Effects of macro *vs*. micro initialization and ocean initial-condition memory on the evolution of ensemble spread in the CESM2 Large Ensemble

Clara Deser & Who Kim

Robb Wills, Isla Simpson, Steve Yeager and Gokhan Danabasoglu

CVCWG session, Annual CESM Workshop June 2024

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1) Does the evolution of ensemble spread depend on the method of initialization (micro or macro perturbation)?

2) How long does ocean initial-condition memory last in the atmosphere and upper ocean?

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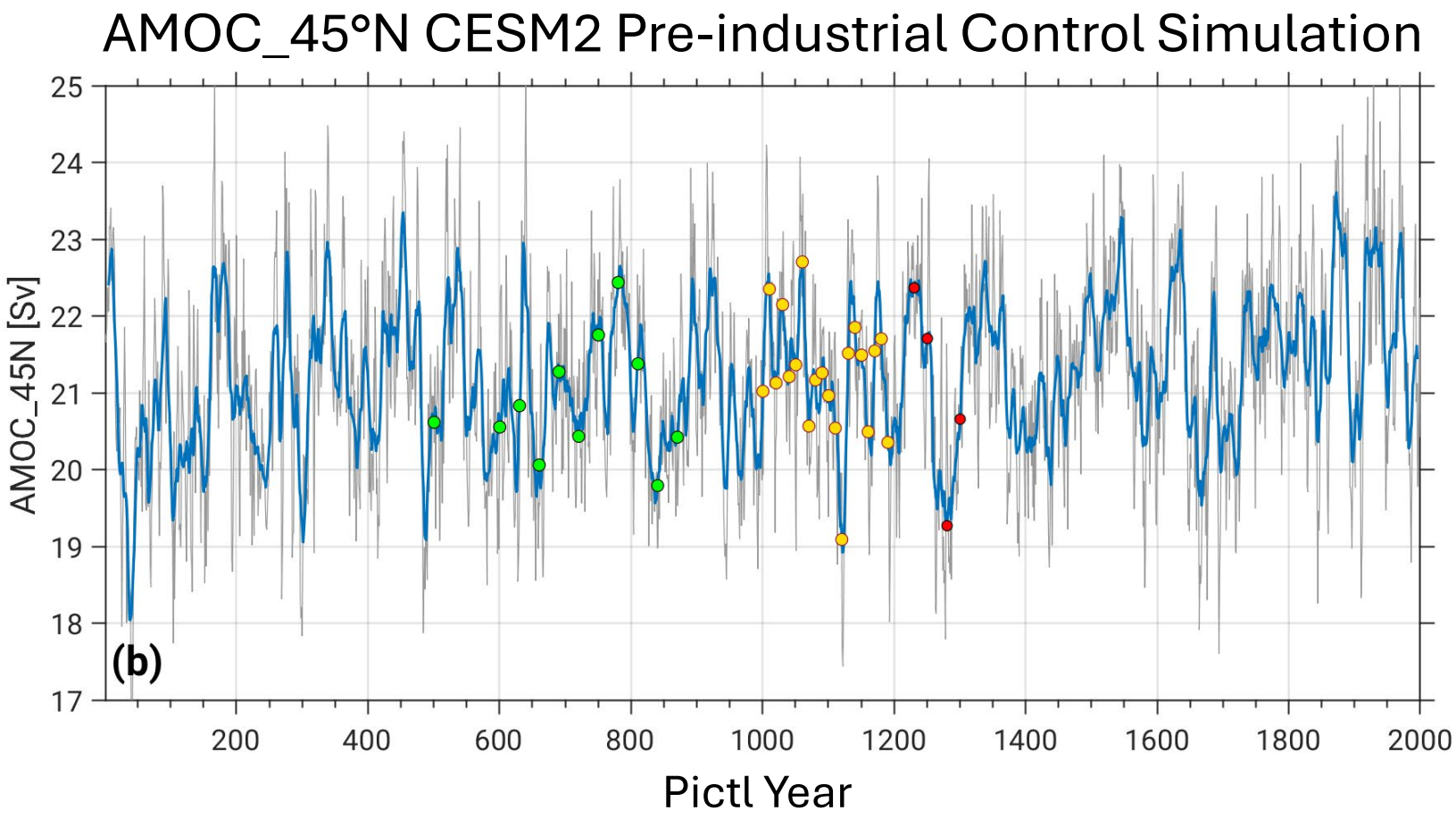
AMOC_45°N CESM2 Pre-industrial Control Simulation
AMOC_45N [Sv]
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(b)
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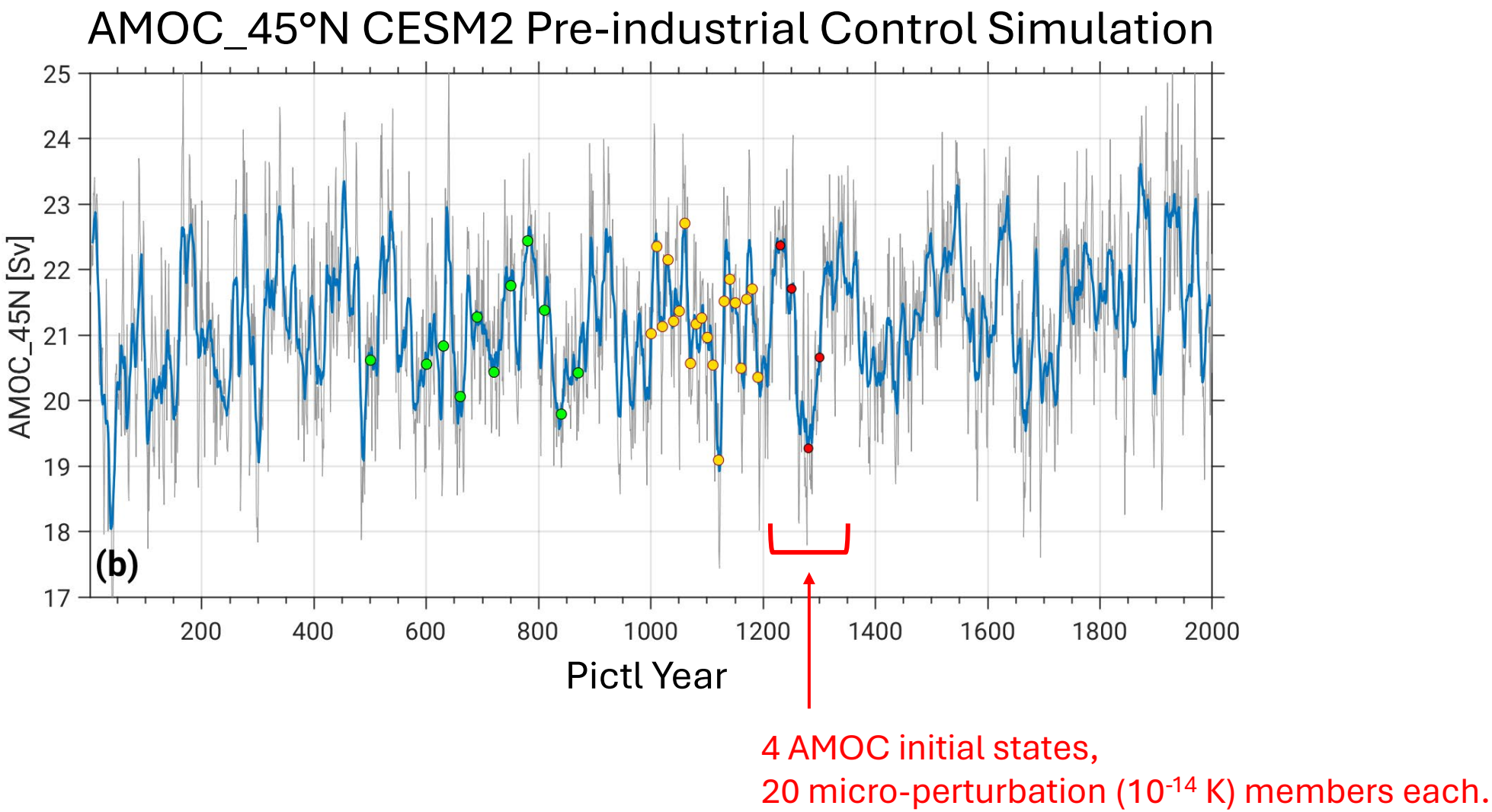
2000
Pictl Year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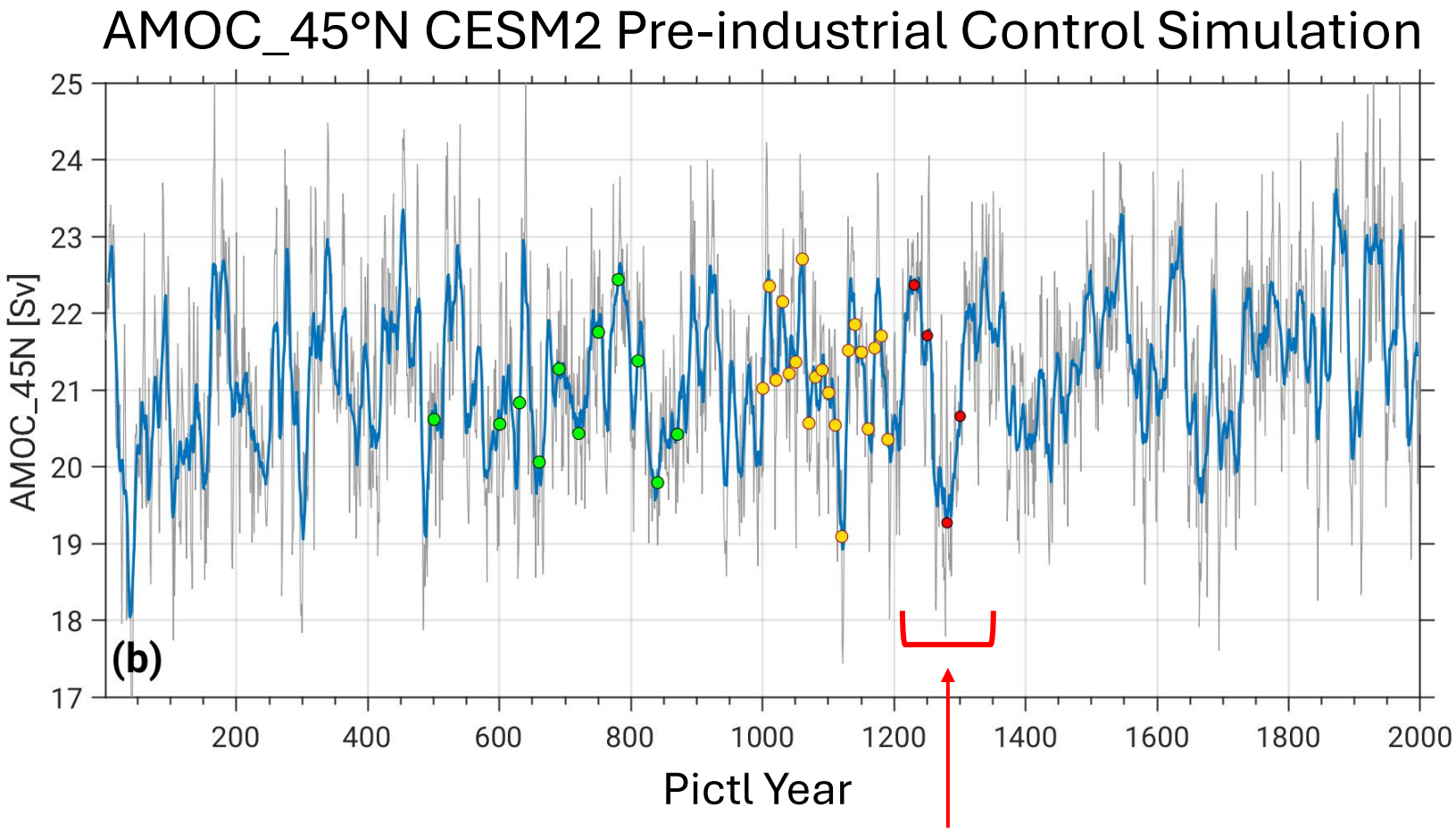
Pictl Year
4 AMOC initial states,
20 micro-perturbation (10-14 K) members each.

