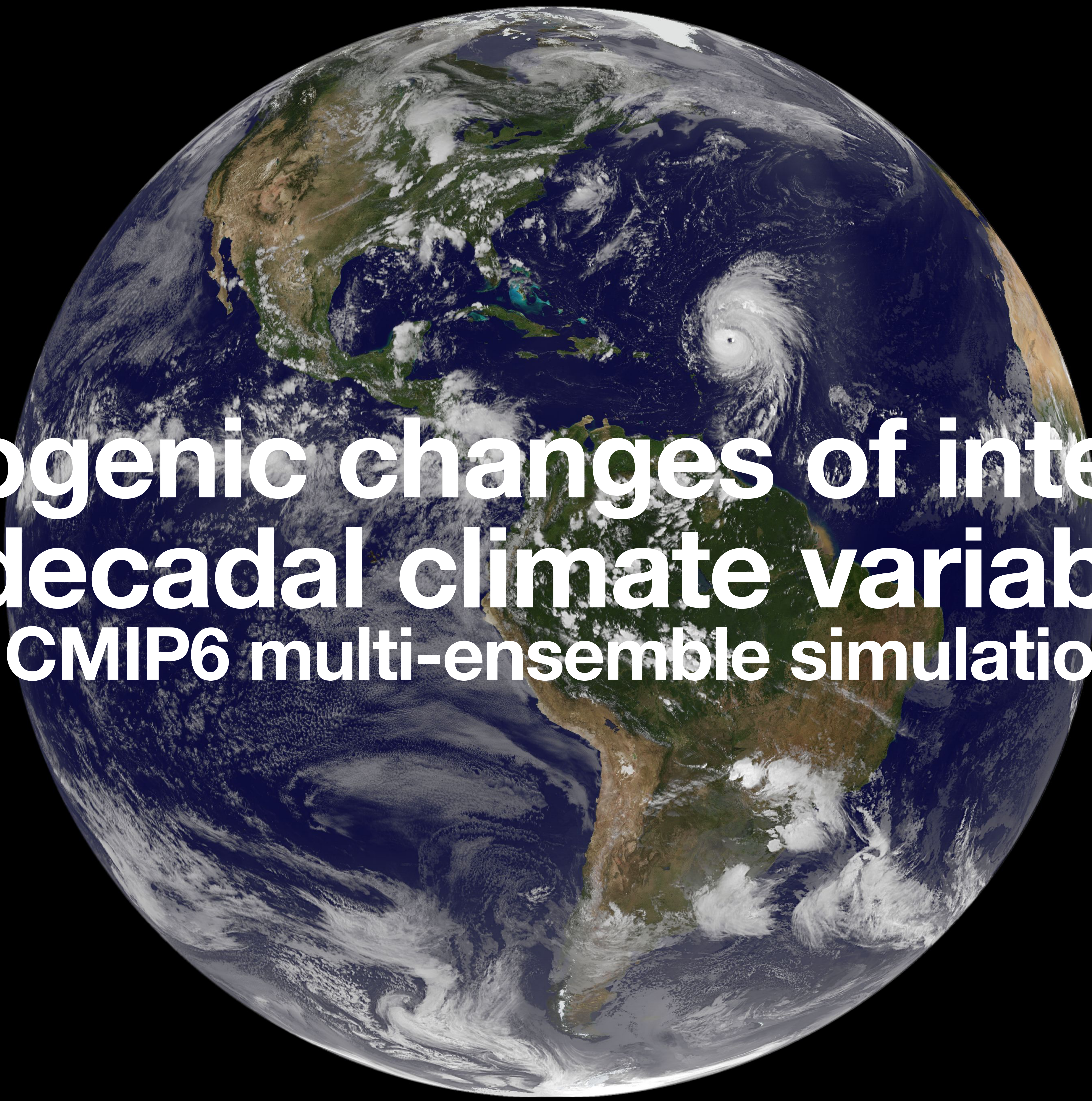

Anthropogenic changes of interannual-to-decadal climate variability

in CMIP6 multi-ensemble simulations

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GDR Théorie Climat - May 2024

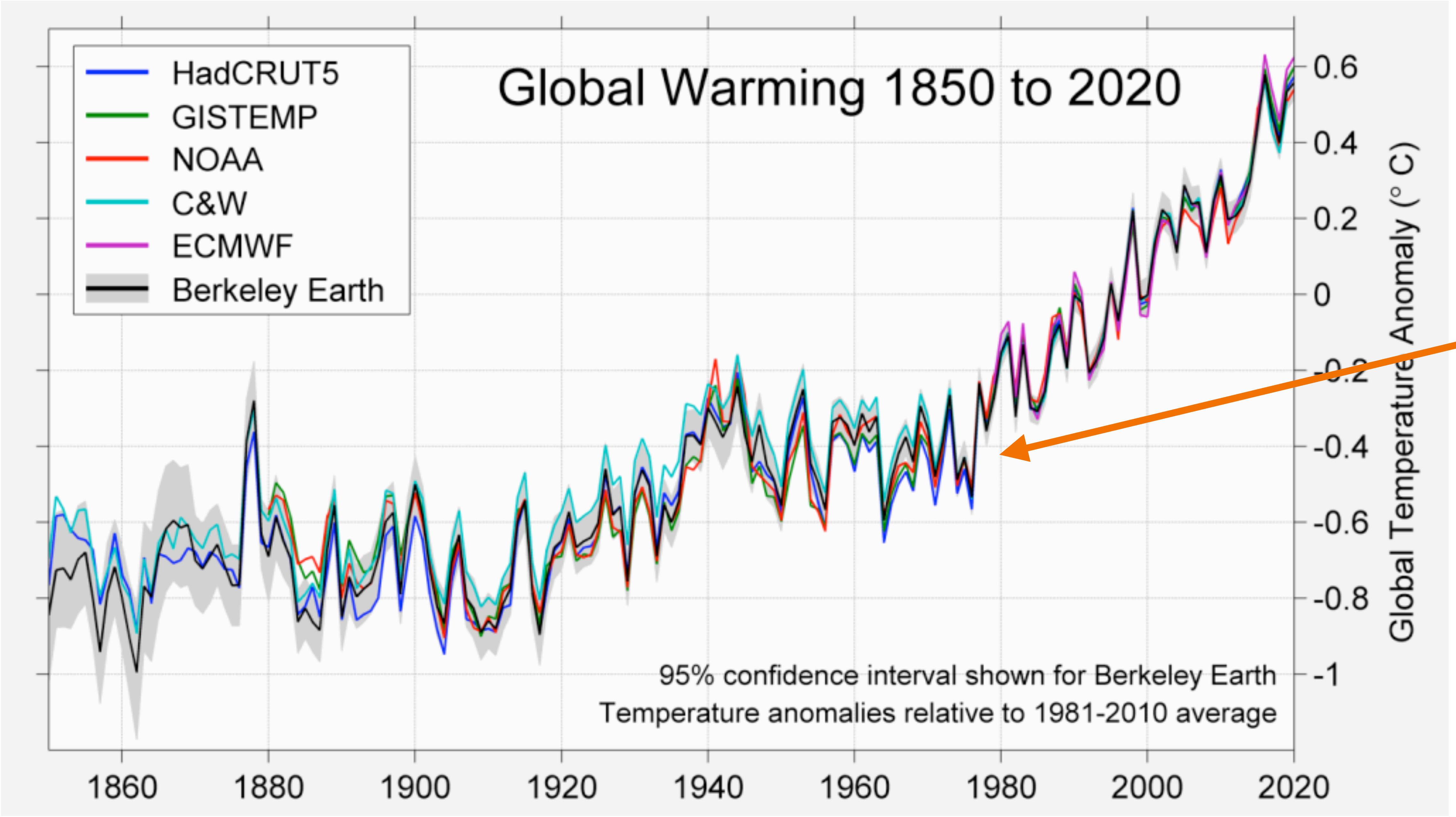
Introduction

Evolution of **Atmosphere/Ocean** states influenced by multiple **factors**

INTERNAL
Eddies, Waves, large scale oscillations (e.g. ENSO) etc.

