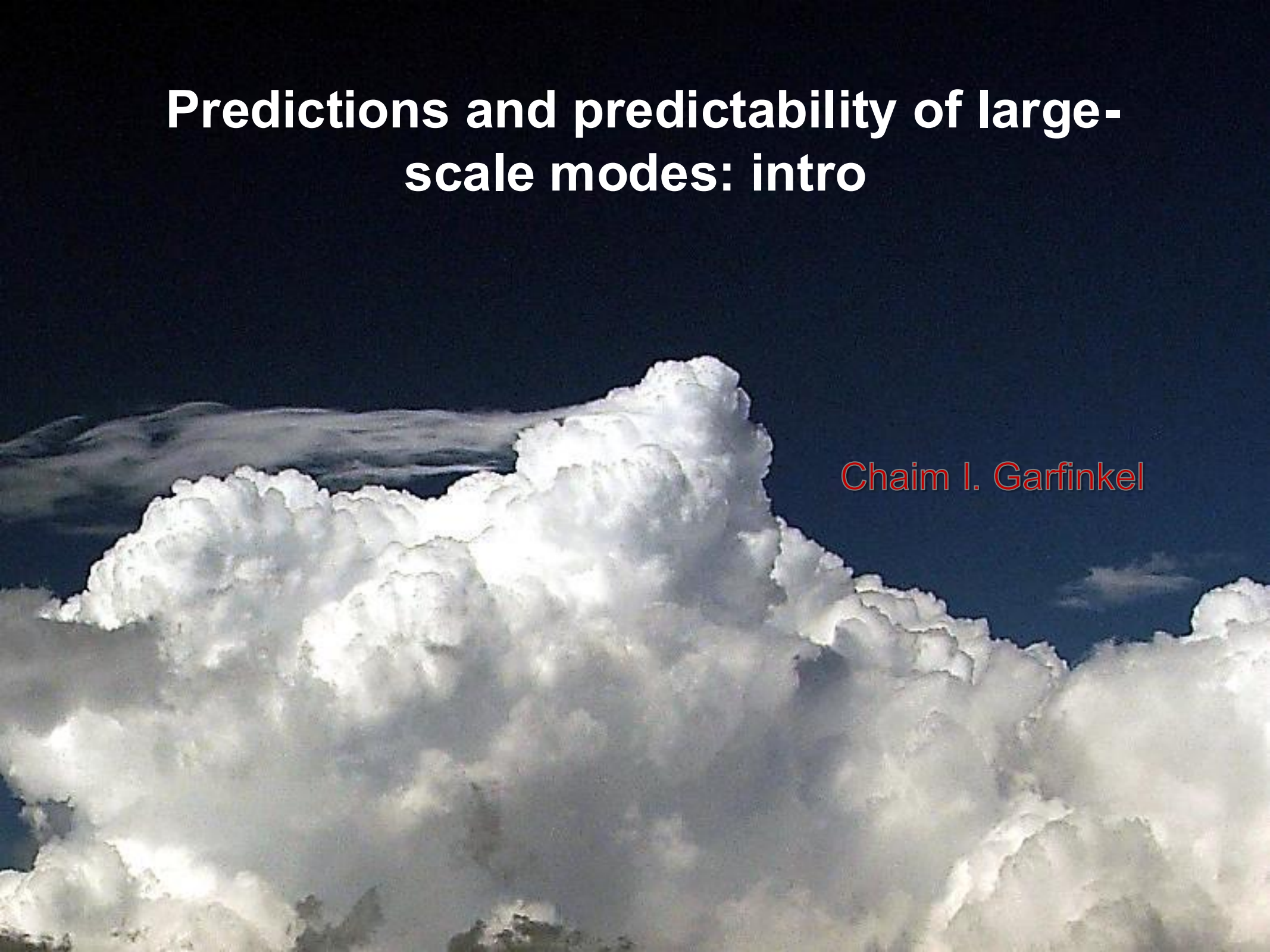
# Predictions and predictability of large-scale modes: intro