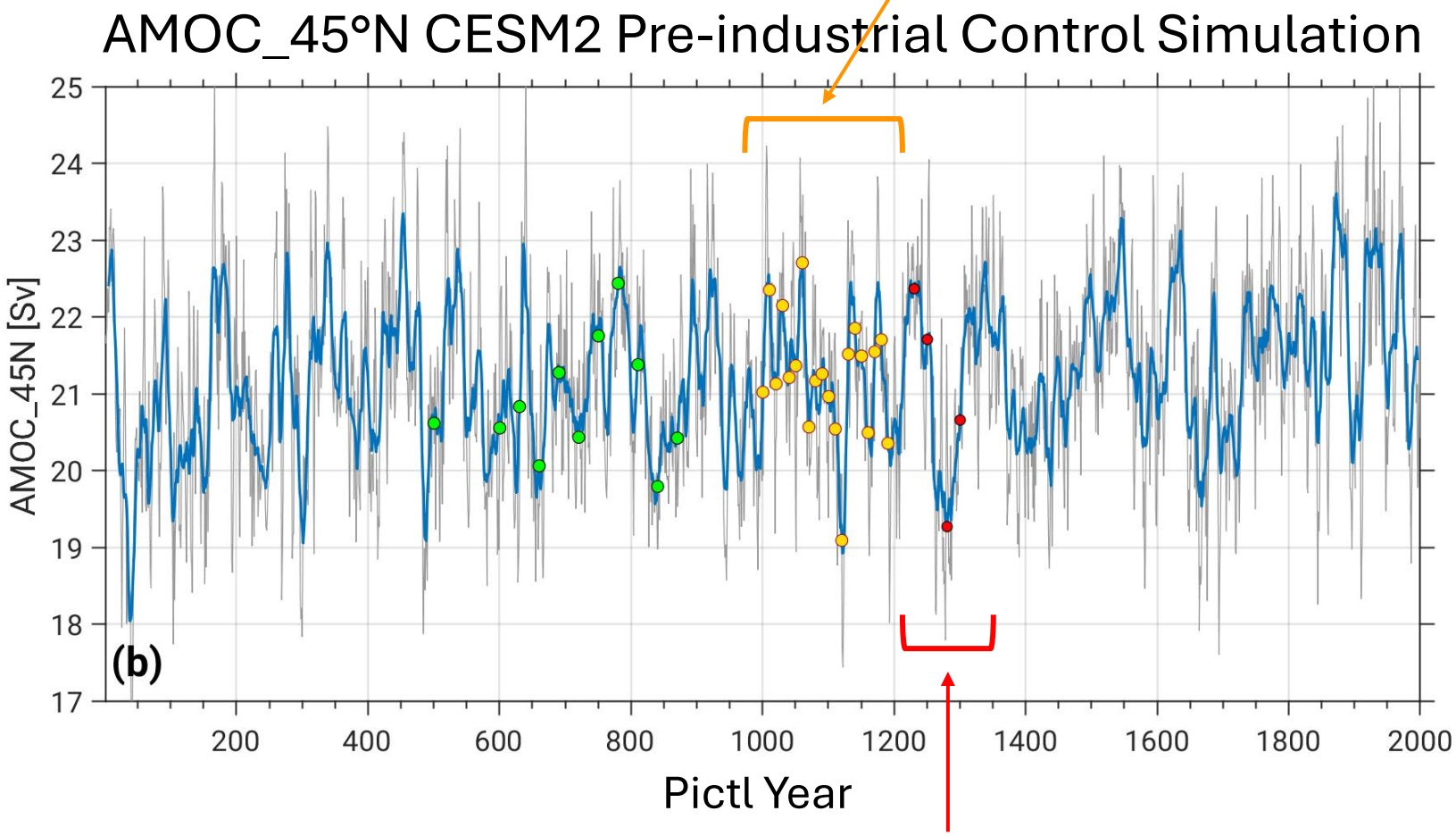


4 AMOC initial states,
20 micro-perturbation (10^{-14} K) members each.

σ Micro (t) = $\sqrt{\sum(xi - xmean)^2}$

Compute for each AMOC initial state, then average the 4 estimates.