EXTERNAL
Volcanic eruptions, solar activity, greenhouse gazes emissions etc.

combined in climate records

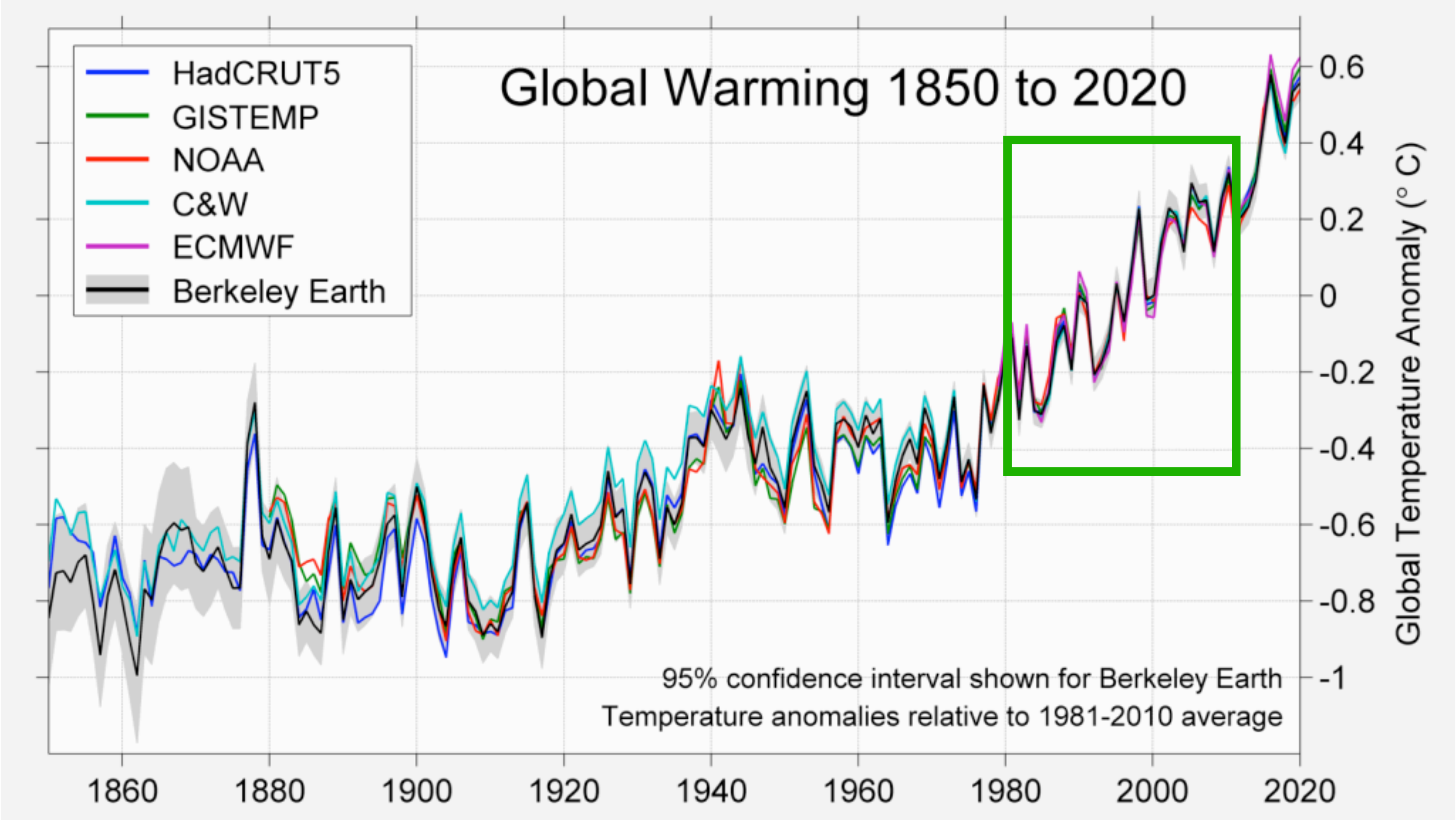


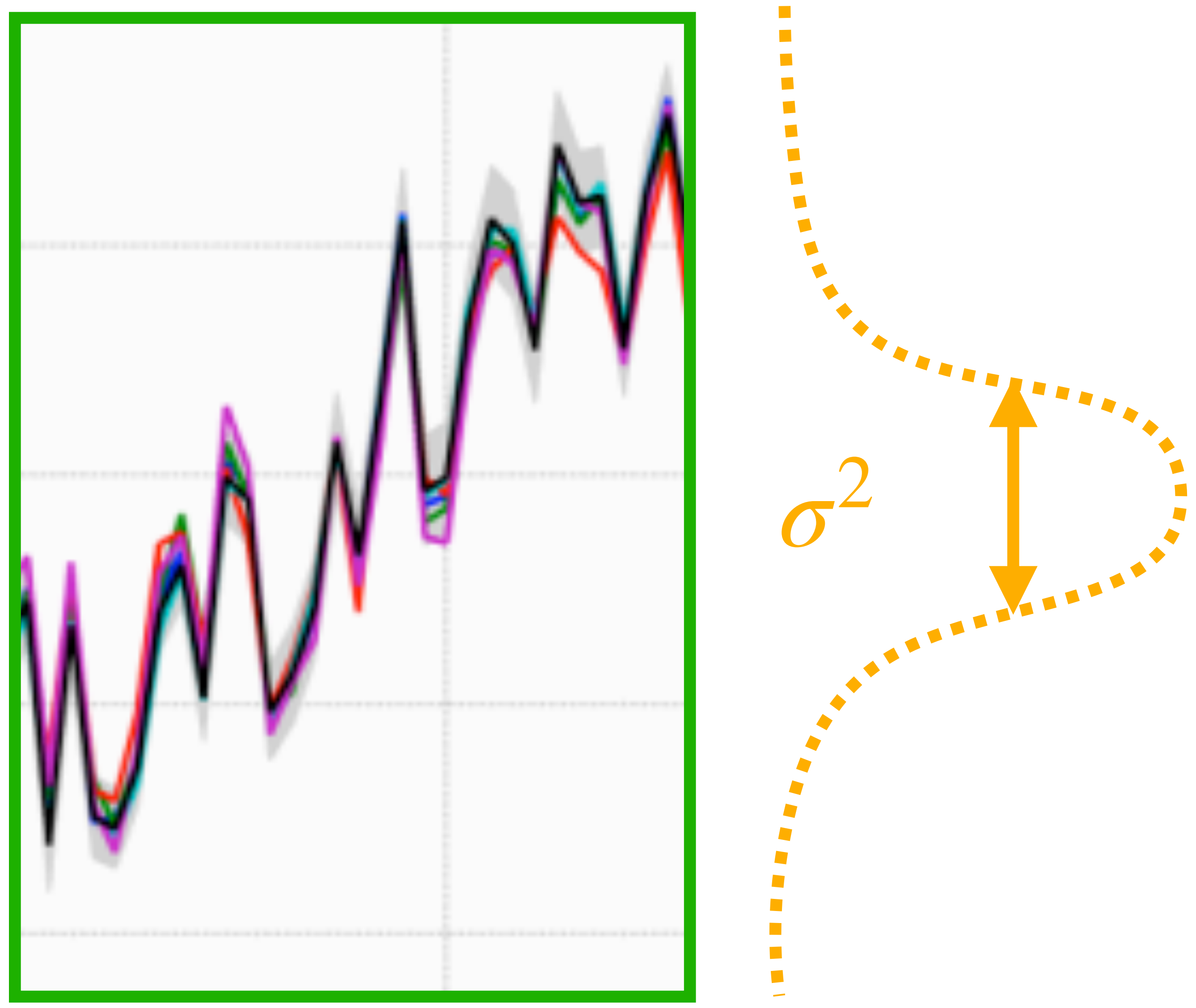
Berkeley Earth

Need to **separate** the **contributions**
(⚠ potential **mutual influences)**

Introduction

When the system oscillates around a stable mean state, we can take a period of few decade and estimate internal variability as the spread during this period





Berkeley Earth

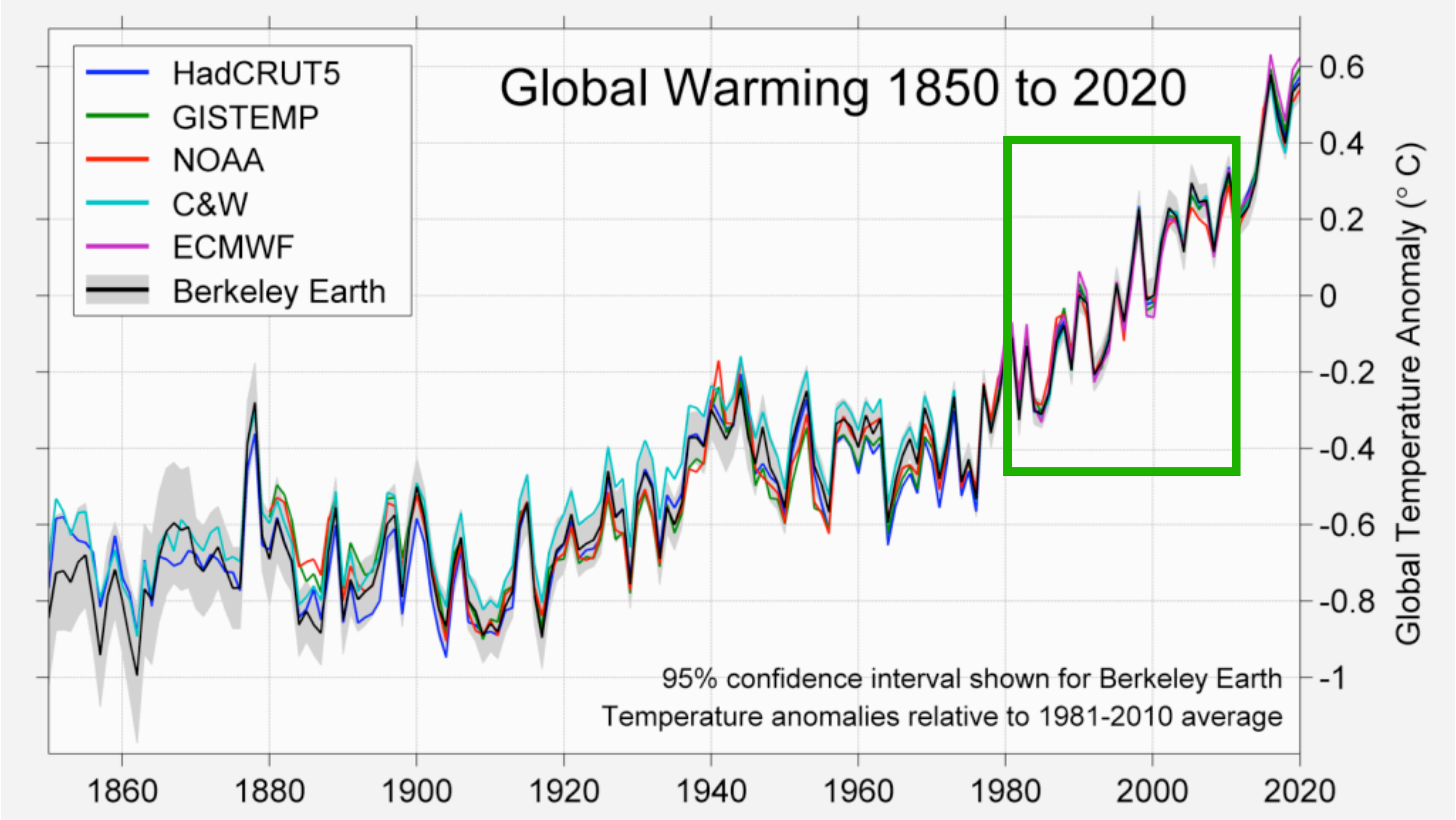
Introduction

When the system oscillates around a stable mean state, we can take a period of few decade and estimate internal variability as the spread during this period