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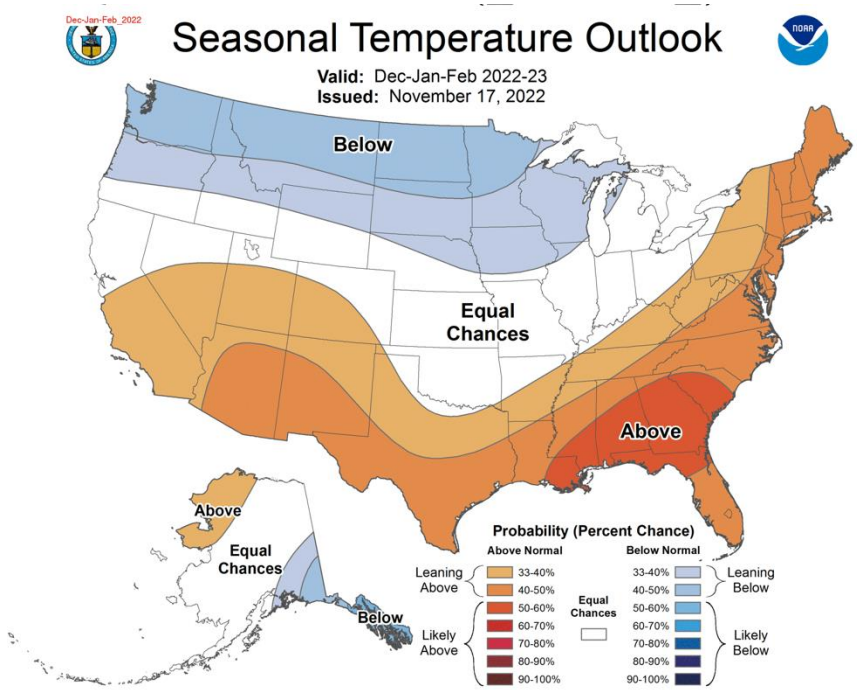
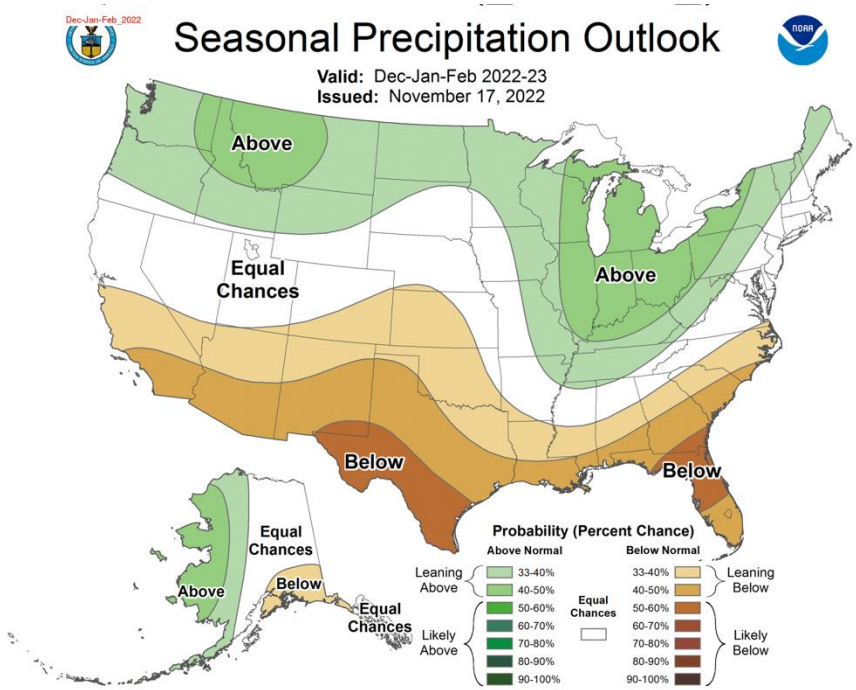
# Clear need for reliable predictions on range of timescales