20 macro-perturbation members



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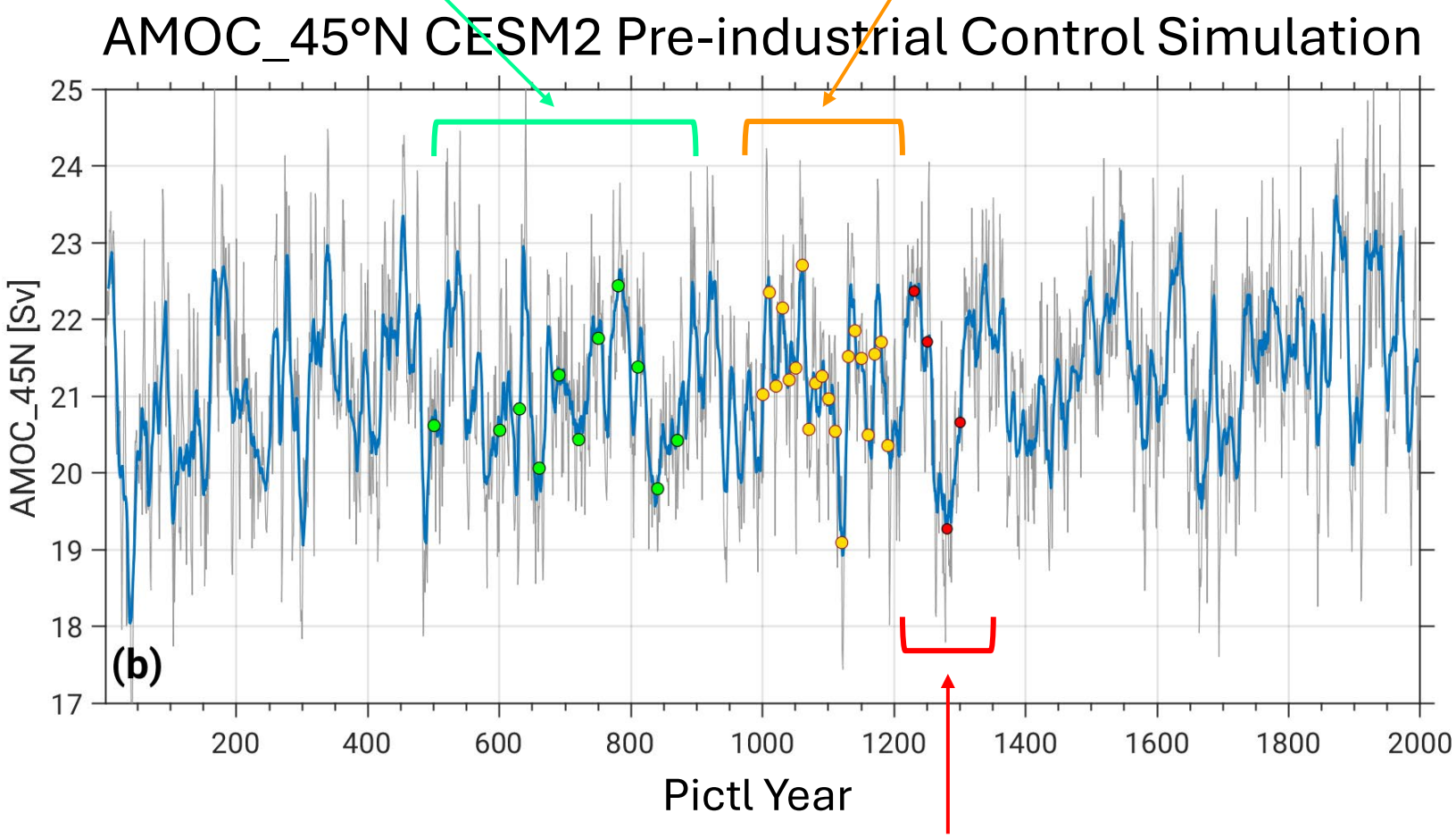
11 macro-perturbation members

20 macro-perturbation members



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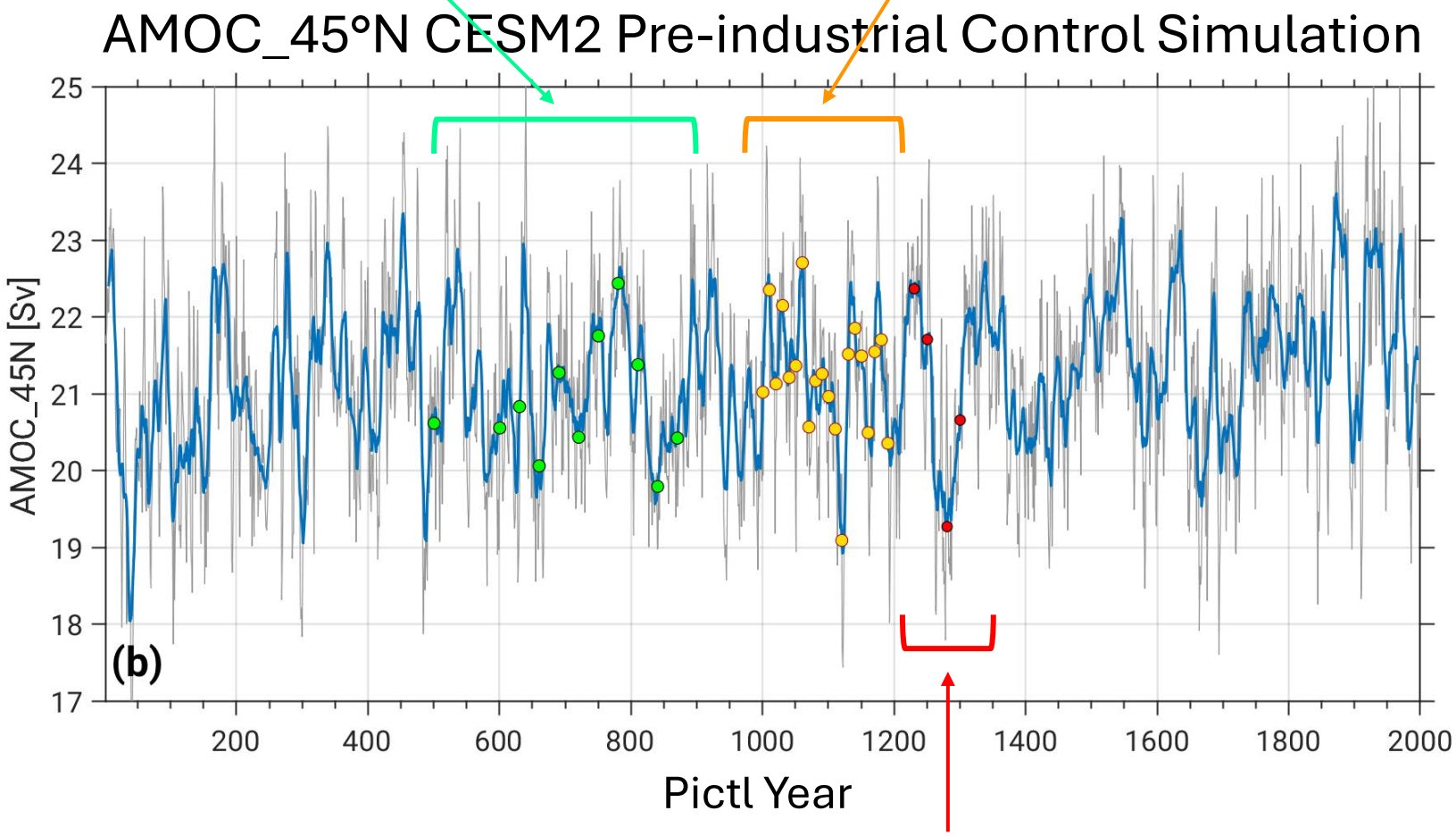