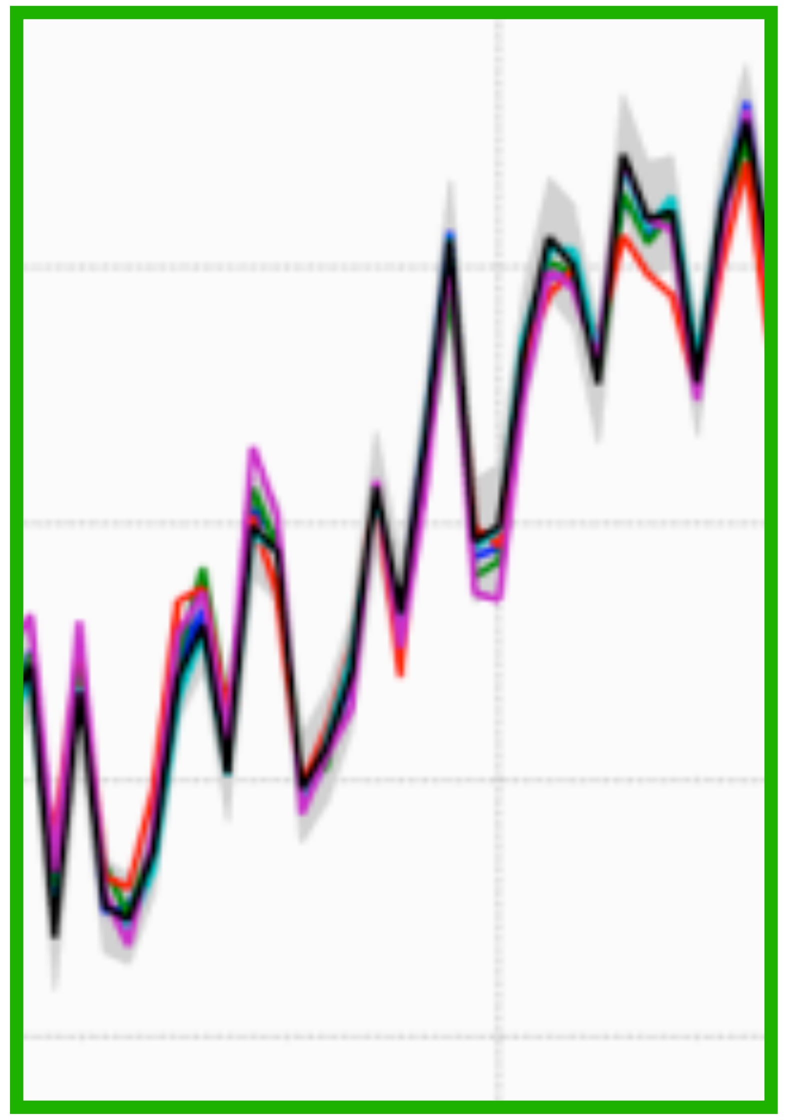
But because of the warming trend, the time window method will not work for 2 reasons:

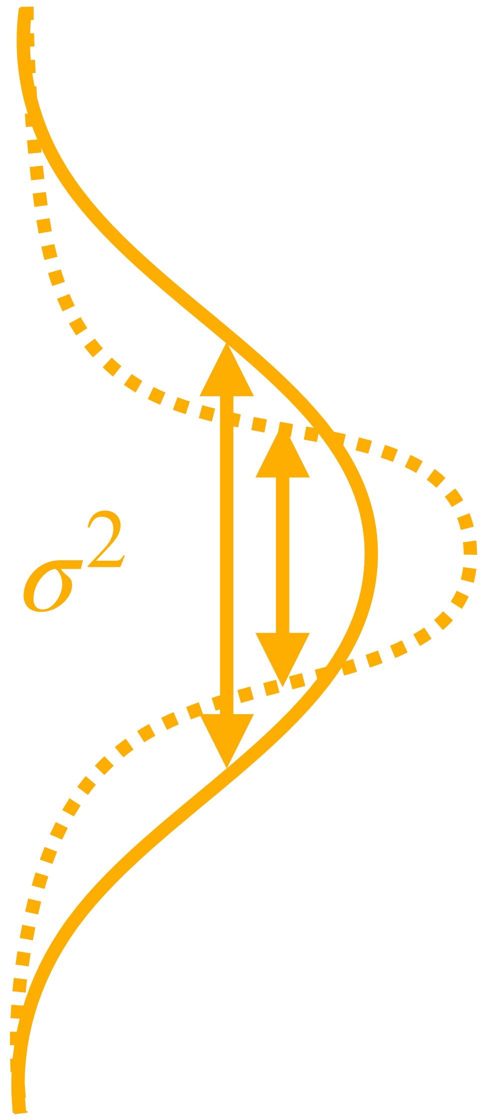
1) The variance inside the window will be exaggerated by the trend → **Need to detrend the data (not straightforward)**

2) The forcing can impact the mechanisms of internal variability



Berkeley Earth





Very common problem when time statistics are not equivalent to ensemble statistics

i.e., NO ERGODICITY

↓

We need an **ensemble**

Introduction

Such ensemble can be obtained using **climate models** and letting **chaos** spread the realizations in the entire space of possible states

Instead simulating a **single** Earth evolving over time, we simulate an **ensemble** of Earths over time

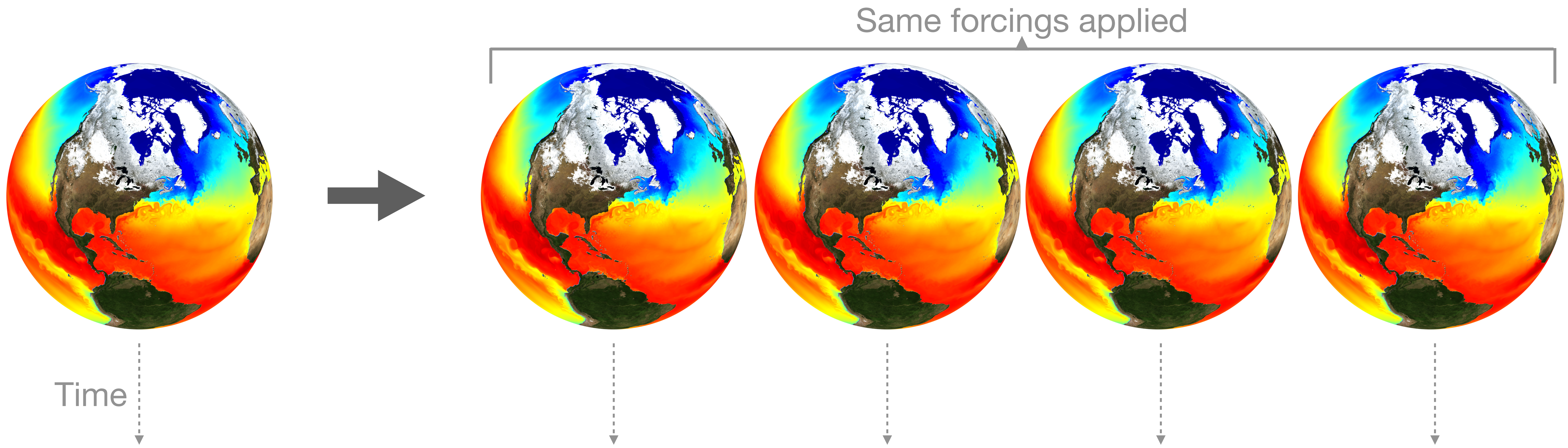


Image from Barcelona Supercomputing Center

<u>At each time step:</u>

- **differences** between simulations ≈ **internal**/chaotic contribution
- **shared** signal among simulations ≈ **forced** contribution