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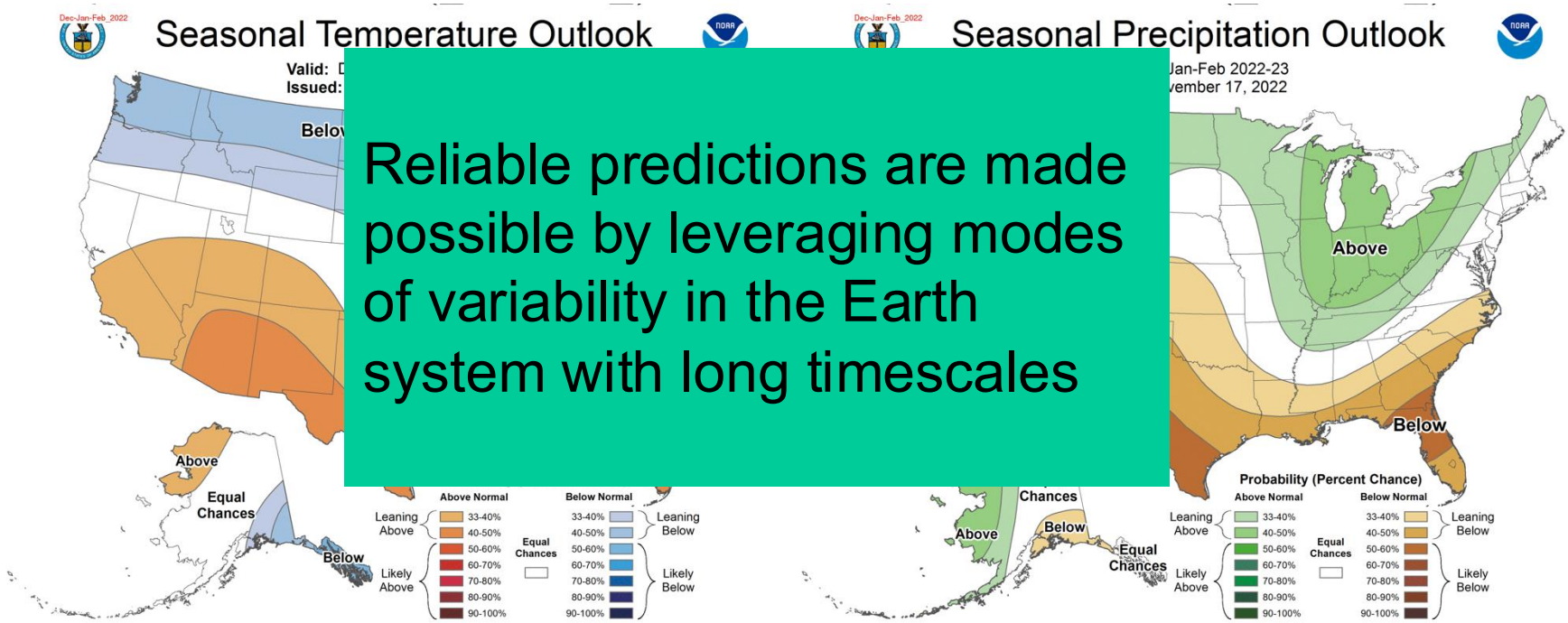
# Clear need for reliable predictions on range of timescales




Reliable predictions are made possible by leveraging modes of variability in the Earth system with long timescales

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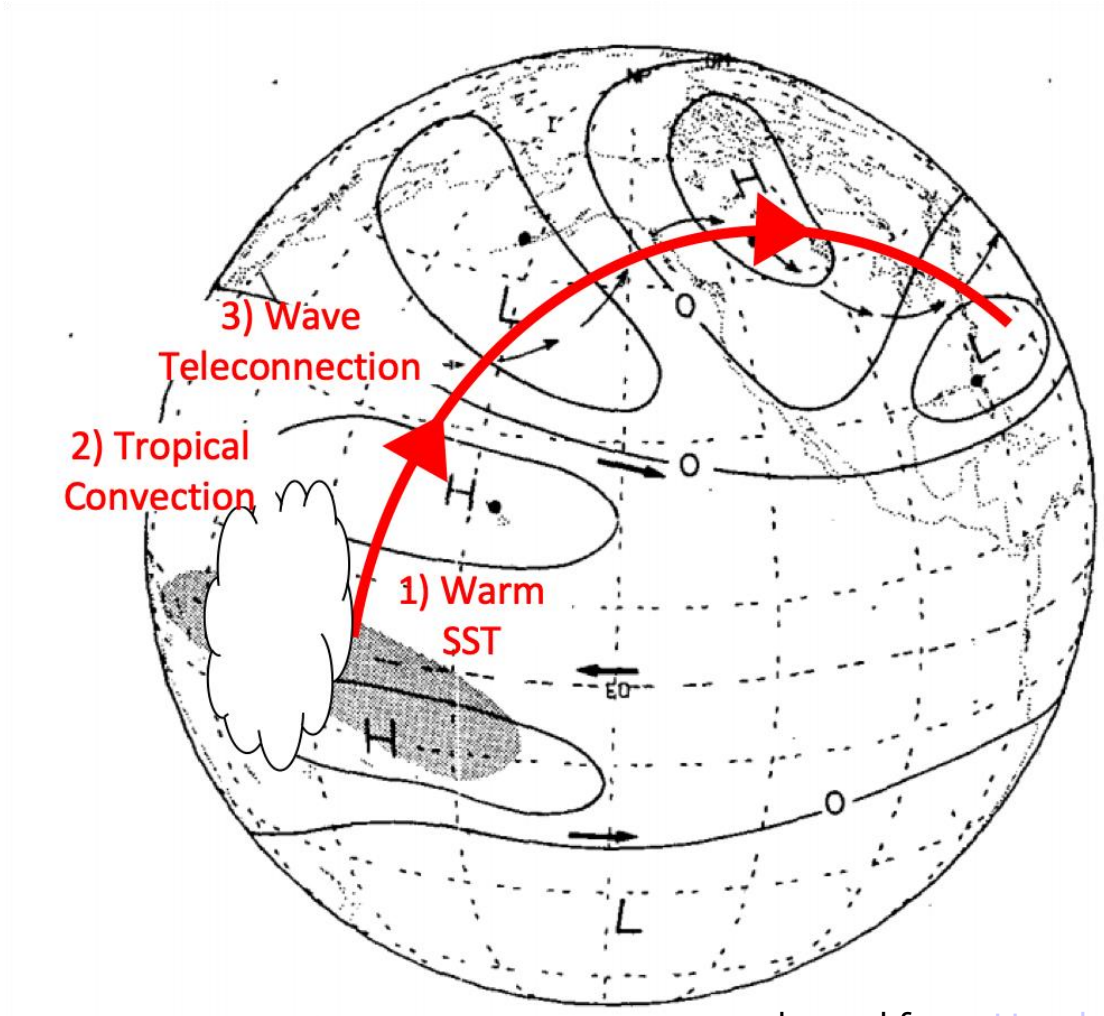
# Tropical to extratropical teleconnections