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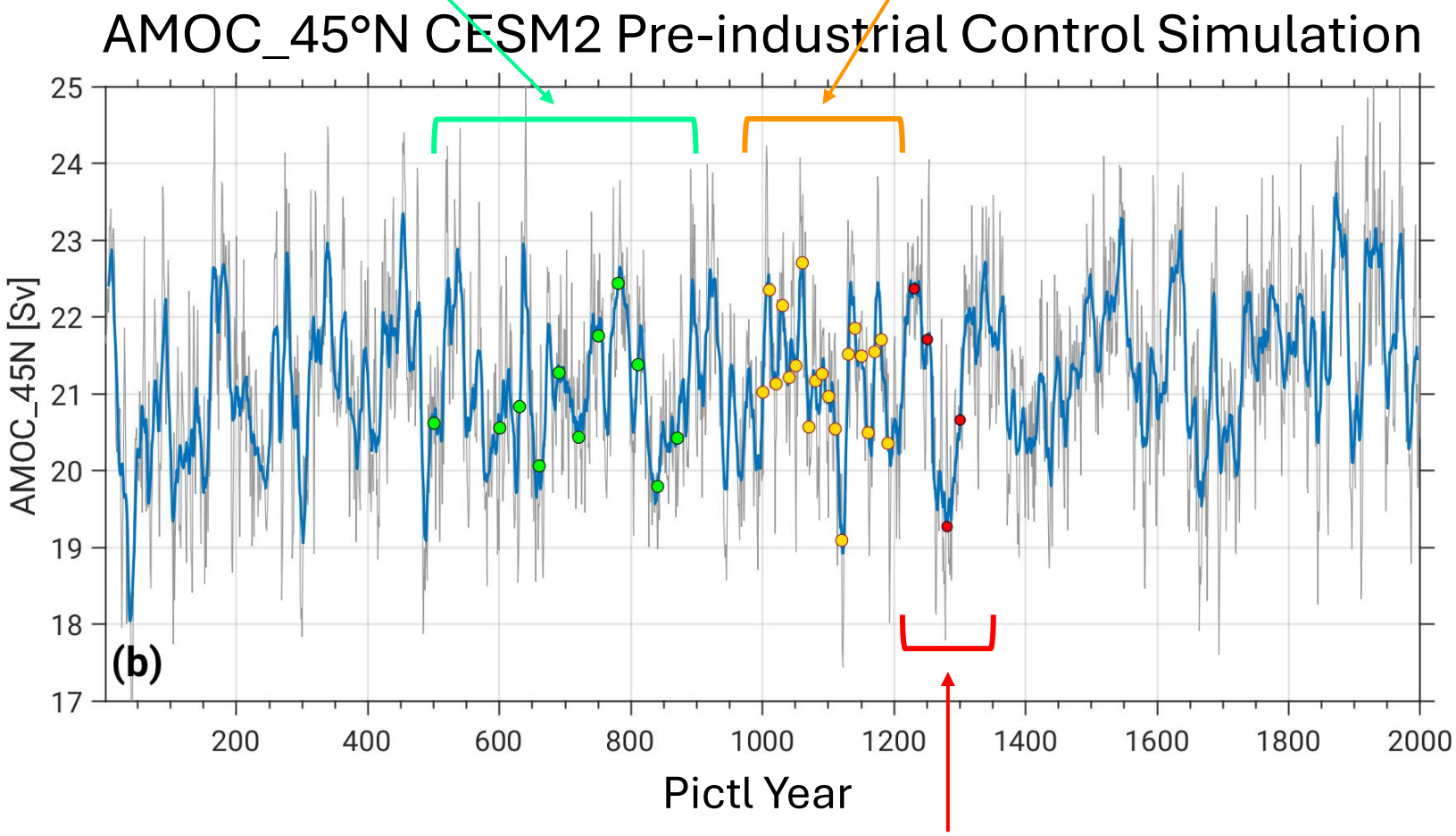

Subtract the control run drift from each member before computing σ Micro (t) and σ Macro (t).

4 AMOC initial states,
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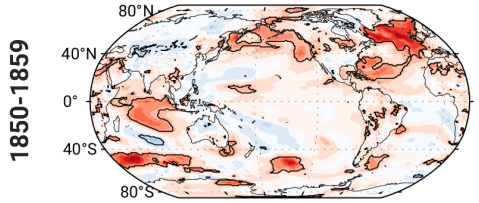
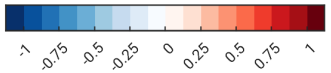
σ Micro (t) = $\sqrt{\sum(xi - xmean)^2}$

Compute for each AMOC initial state, then average the 4 estimates.

Surface Temperature (TS)

(σ Macro - σ Micro) / σ Micro





Contours indicate differences are significant compared to random chance.

(Based on random draws of 31 members and 80 members, respectively, from the pictl simulation, repeated 2000 times with replacement obtain the 2.5th-97.5th % range.)

Surface Temperature (TS)

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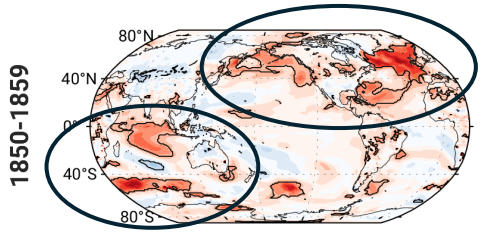

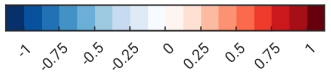

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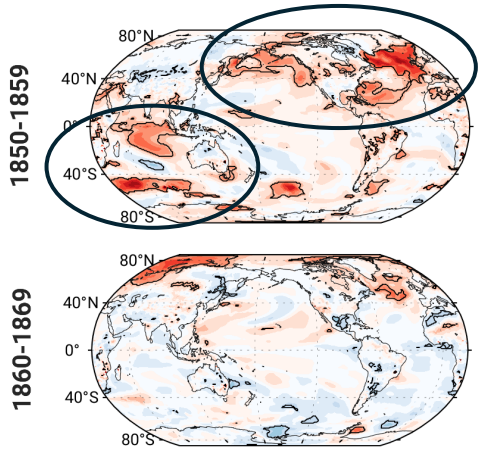

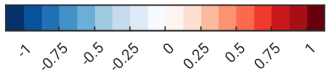

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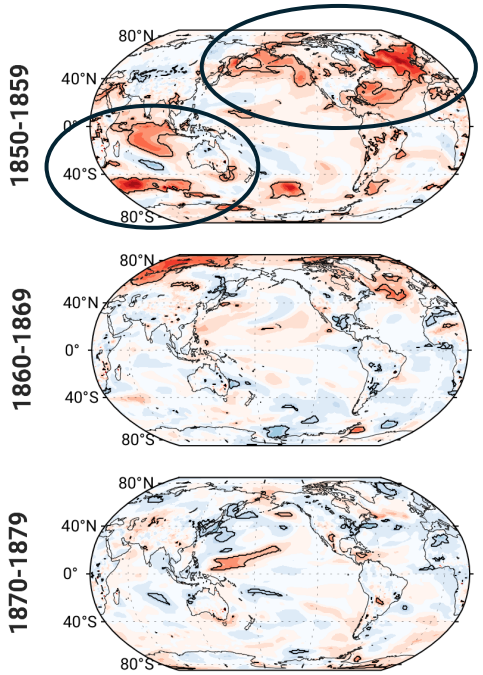

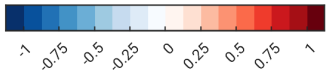

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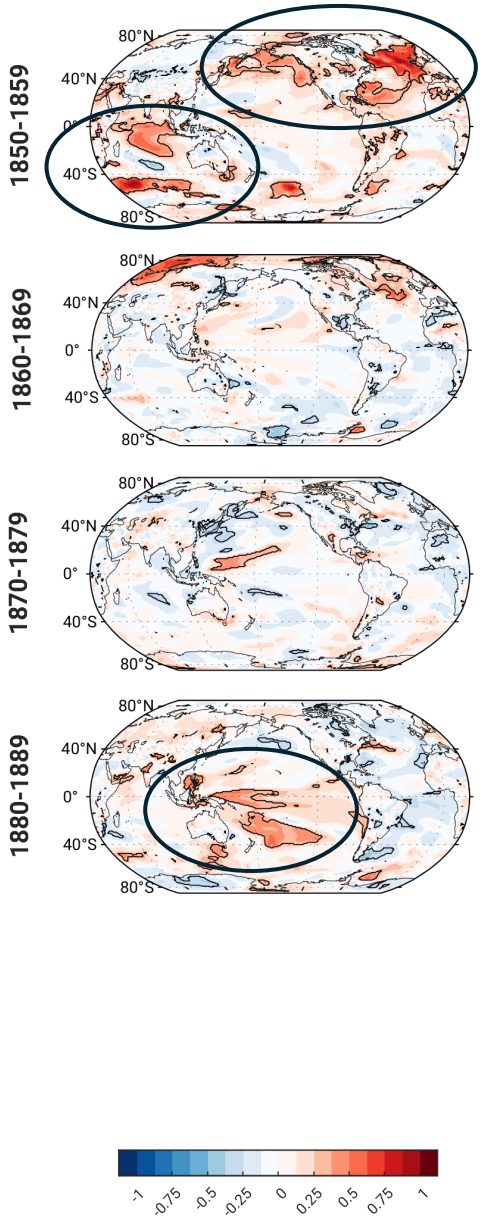