Material

Select ensembles with:
>20 members
from 1850
with SSP1-2.6, SSP2-4.5, SSP5-8.5

➡ **4** CMIP6 Ensemble models

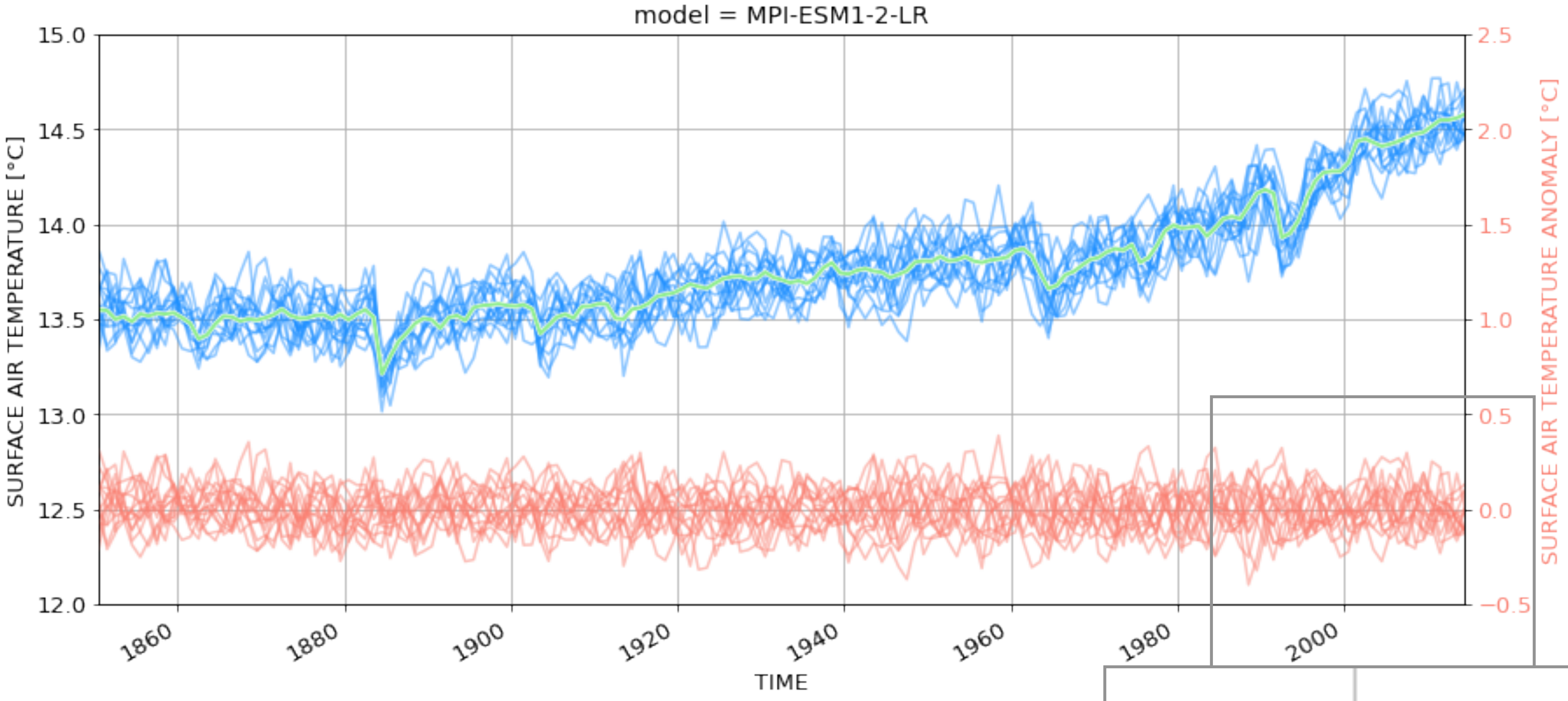
Model	Institution	Number of members	Ocean / Atmosphere (lon x lat)
ACCESS-ESM1-5	CSIRO (Australia)	40	ACCESS-OM2 (1° x 0.6°) HadGAM2 (1.87° x 1.25°)
CanESM5	CCCma (Canada)	25	NEMO 3.4.1 (1° x 0.6°) CanAM5 (2.8° x 2.8°)
MIROC6	MIROC (Japan)	50	COCO 4.9 (1° x 0.7°) CCSR AGCM (1.4° x 1.4°)
MPI-ESM1-2-LR	MPI-M (Germany)	30	MPIOM 1.63 (1.4° x 0.8°) ECHAM 6.3 (1.87° x 1.87°)

Methods

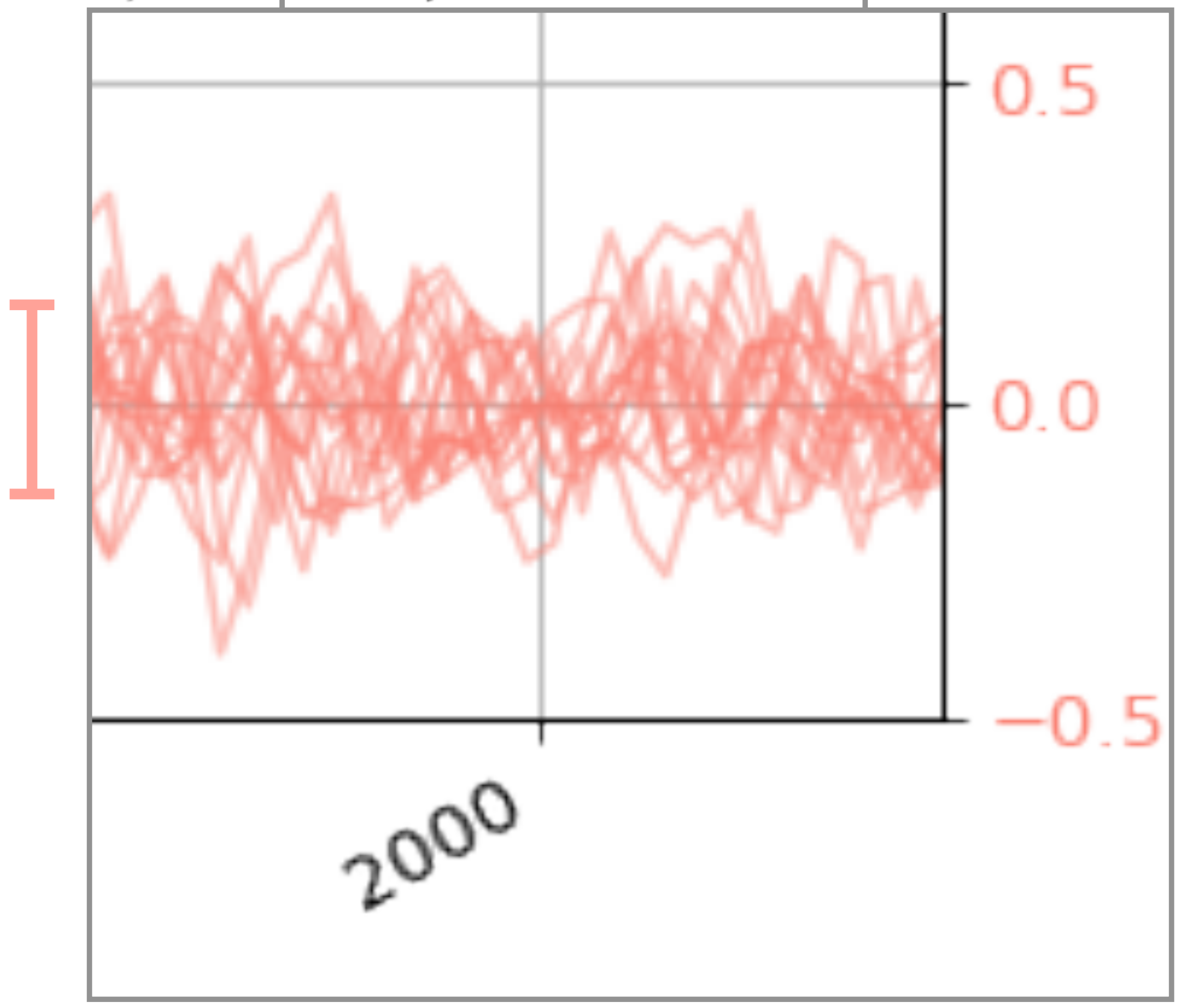
$$\underset{\text{Total Signal}}{T} = \underset{\text{Ensemble Mean}}{\hat{T}} + \underset{\text{Ensemble Anomaly}}{T'}$$

Total Signal | Ensemble Mean | Ensemble Anomaly

External / Forced contribution | Internal / Chaotic contribution



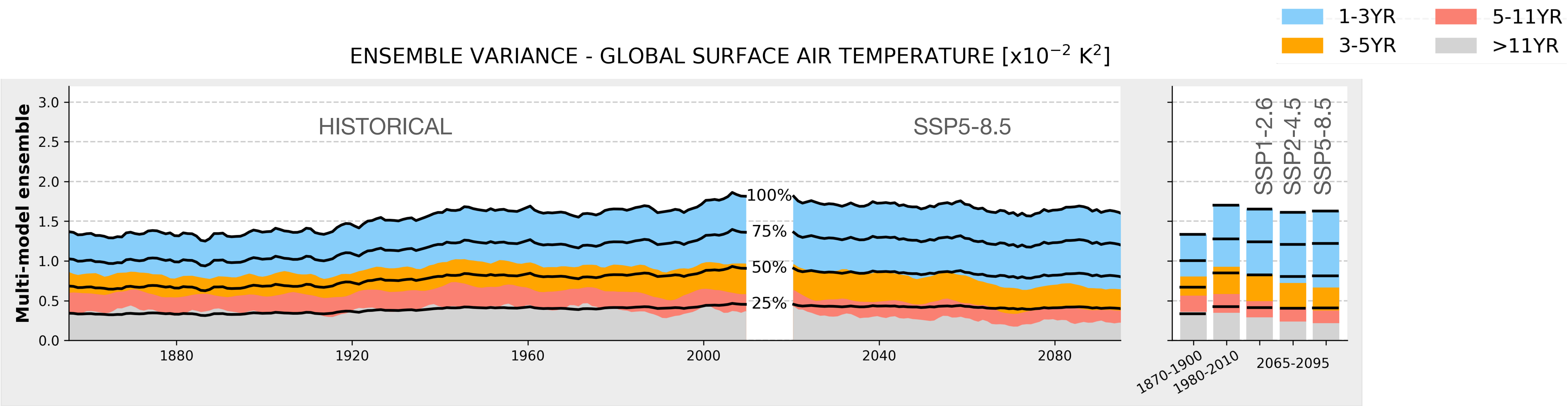
≈ spread of members around ensemble mean