adapted from Horel and Wallace, 1981

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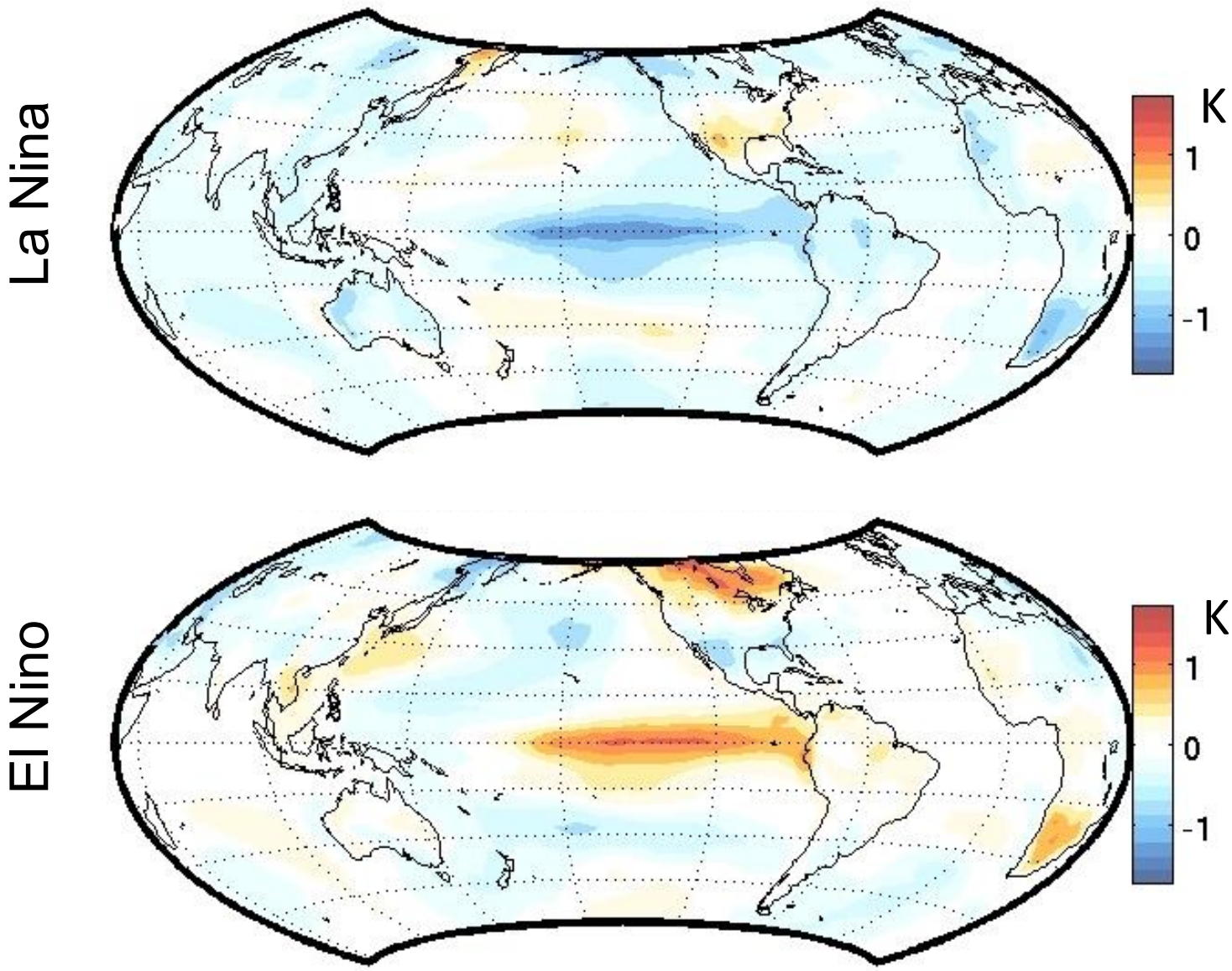
# El Nino-Southern Oscillation

