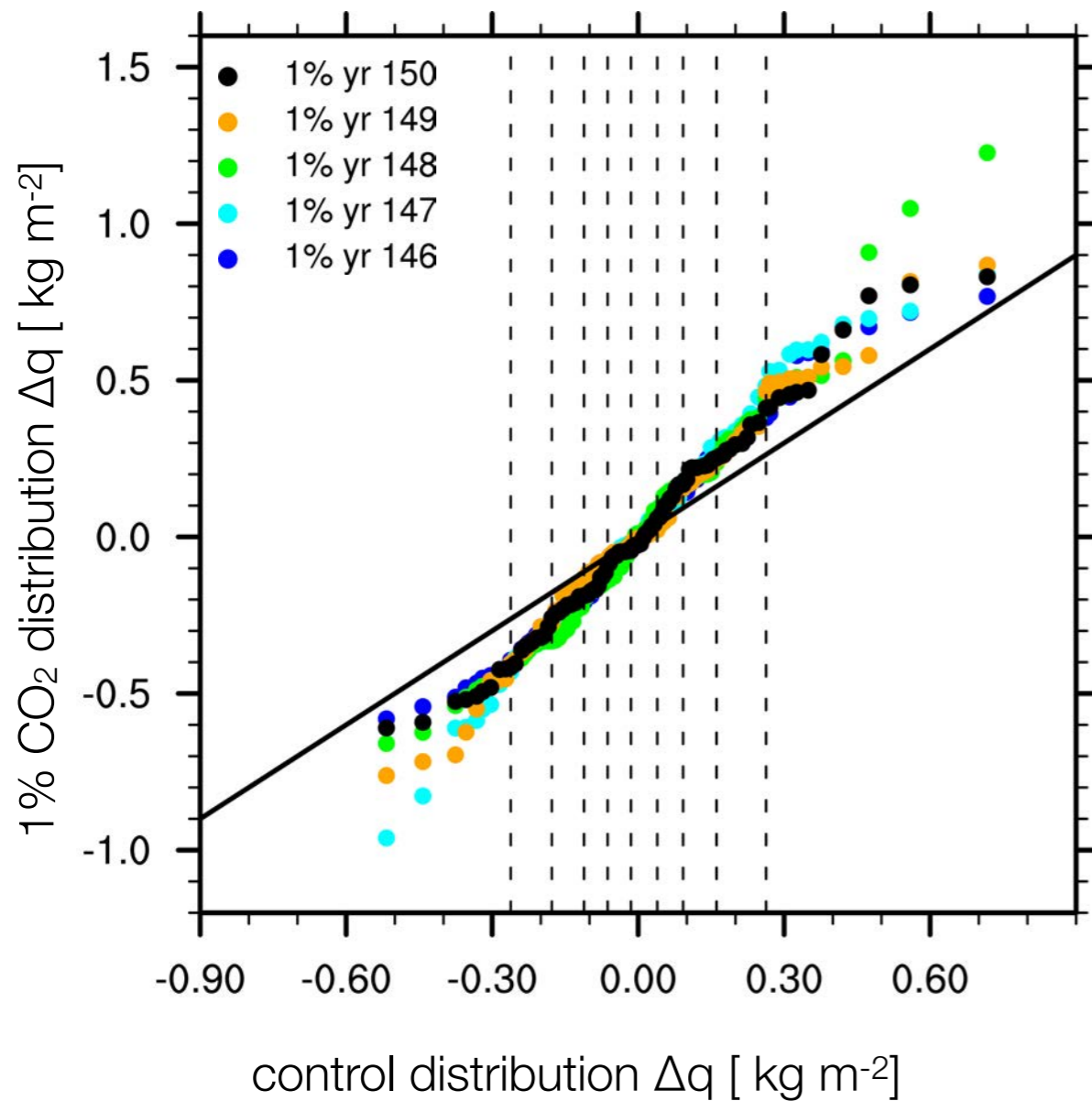
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