- Use **ensemble variance** as a **proxy** of **inter-member/internal variability**
- **Separation of time scales** -> **Low/band pass filter the data** (1-3, 3-5, 5-11, 11YR)

Results

Evolution of internal variability at **global** scale



Increase of interannual variability (1-3yr) (absolute & relative)

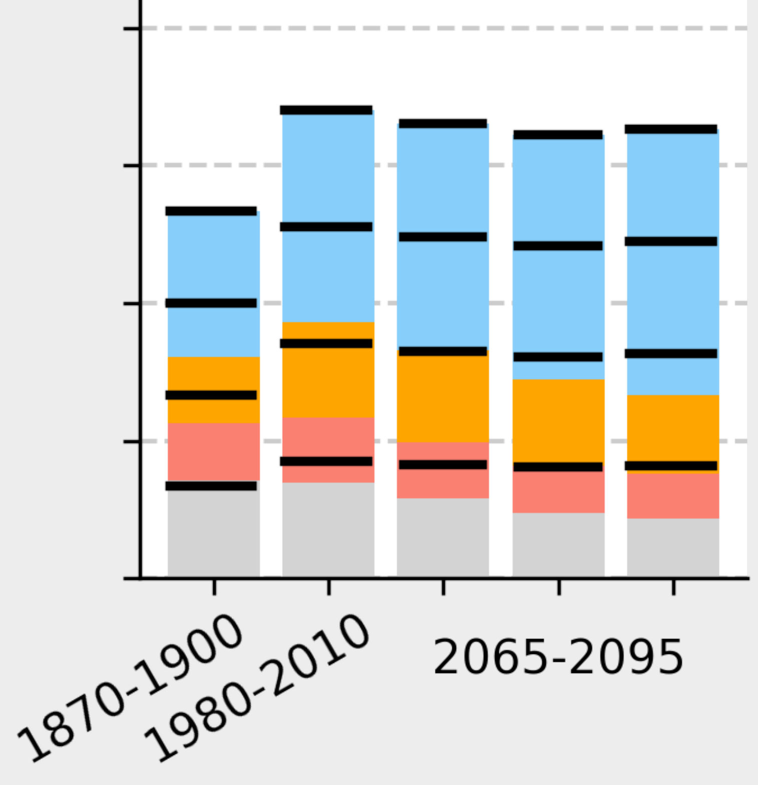
Decrease of low-frequency variability (absolute & relative)

Same process?