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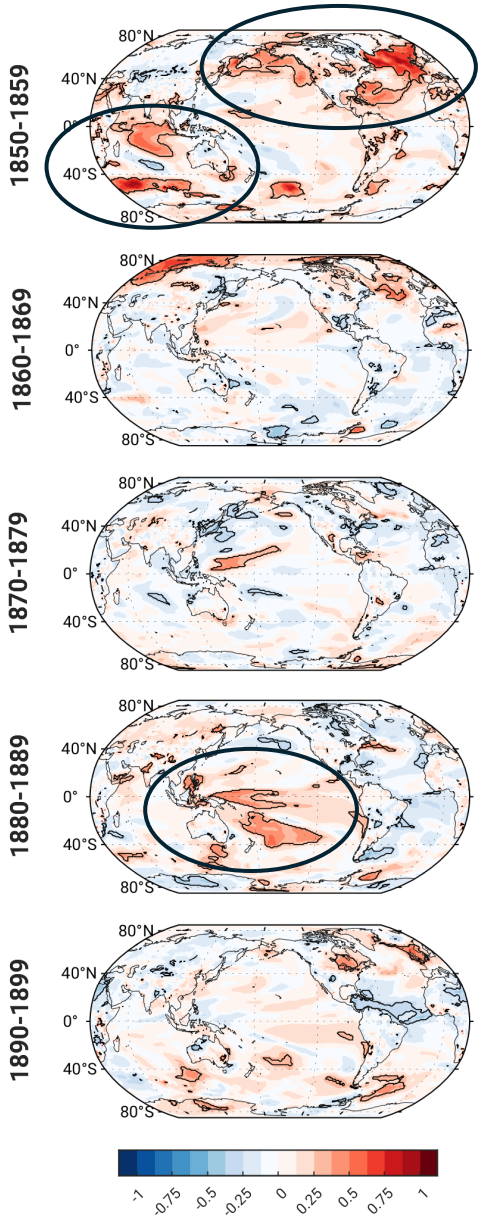

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Surface Temperature (TS)
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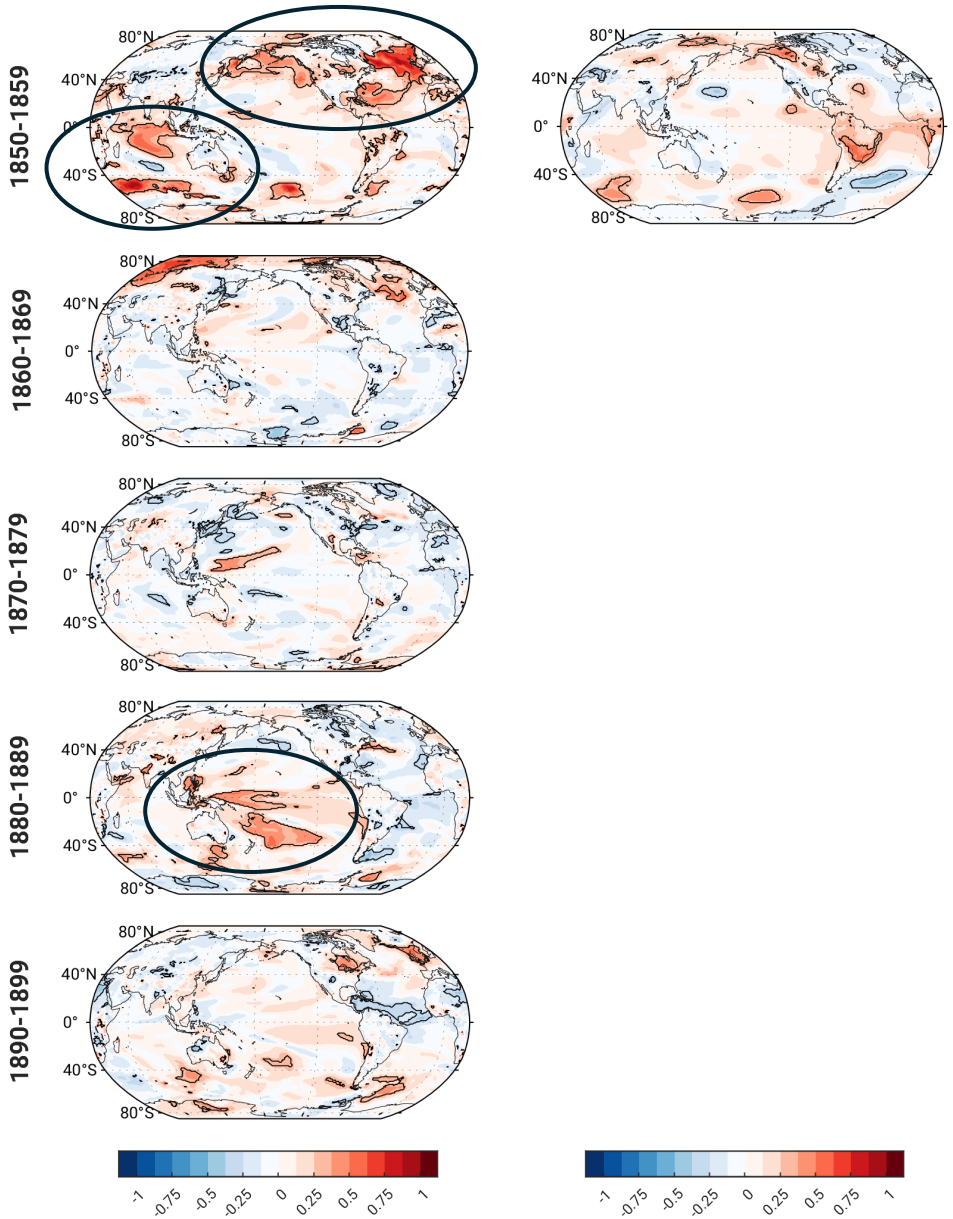
Sea Level Pressure



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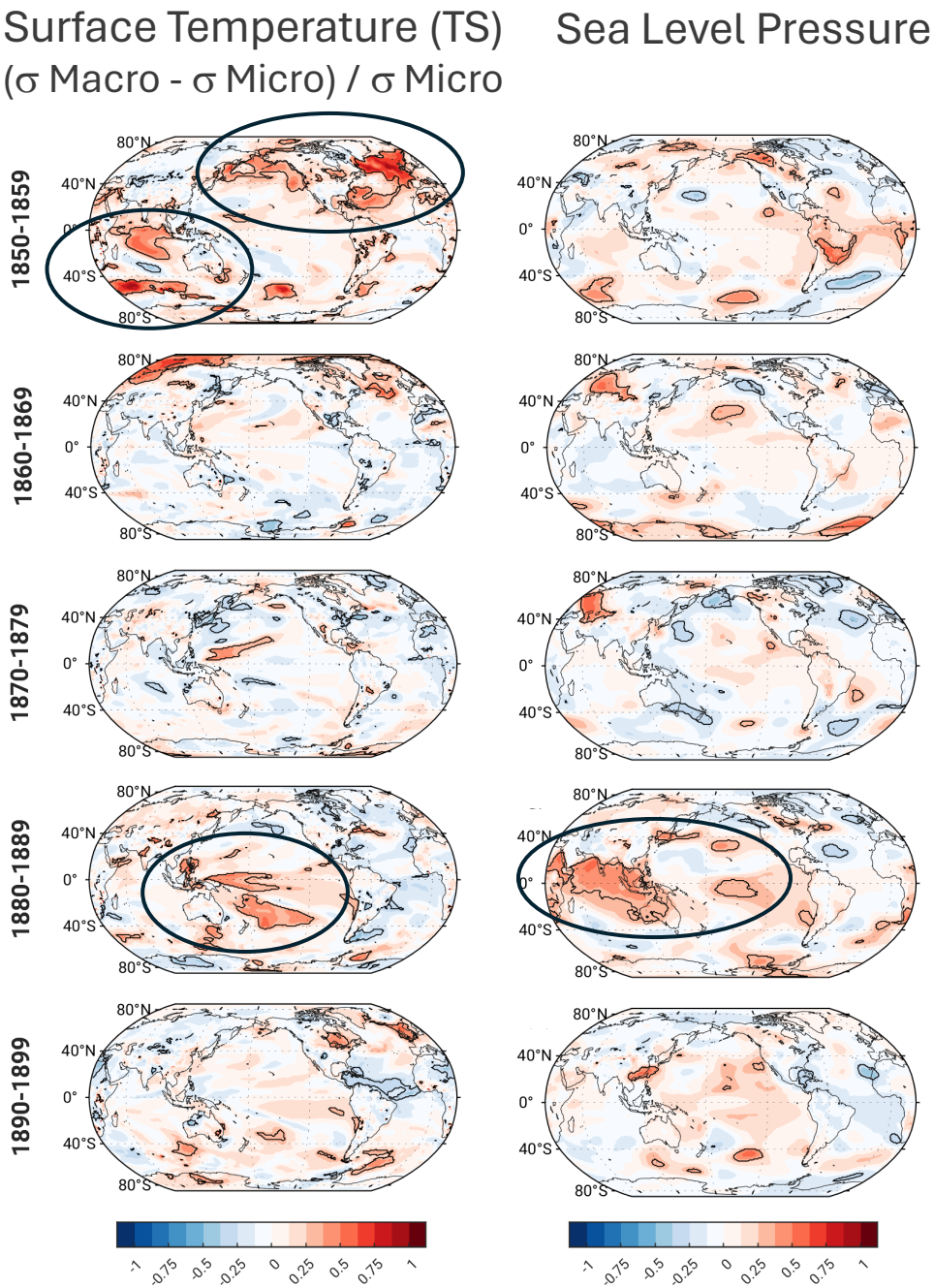