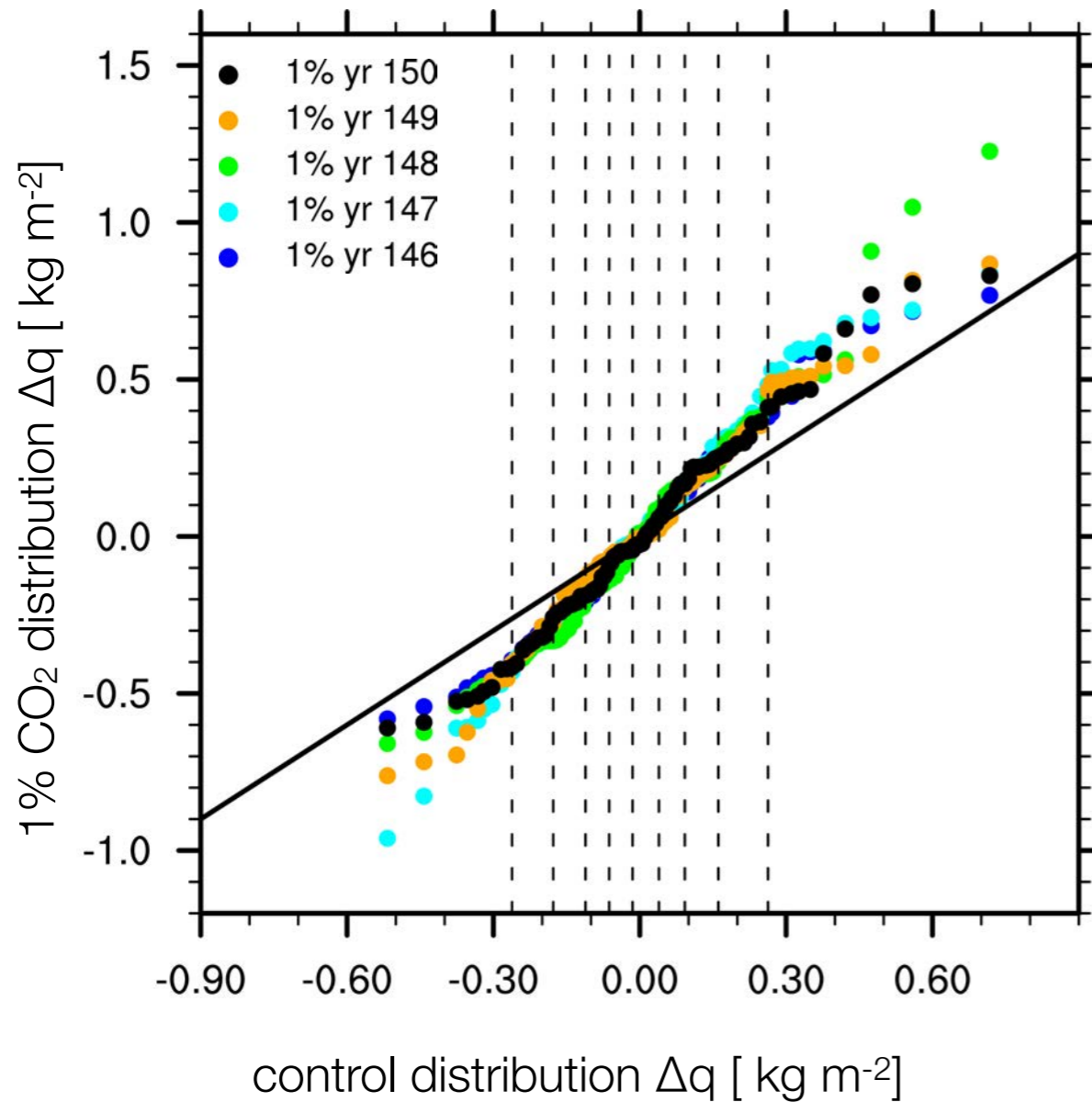