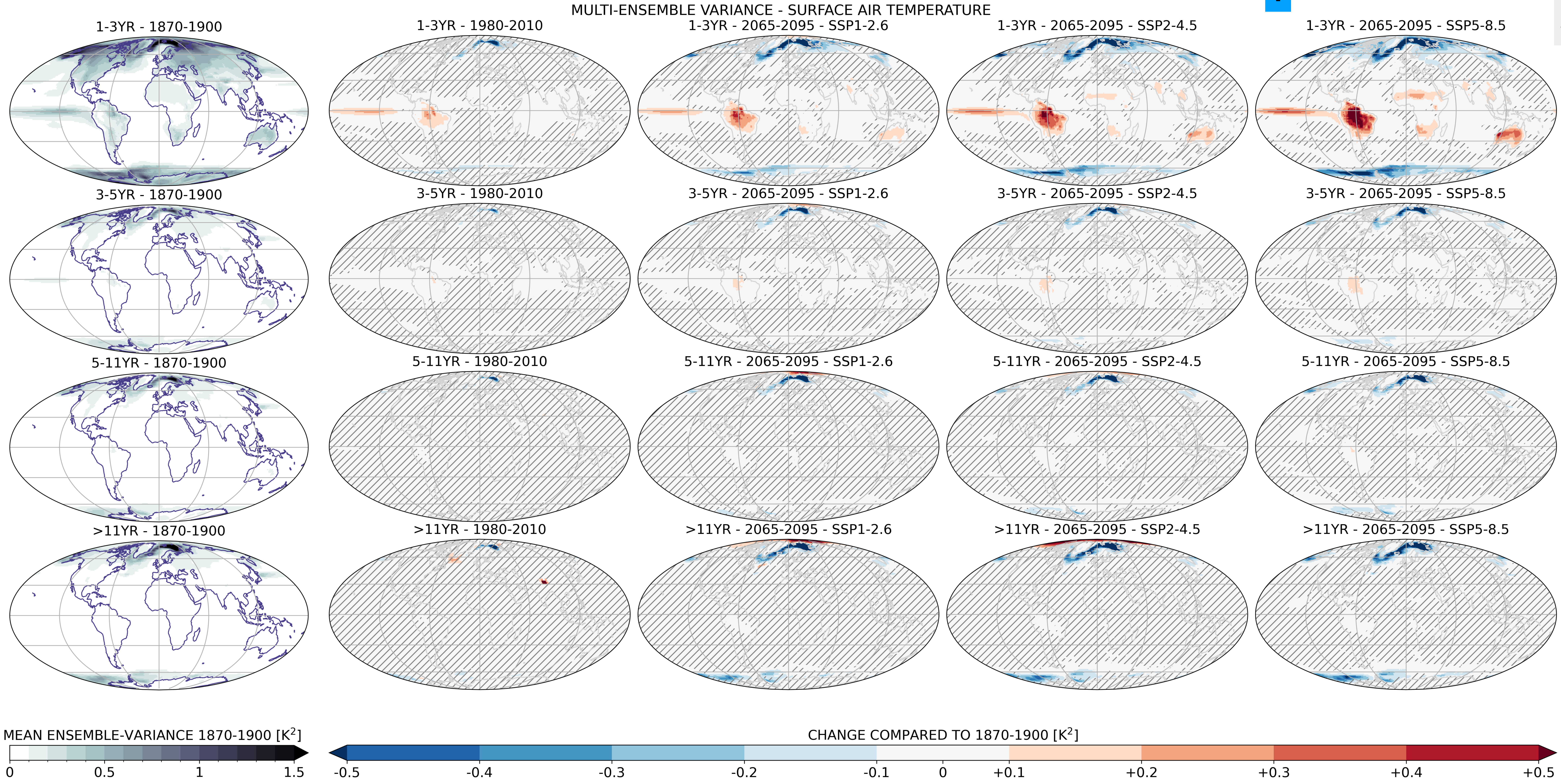
Results

Evolution of internal variability at **local** scale

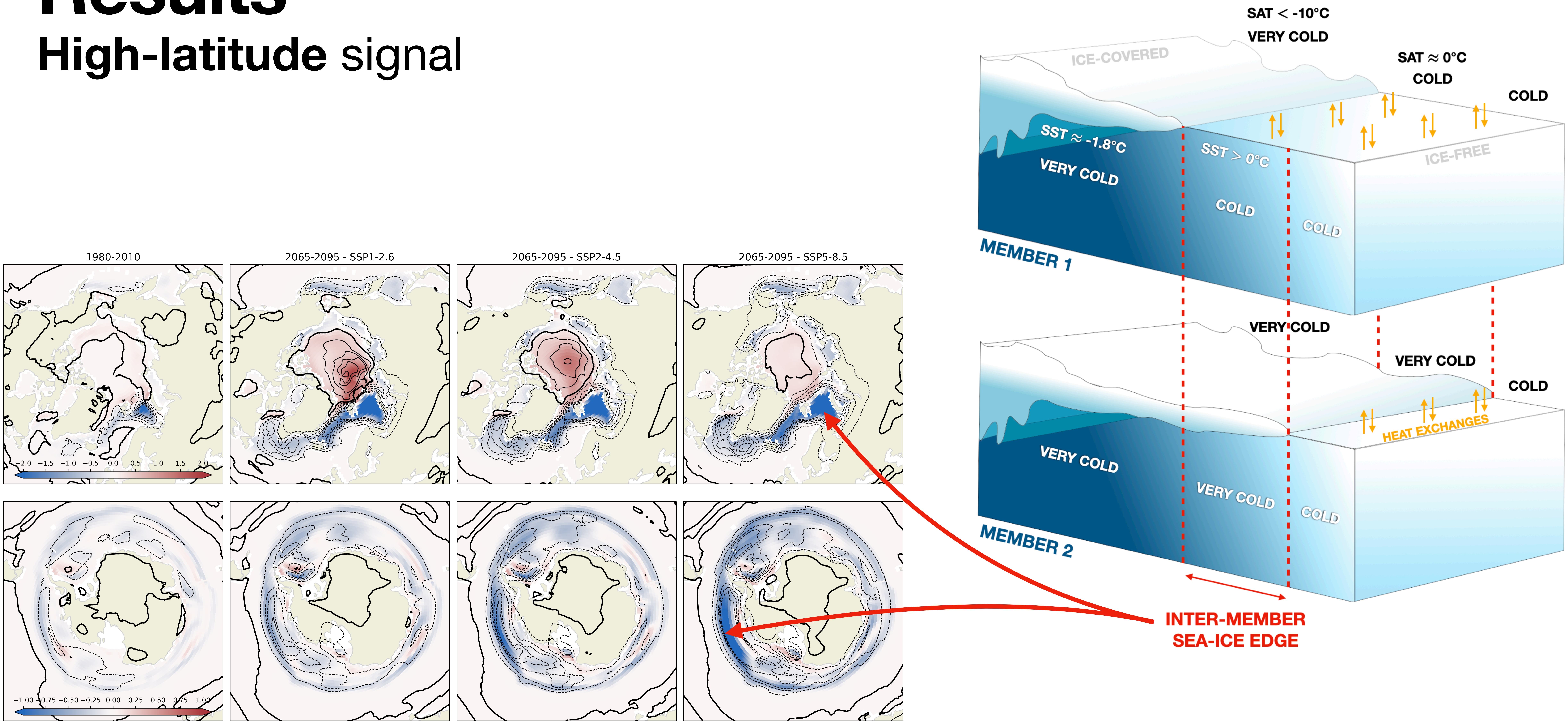
Multi-model ensemble



?