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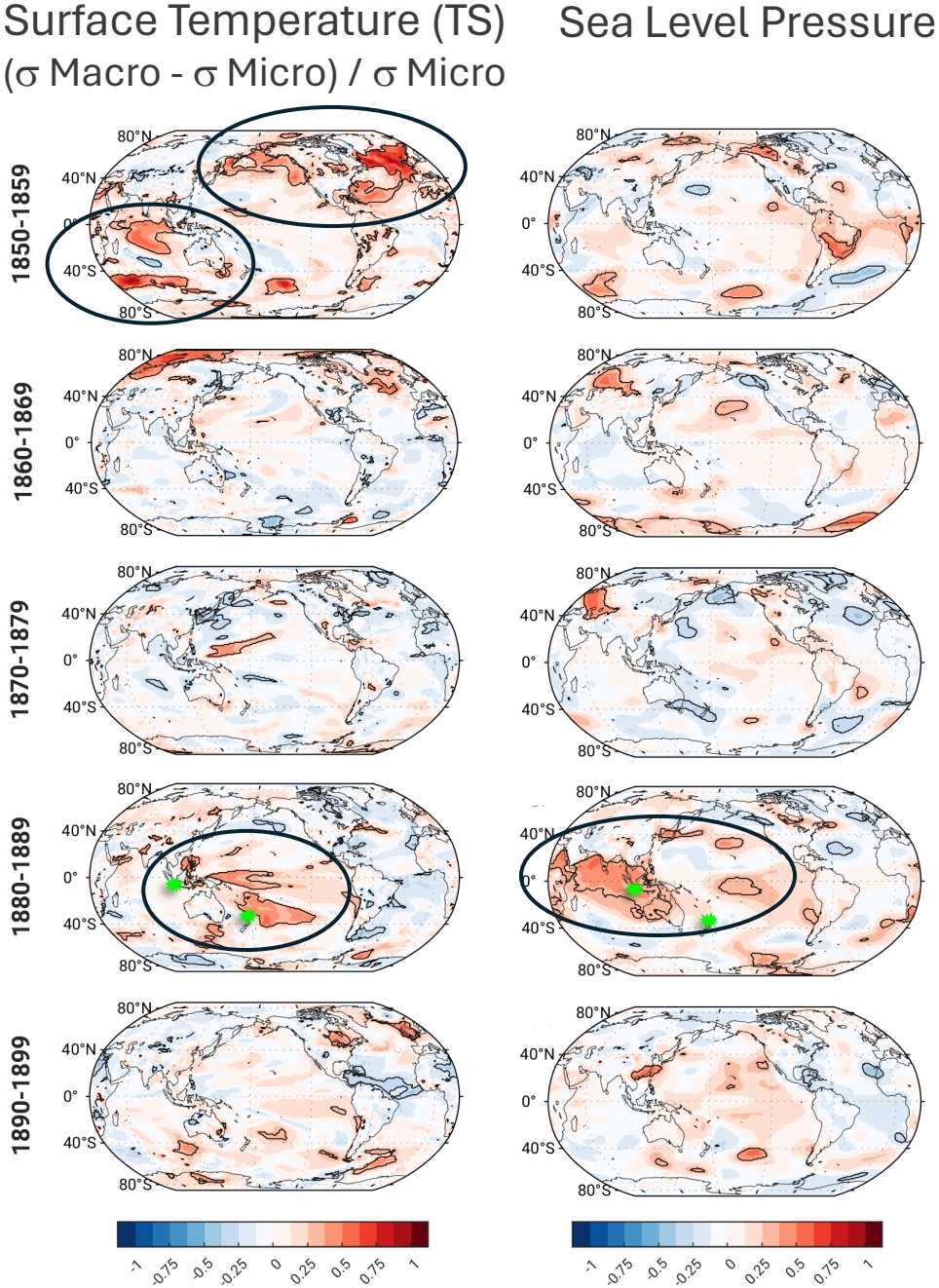

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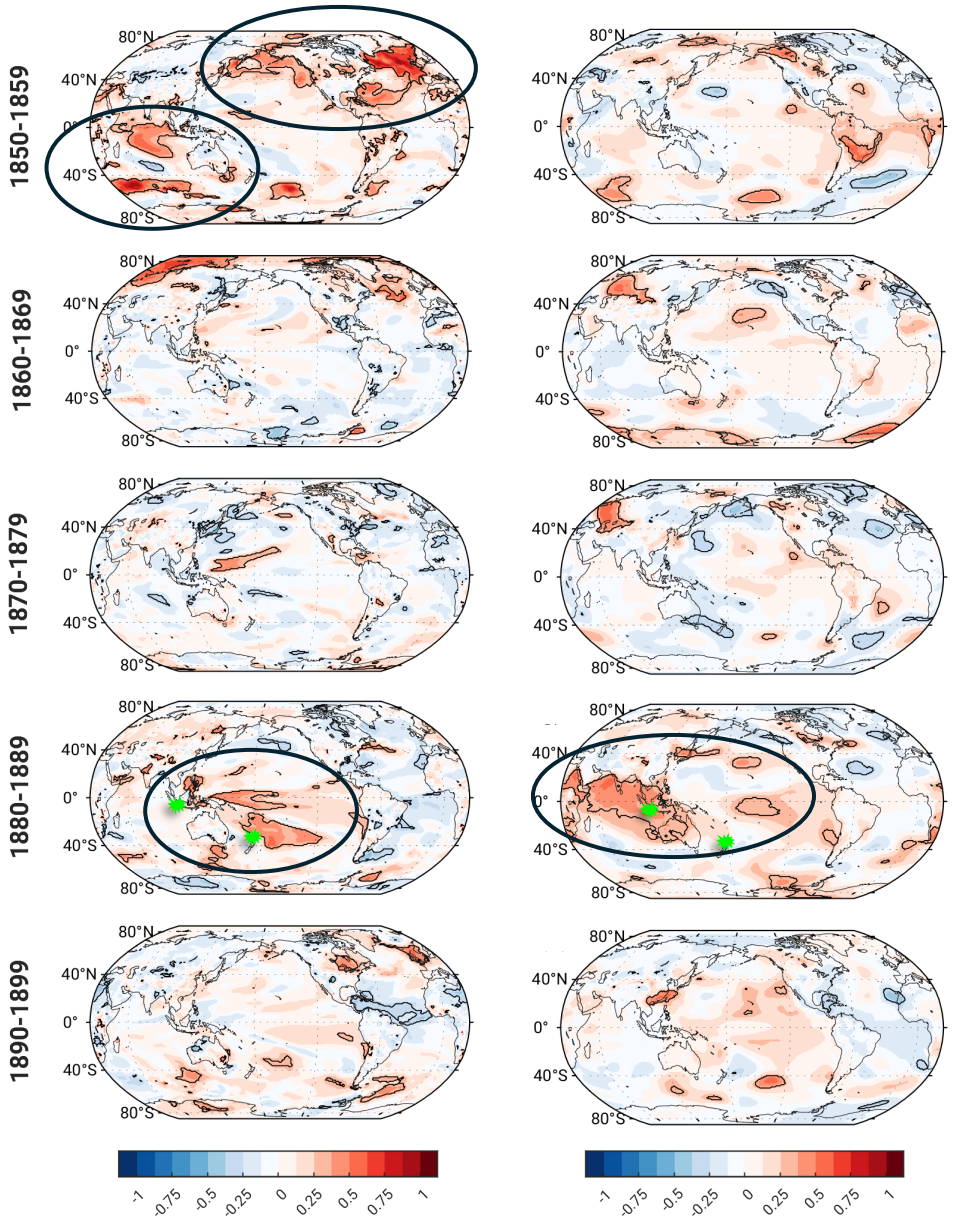
- Krakatoa (1883)
- Tarawera (1886)