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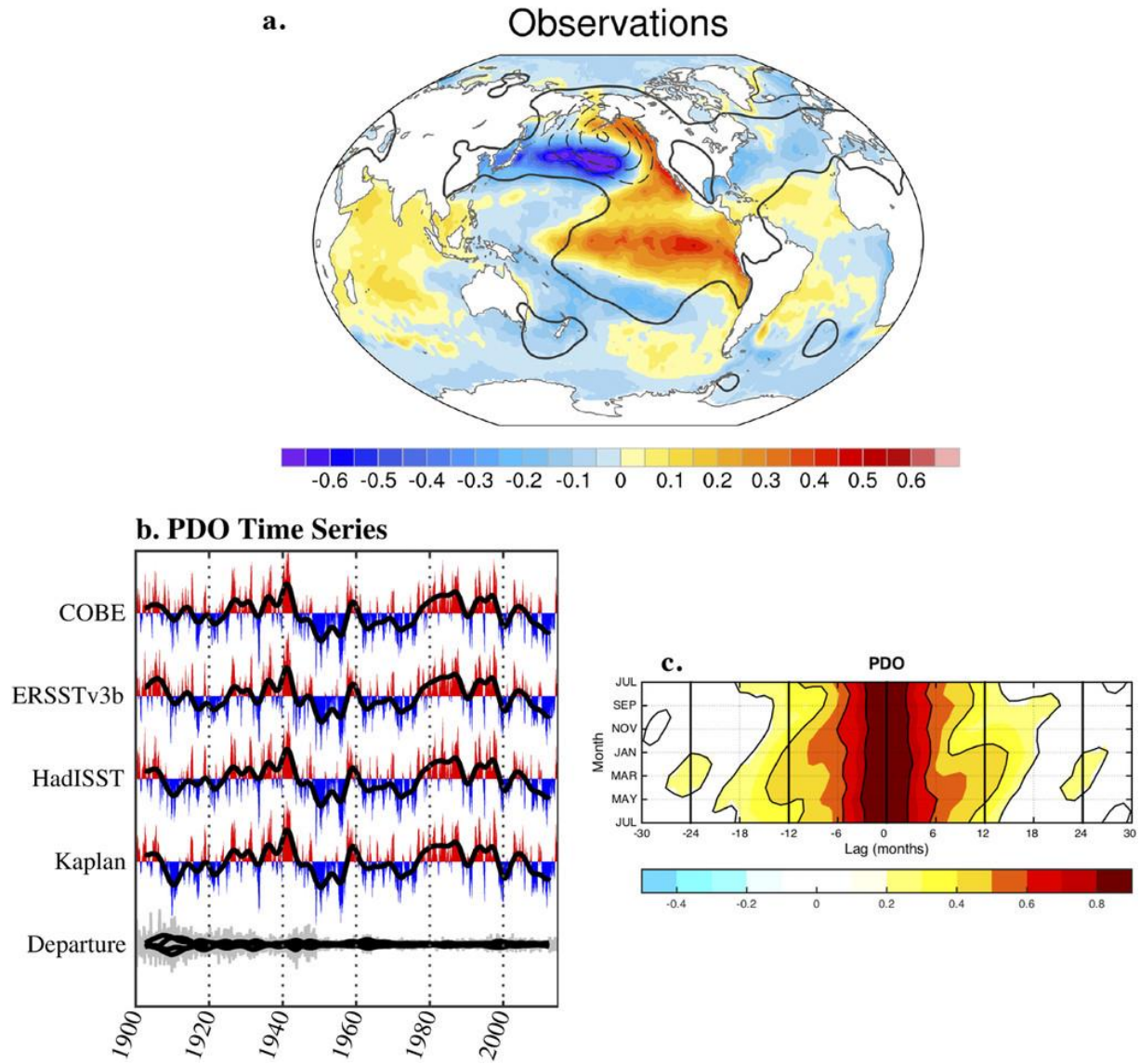
# Pacific Decadal Oscillation