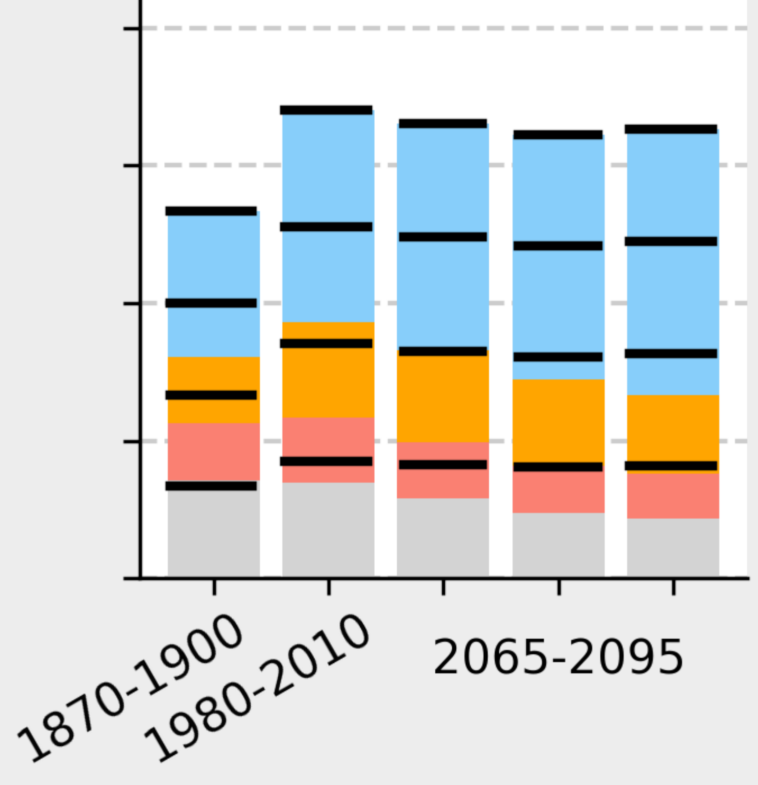
Results
High-latitude signal



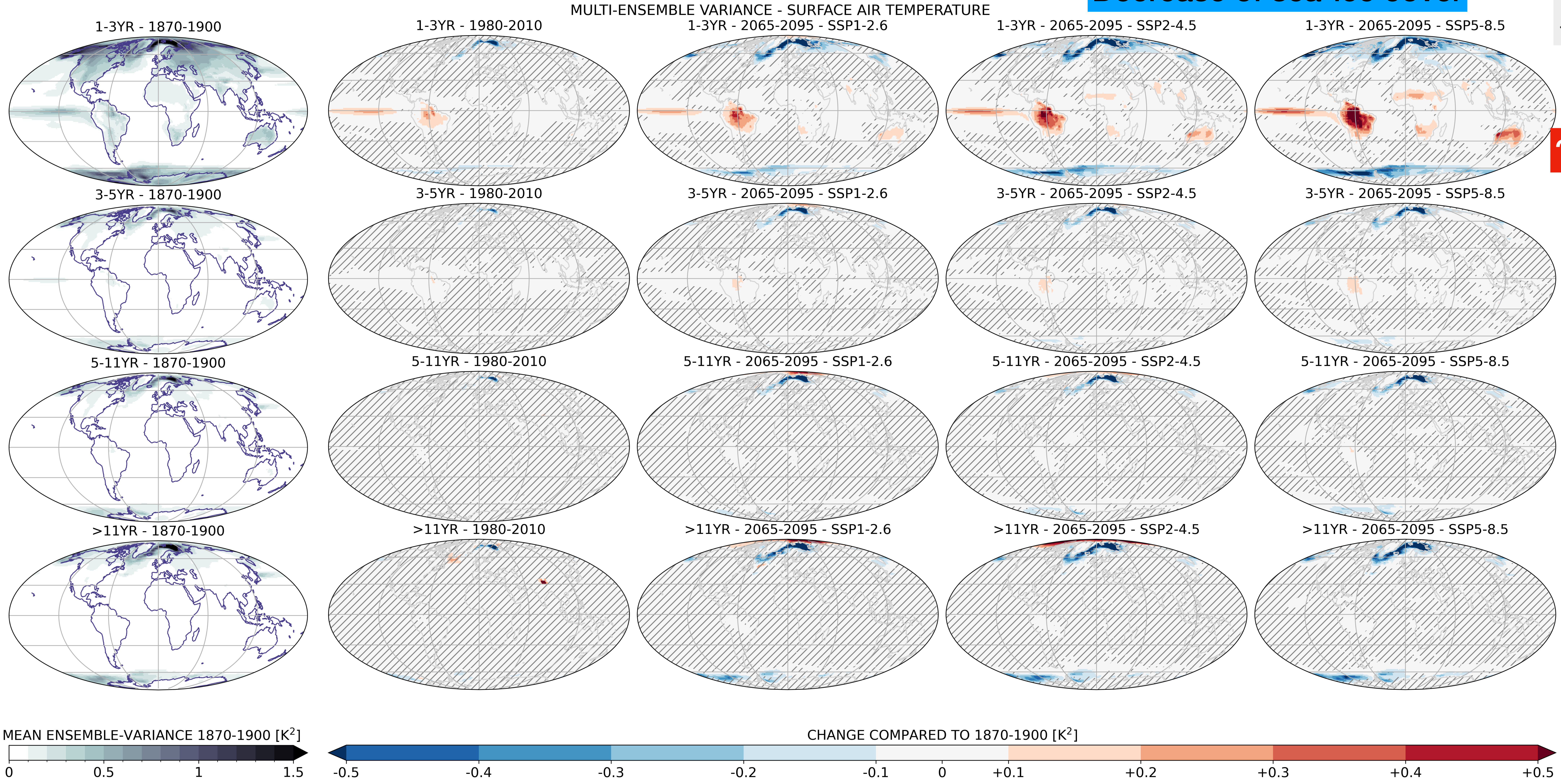
Results

Evolution of internal variability at **local** scale

Multi-model ensemble



Decrease of sea-ice cover

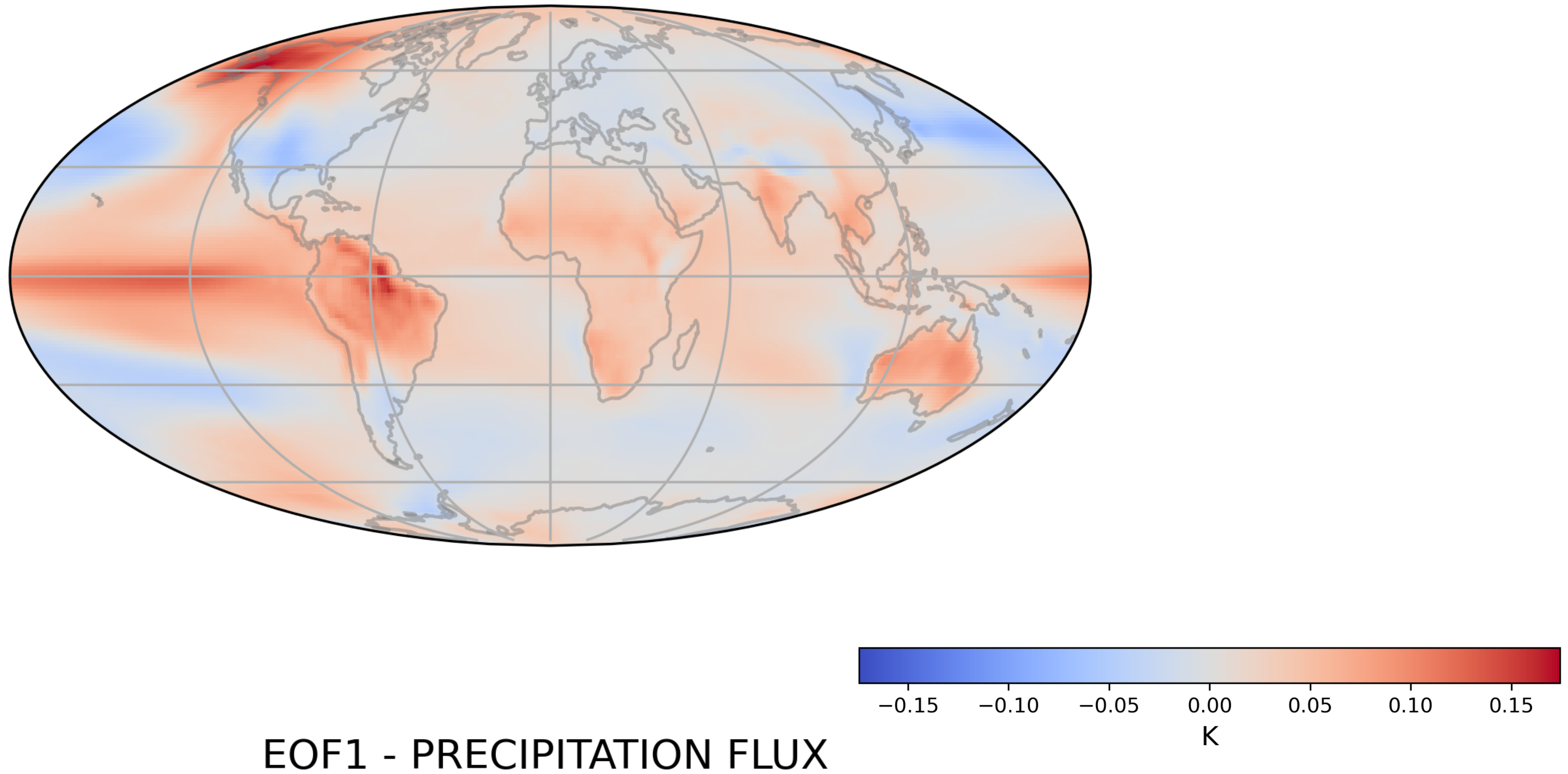


?