Surface Temperature (TS)
(σ Macro - σ Micro) / σ Micro

Sea Level Pressure



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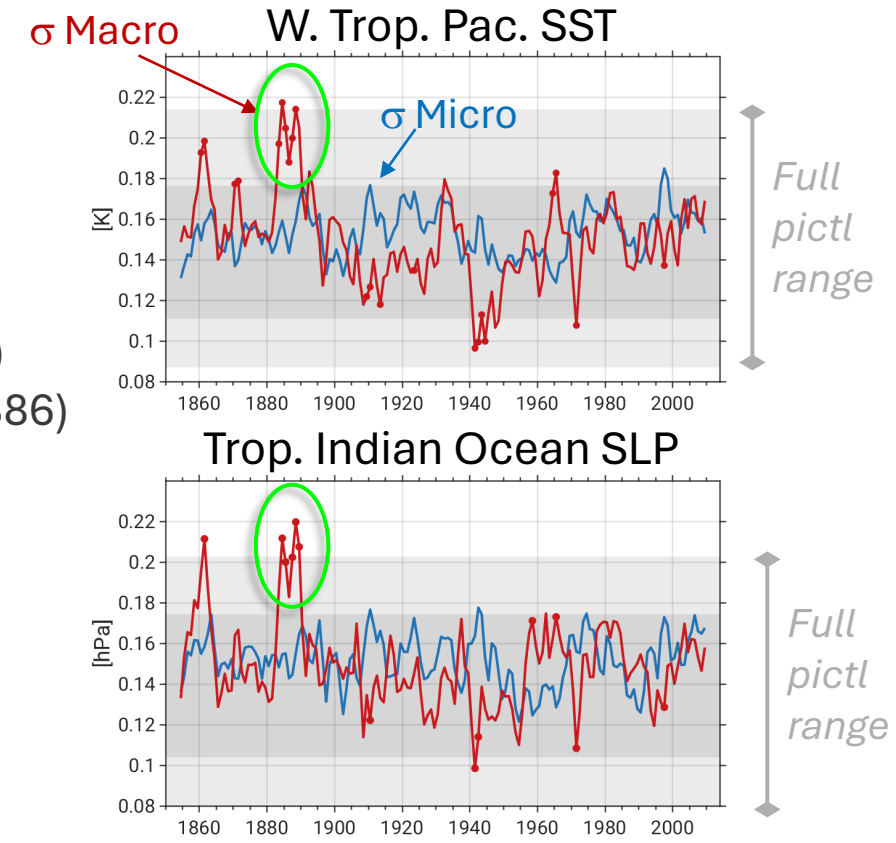

2) How long does ocean initial-condition memory last in the atmosphere and upper ocean?

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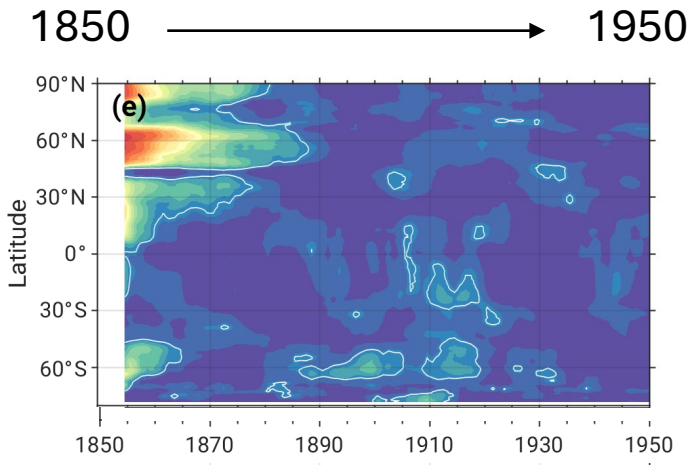
- Use the 4 AMOC ensembles (20 micro-perturbation members each).
- Form ensemble means of each AMOC ensemble, then compute $\sigma(t)$ across the 4 ensemble means (= σ ocean).
- Compare with $\sigma(t)$ across all 80 members (= σ total).
- Test whether σ ocean / σ total is significant based on random draws from the pictl simulation.

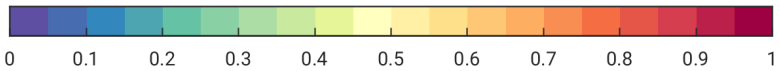
Hovmuller Diagram
σ ocean / σ total

Zonally averaged SST

(significant values contoured)



Global domain



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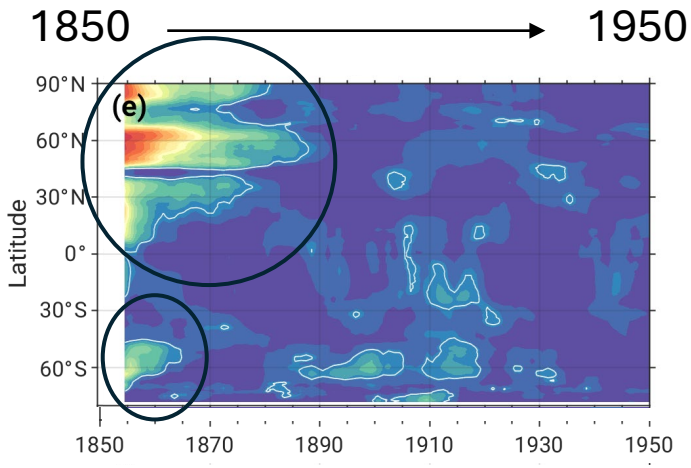

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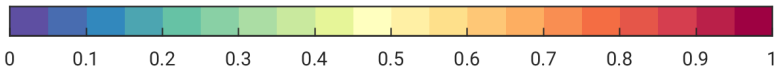

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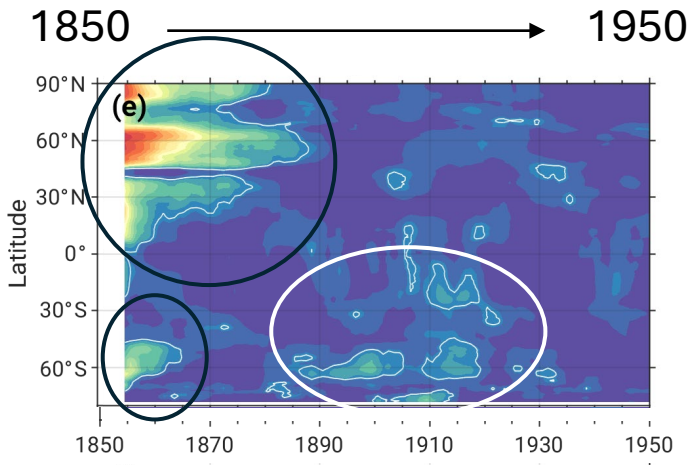

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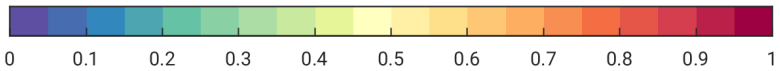