Newman et al 2016

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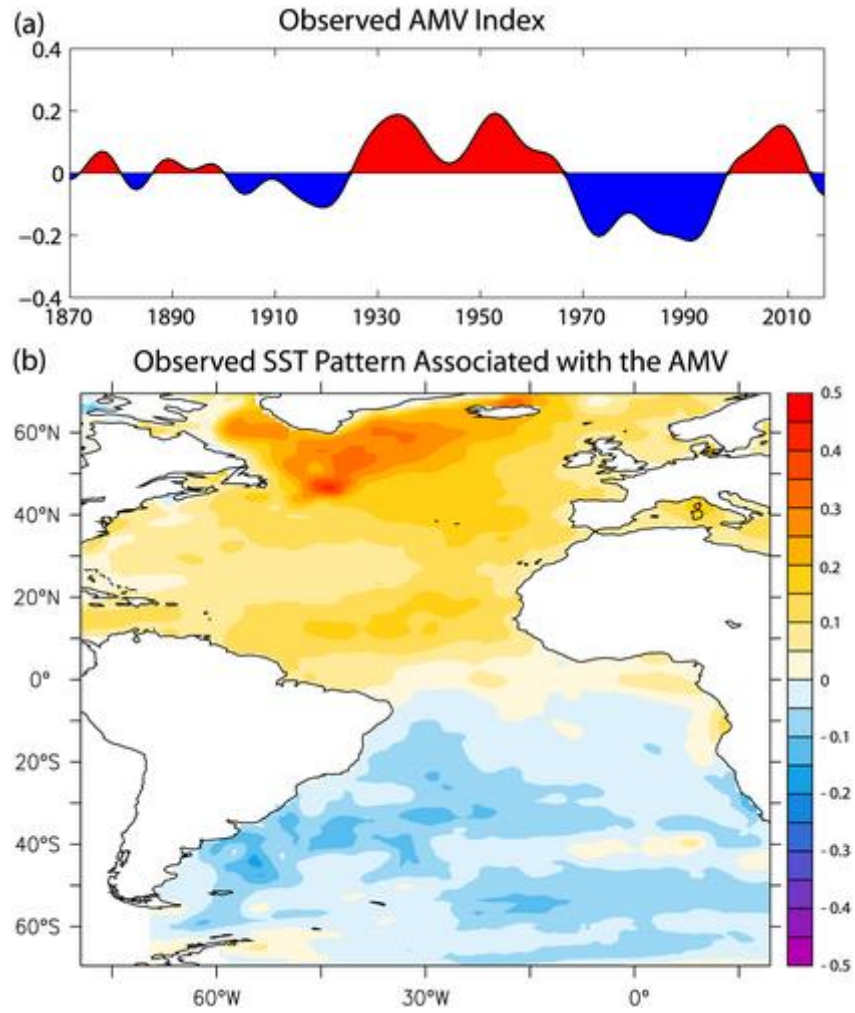
# Atlantic Multidecadal Variability




Zhang et al 2019

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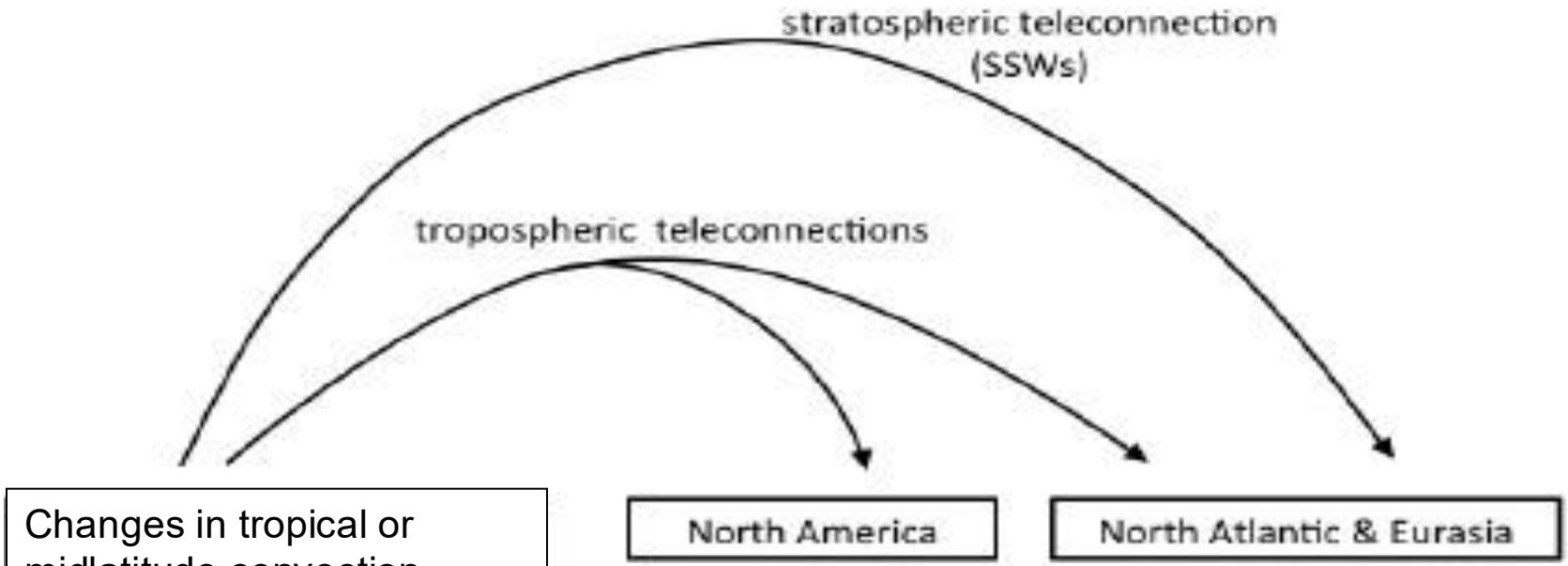
# Pathways for PDO/AMOC/ENSO to modulate surface climate