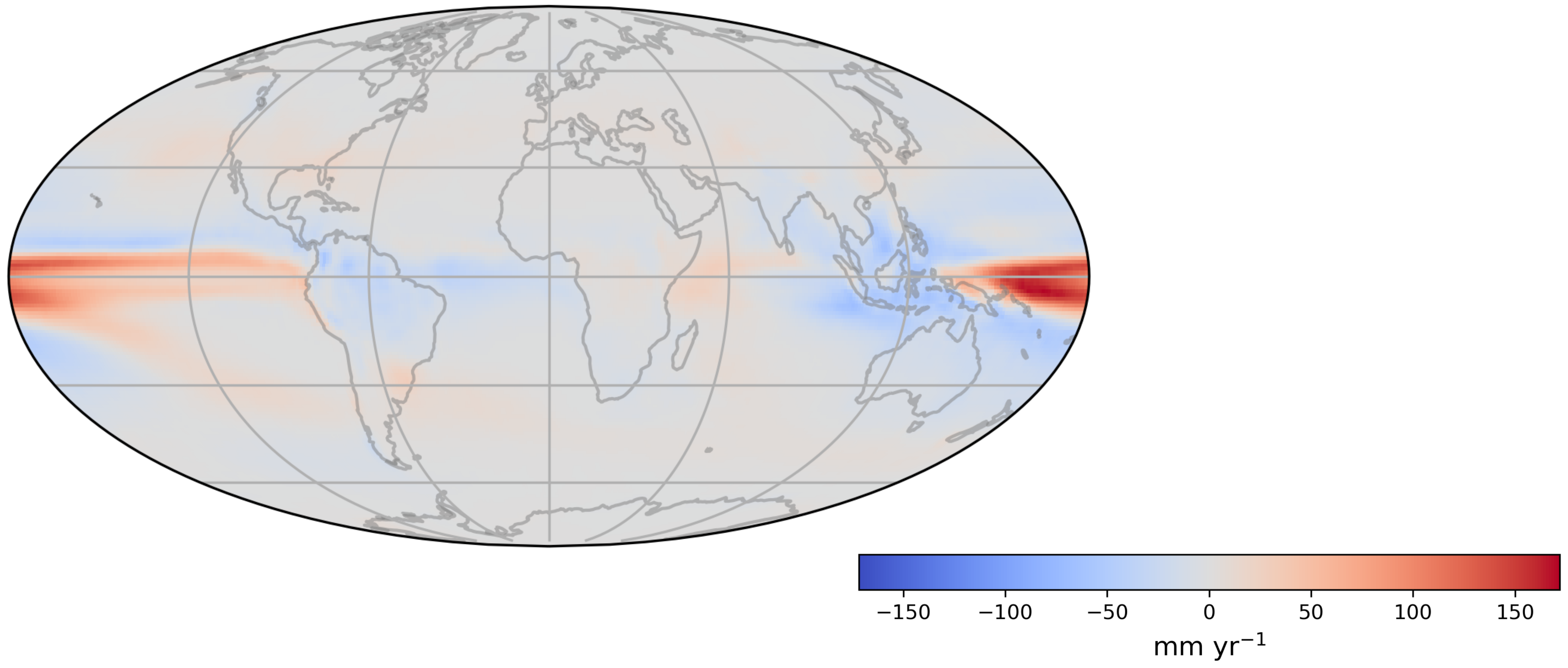
Results

Low-latitude interannual signal

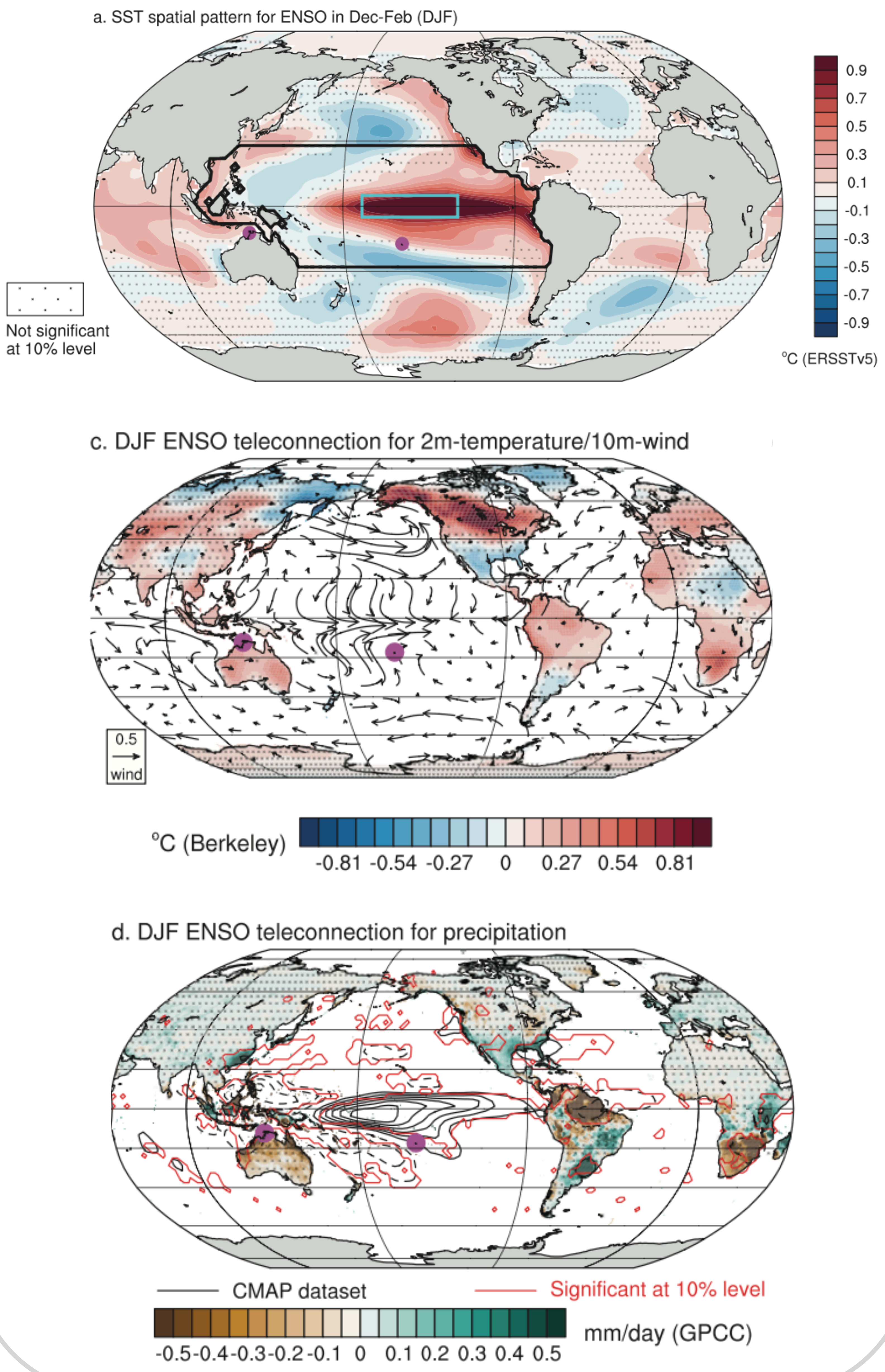
EOF1 - SURFACE AIR TEMPERATURE



EOF1 - PRECIPITATION FLUX

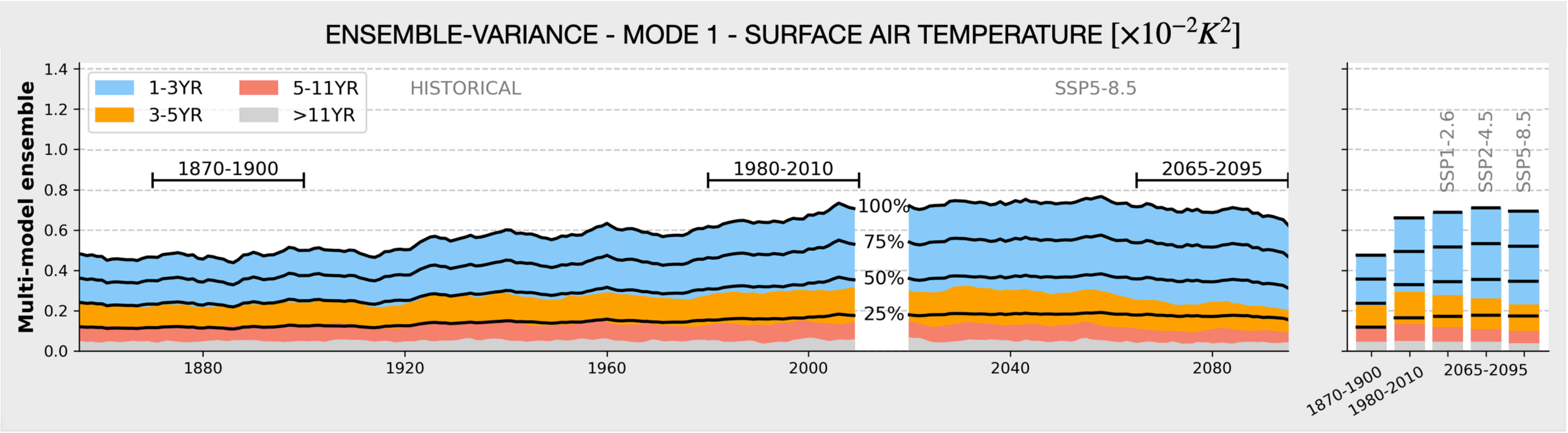


TYPICAL ENSO PATTERN



Results

Low-latitude interannual signal



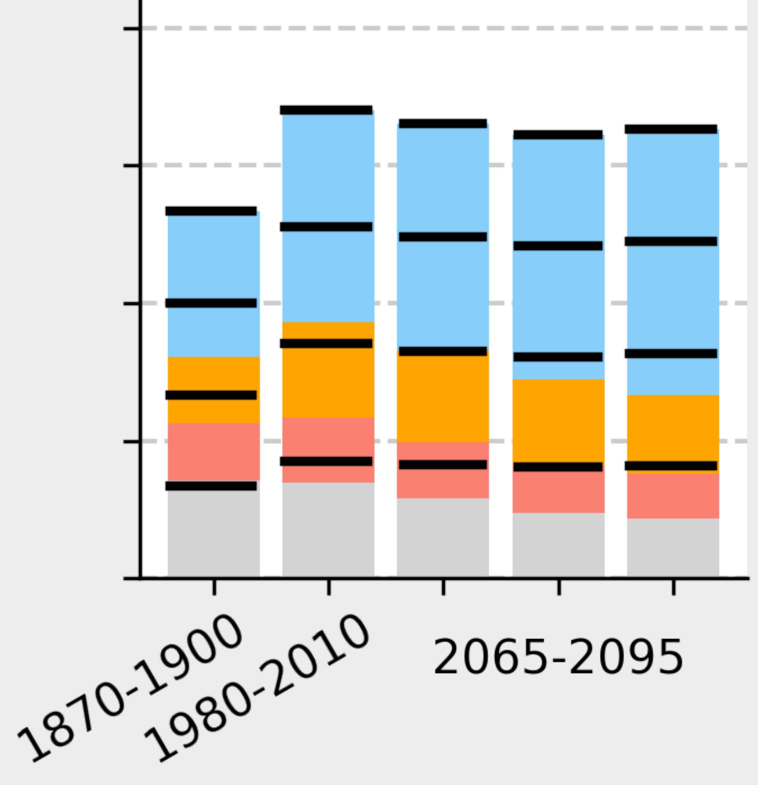
Interannual ↗ (1-3yr) (**absolute** & **relative**)

Correlated with scenario intensity

Results

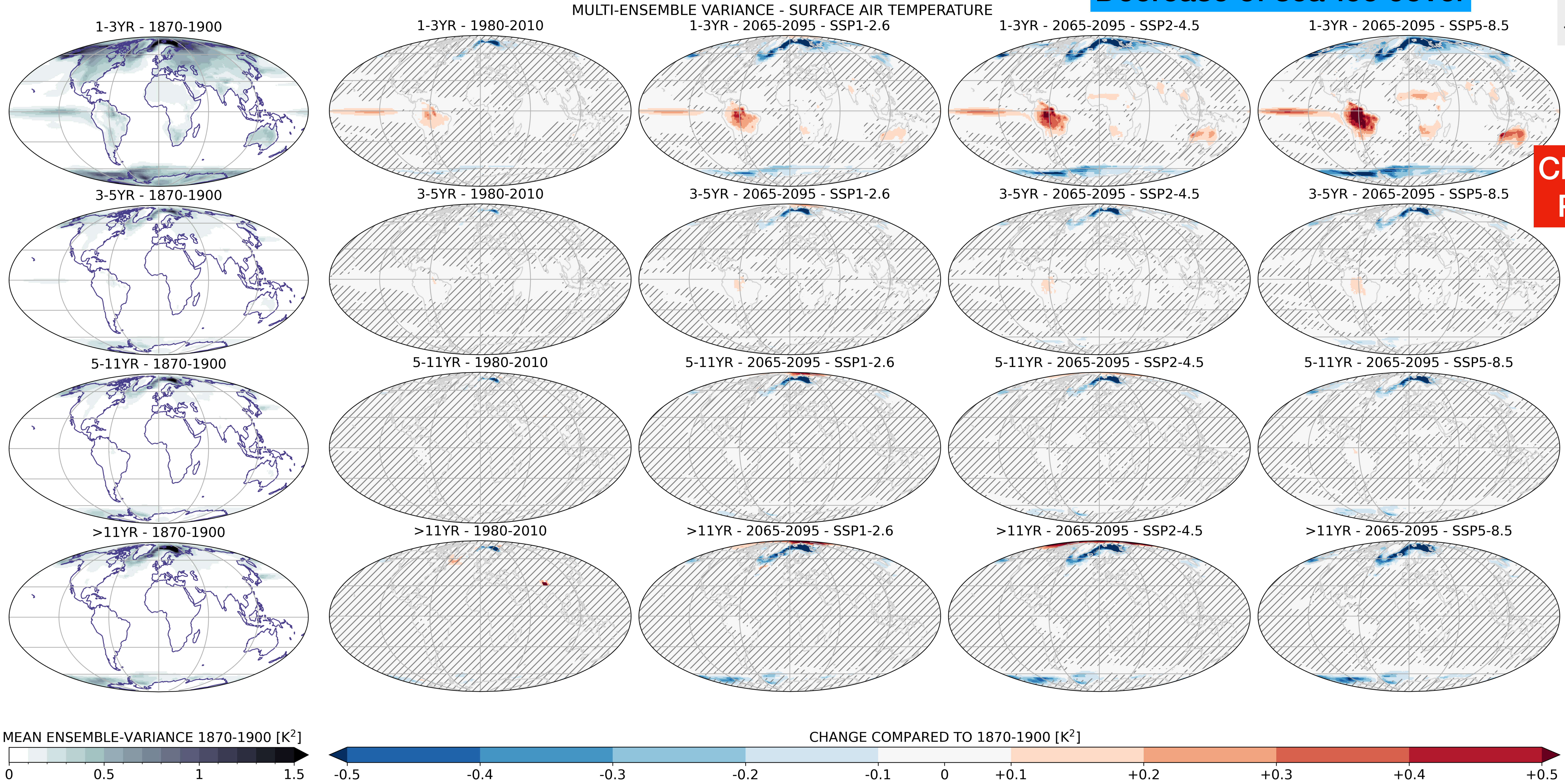
Evolution of internal variability at **local** scale

Multi-model ensemble



Decrease of sea-ice cover

Changes in Tropical Pacific Variability



Take-home message

- **Internal variability** has **changed** since PI, and **will** likely **change** in the future
(observable thanks to “large” ensembles of climate simulations, reinforces importance of ensembles, difficulties in observations)

- **2 distinct mechanisms** identified:
  - **Poleward shift of sea-ice edge**
  - **Increase of interannual variability at low-latitude** (confirmed with precipitation)

- **Increase of “Tropical Pacific variability” frequency,** that appears **concomitant** with the **increase of radiative forcing**

Coquereau, A., F. Sévellec, T. Huck, J. J. Hirschi, and A. Hochet, 2024: Anthropogenic changes of interannual-to-decadal climate variability in CMIP6 multi-ensemble simulations. *J. Climate*, https://doi.org/10.1175/JCLI-D-23-0606.1, in press.

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