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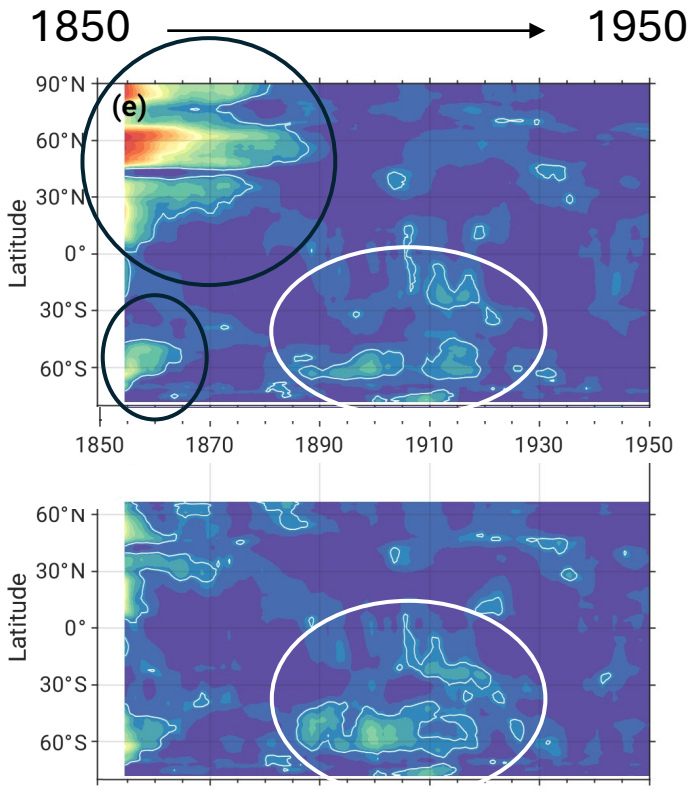
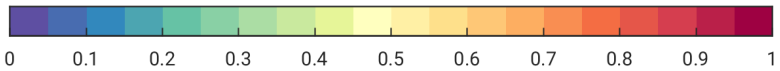


Global domain

Pacific



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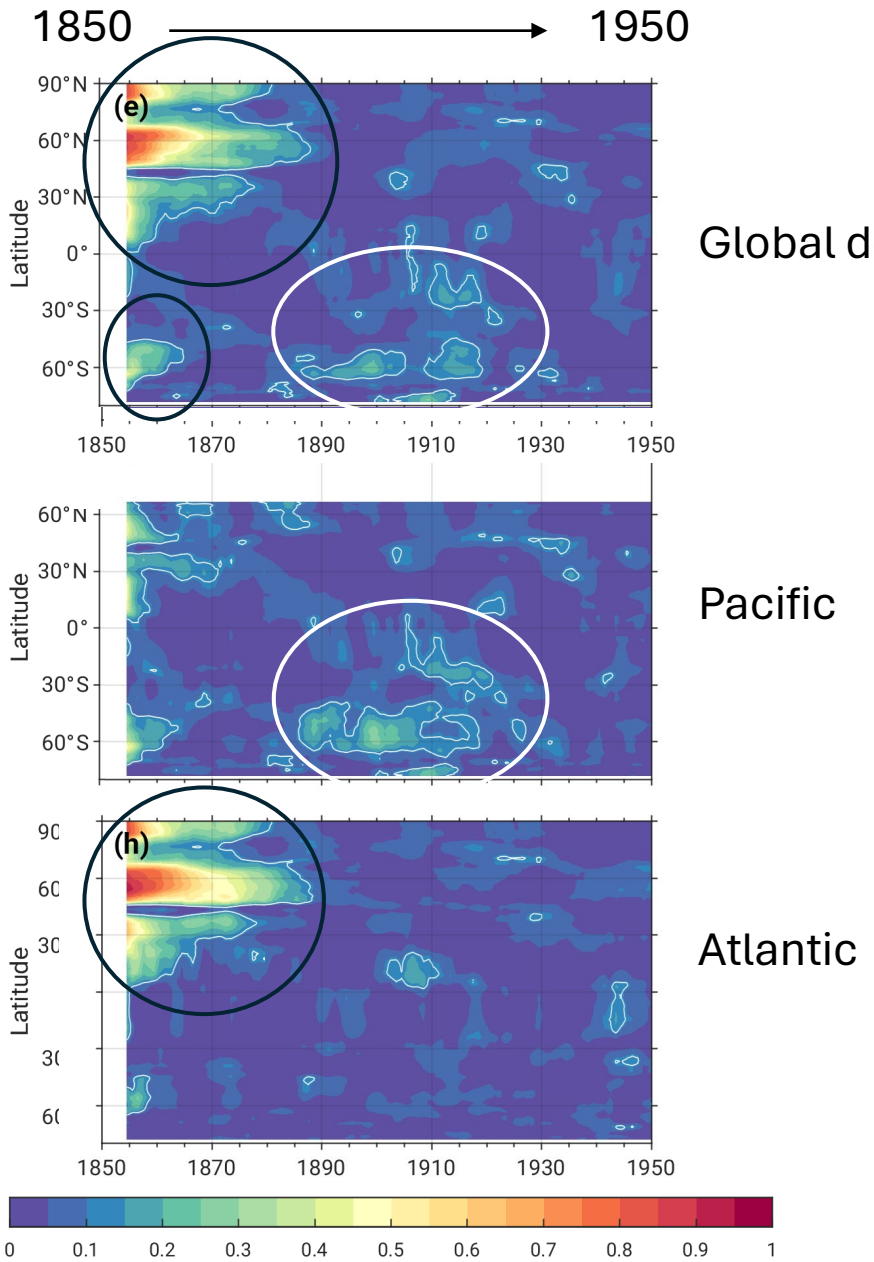

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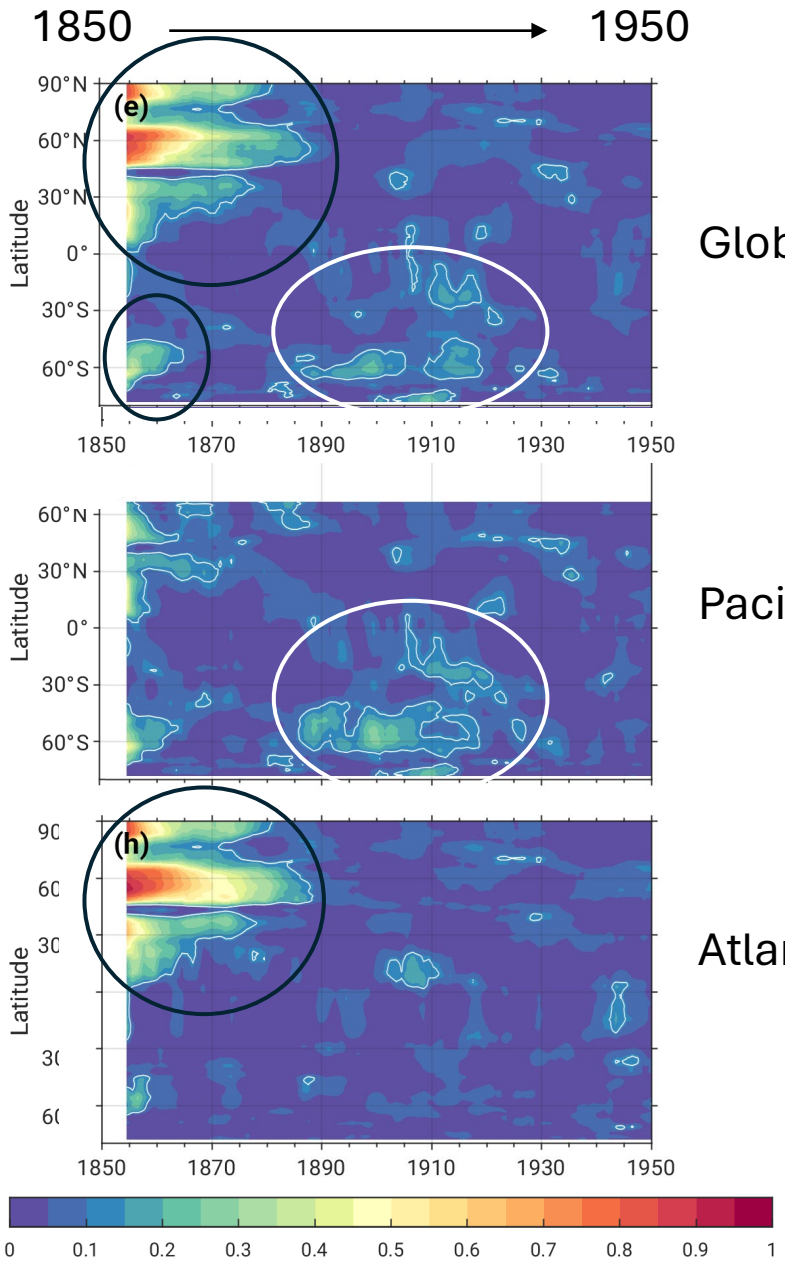

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Pacific

Atlantic

Resurgence of ocean initial-condition memory in the Pacific sector after 40-70 years.