Changes in tropical or midlatitude convection (e.g. ENSO, AMOC, PDO)

After Butler et al 2014

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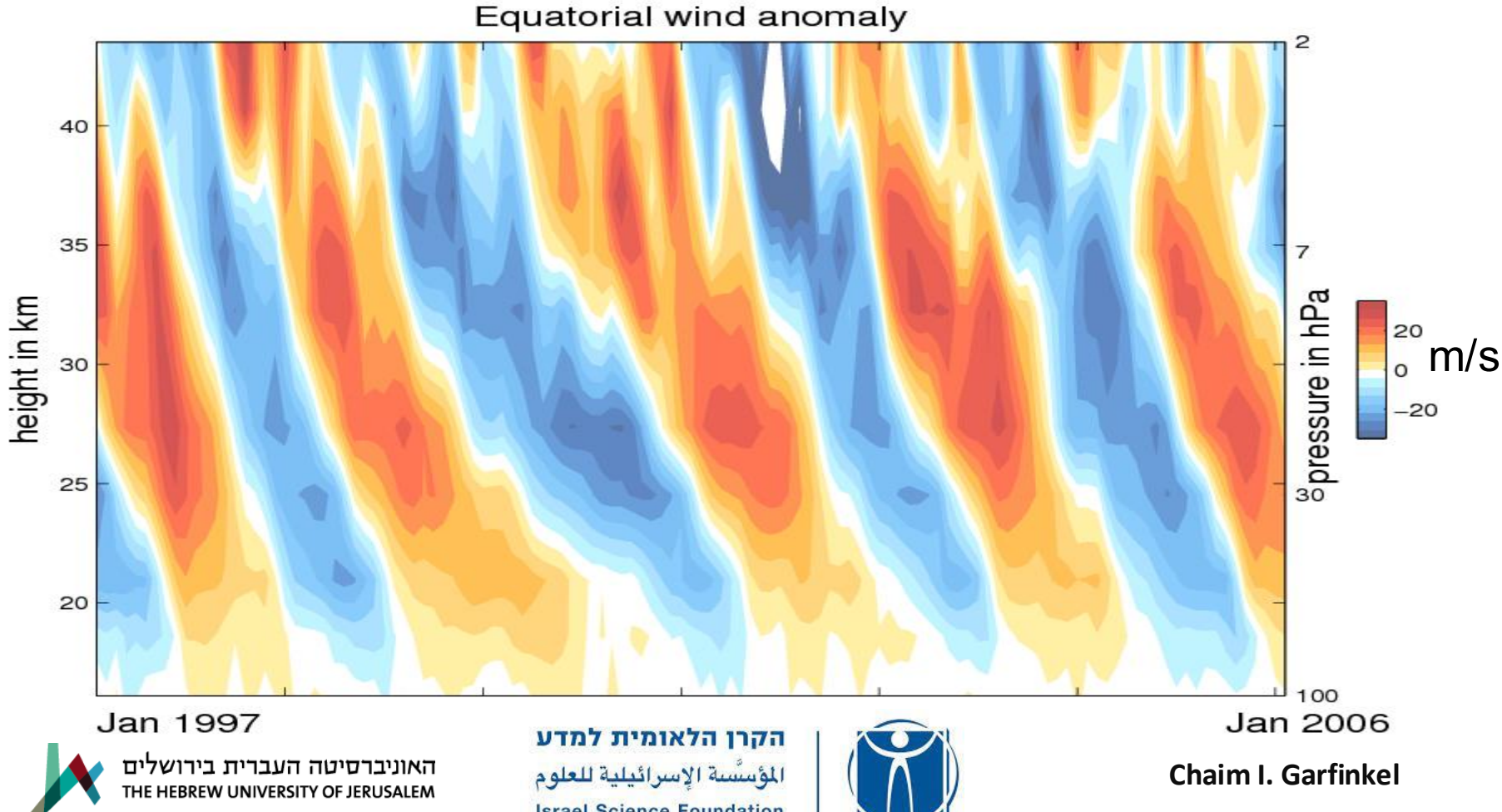
# Quasi Biennial Oscillation(QBO)