Are these changes robust?

- compare last five years

Large anomalies (upper/lower 10%)

- sign of change is robust



## Are these changes robust?

- compare last five years

## Large anomalies (upper/lower 10%)

- sign of change is robust

## Smaller anomalies (mid 80%)

- magnitude and sign of change is robust



A new analysis framework to quantify changes of internal variability

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- well-defined estimate of internal variability in a transient climate
- detect changes in internal variability in response to a forcing change
- assess robustness of detected changes
- differentiate between anomalies of different amplitude



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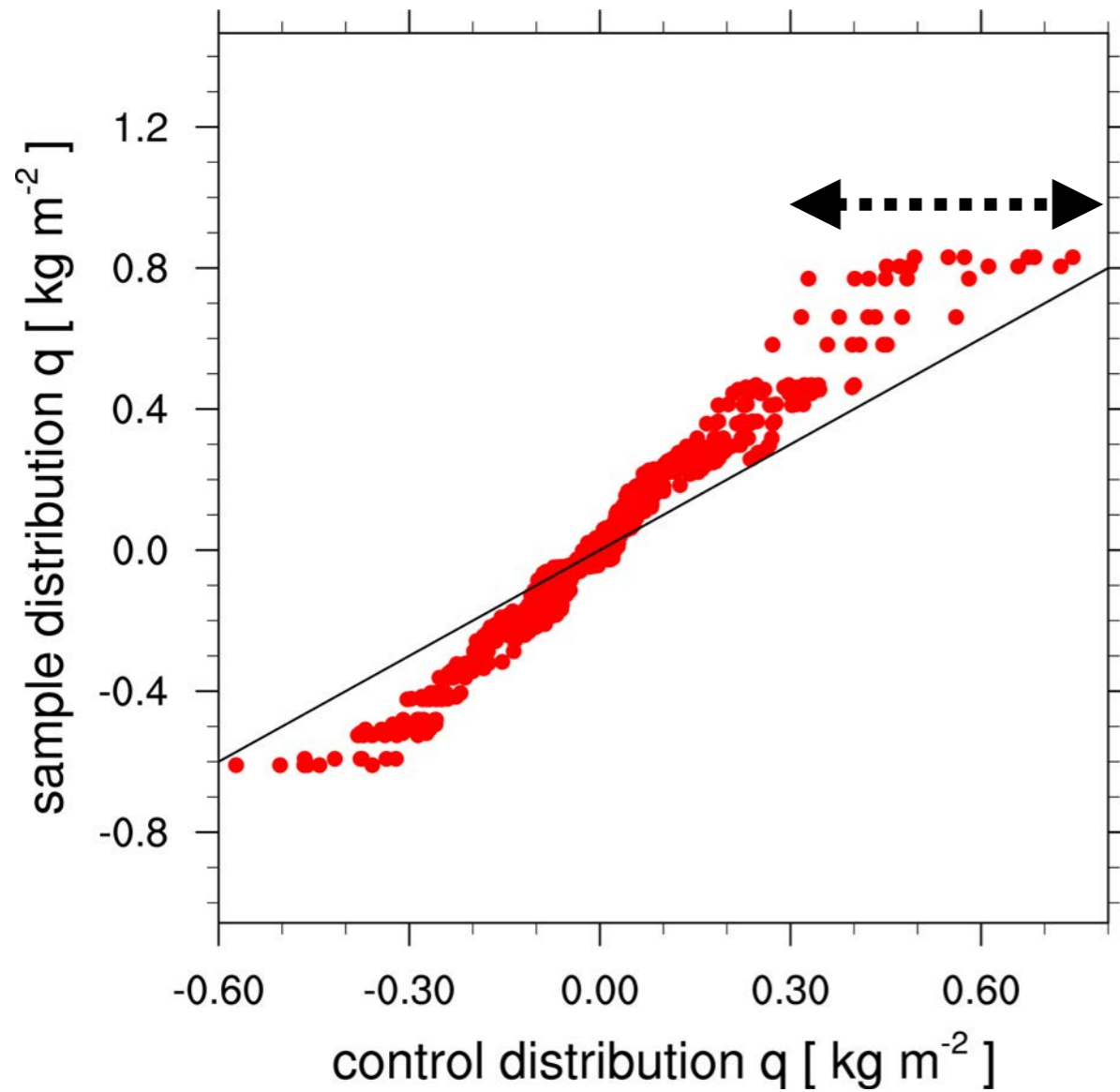
Special issue in *Earth System Dynamics* open for submissions until the end of September 2019:

Large Ensemble Climate Model Simulations: Exploring Natural Variability, Change Signals and Impacts.

Guest editors:

Nicola Maher, Ralf Ludwig, Sebastian Milinski, and Valerio Lucarini

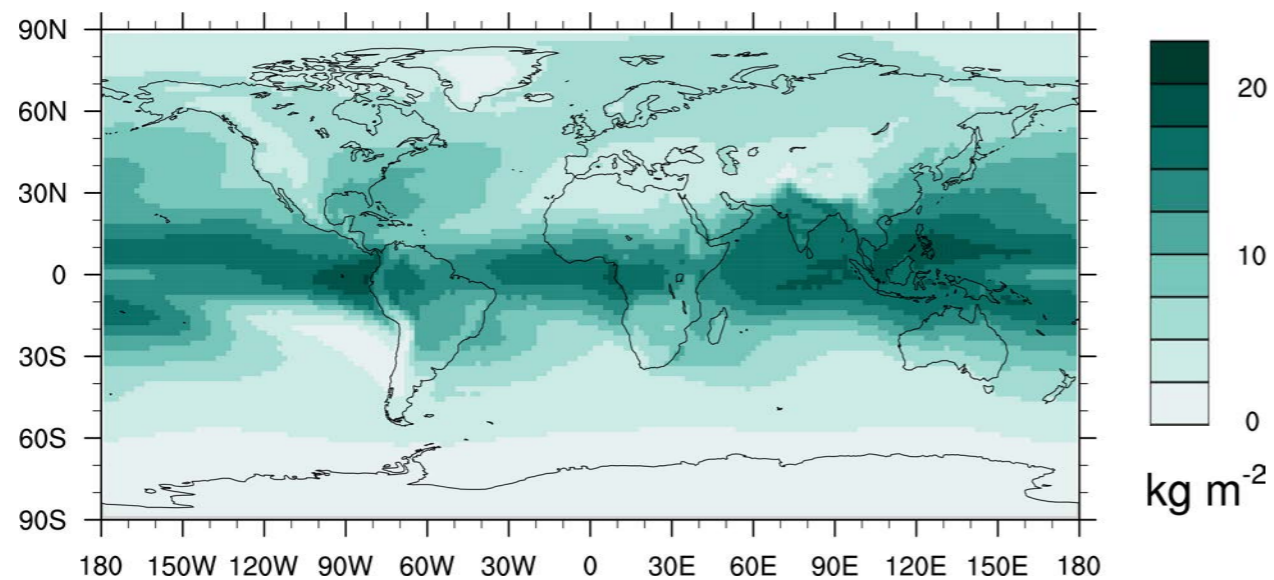
# Sampling uncertainty in the reference distribution



- Small sample size in the reference distribution introduces additional uncertainty

# Difference last year 1% CO<sub>2</sub> - PiControl

## Change in mean precipitable water



## Change in the internal variability