1. Alternating zonally symmetric westerlies and easterlies in tropical stratosphere
2. Weakens poleward of 10N and 10S
3. Period of ~28 months

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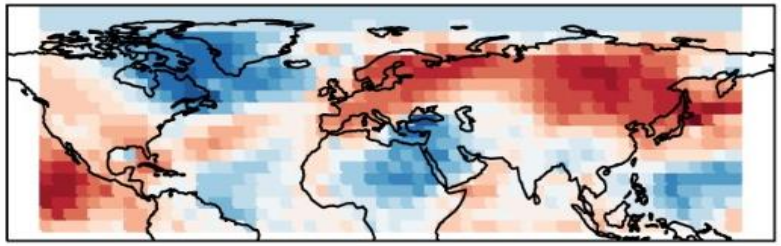
# Decadal variability in stratospheric polar vortex?

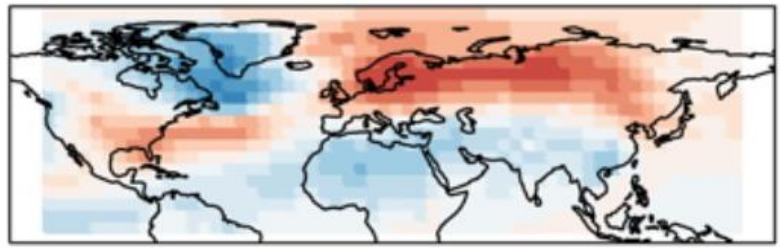
**Temperature anomalies, 1986-1997**

Observed



Raw CMIP output

CMIP output after post facto bias correction




°celsius

Forced or unforced?

Smith et al 2020

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**Temperature anomalies, 1986-1997**

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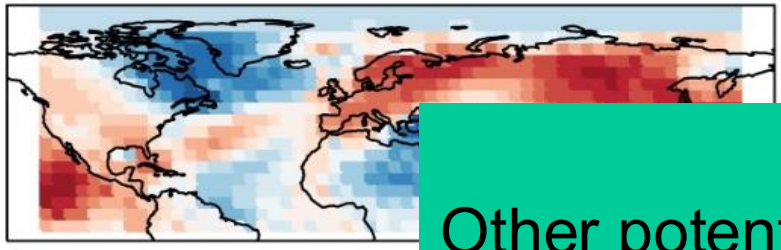

Raw CMIP

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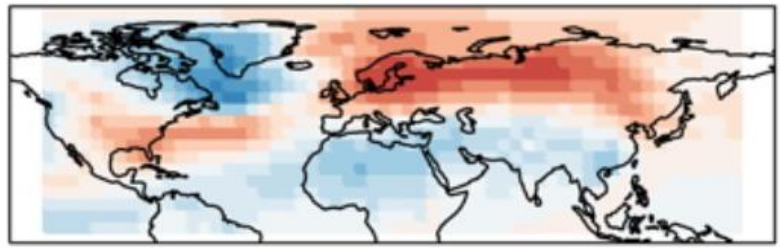


°celsius

Other potential sources include: land-use, aerosols (spatial pattern), solar variability, volcanic eruptions

or unforced?

Smith et al 2020

# Outlook

- ENSO (and MJO) teleconnections too weak over the Pacific-North America region in S2S, seasonal, and climate models. [Beverly et al 2023; Garfinkel et al 2022]

- QBO in the lower stratosphere and QBO teleconnections are much too weak in S2S, seasonal, and climate models [Rao and Garfinkel 2020; Garfinkel et al 2018; Portal et al 2022]

- AMOC has too-weak decadal-scale variability in CMIP models [Zhang et al 2019]

- Polar stratosphere not sensitive enough to tropospheric variability in S2S models [Garfinkel et al 2025].

- These process-level problems might contribute to model vs. observations discrepancies in the historical period (Blackport and Fyfe 2022; Shaw et al 2024, many others)

How do we best use our models despite their flaws to predict upcoming surface weather and climate?

Are forecast busts caused because we failed to properly bias-correct our flawed models, or because of unpredictable chaotic variability?

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