

Quantifying Forced Changes to Unforced Modes of Atmospheric Variability

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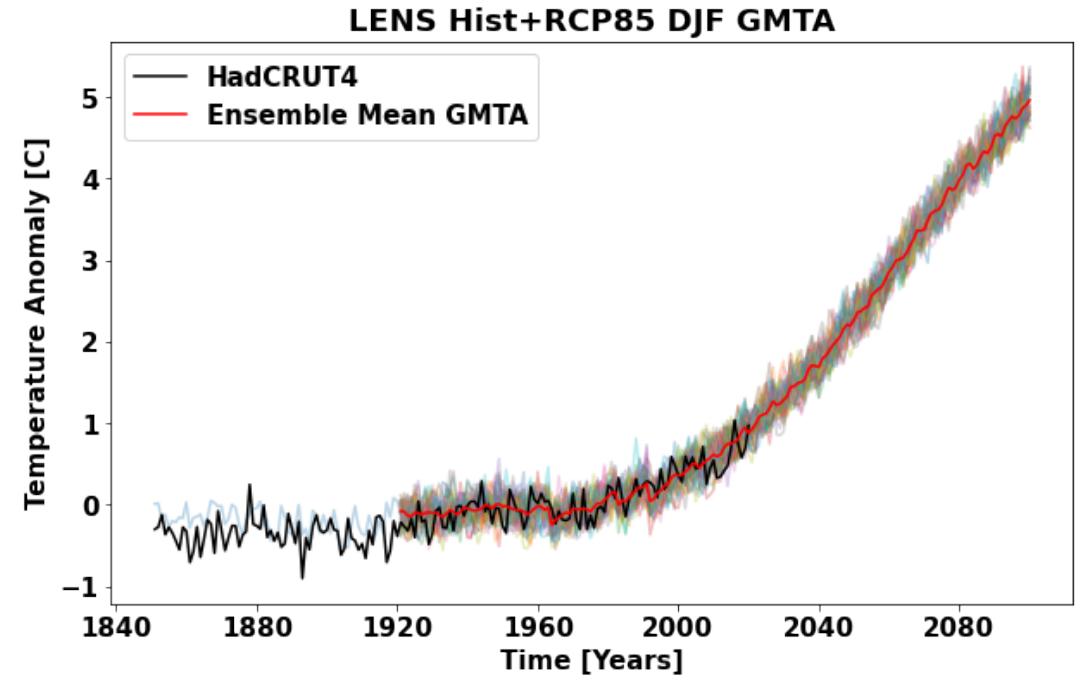
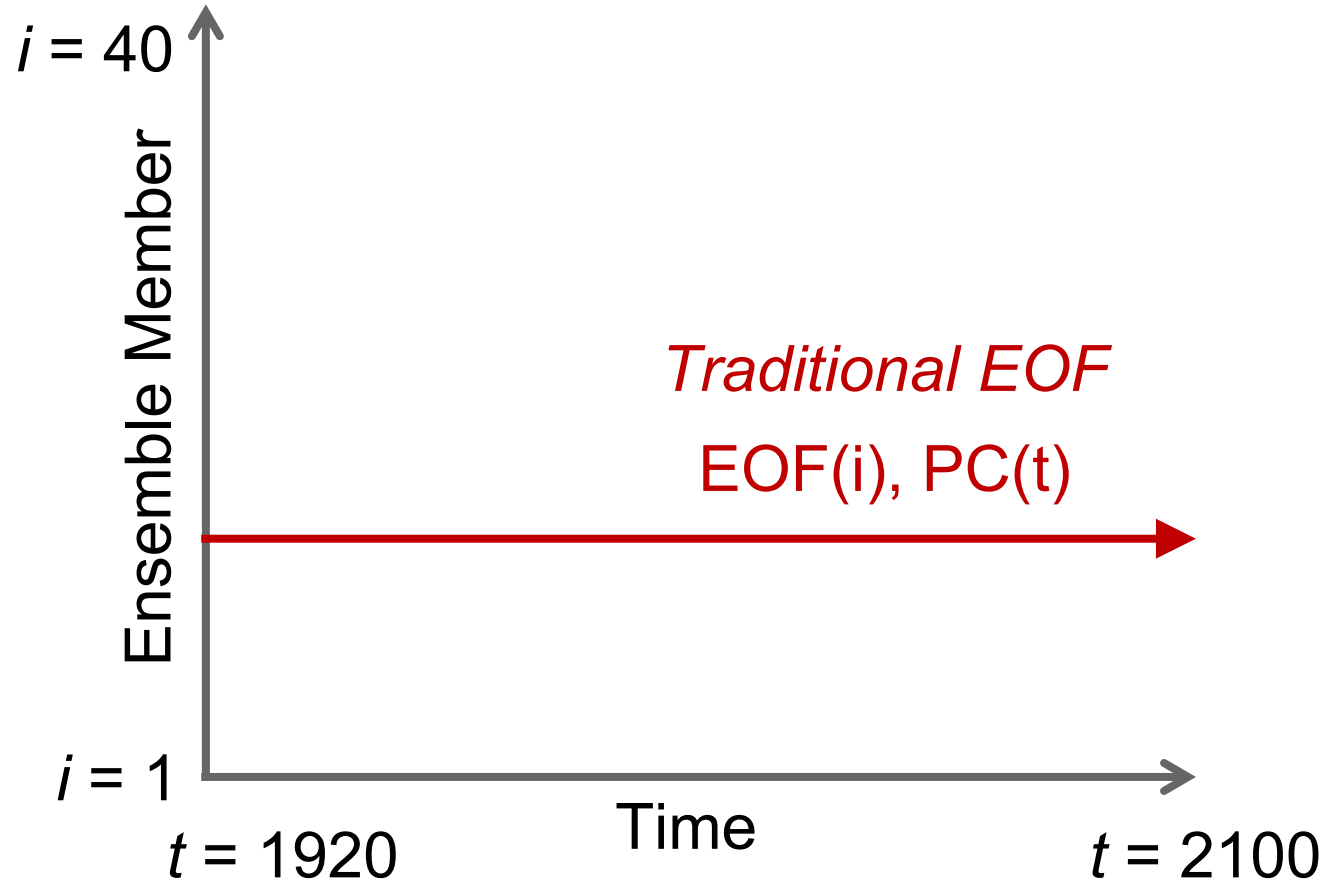
Overview

1. Goal: To assess the role external (anthropogenic) forcing has on internal unforced atmospheric modes of variability. Here we're going to focus on interannual North Pacific atmospheric variability in the boreal winter.
2. Data: We employ the 40-member CESM Large Ensemble (Kay et. al. 2015) combining the historical and future (RCP 8.5) simulations totaling 180 years spanning 1921 – 2100. All quantities are DJF averages.
3. Methods: We apply an ensemble-based EOF method – otherwise known as a Snapshot EOF (SEOF) (Herein et al 2016).

What is a Snapshot EOF?

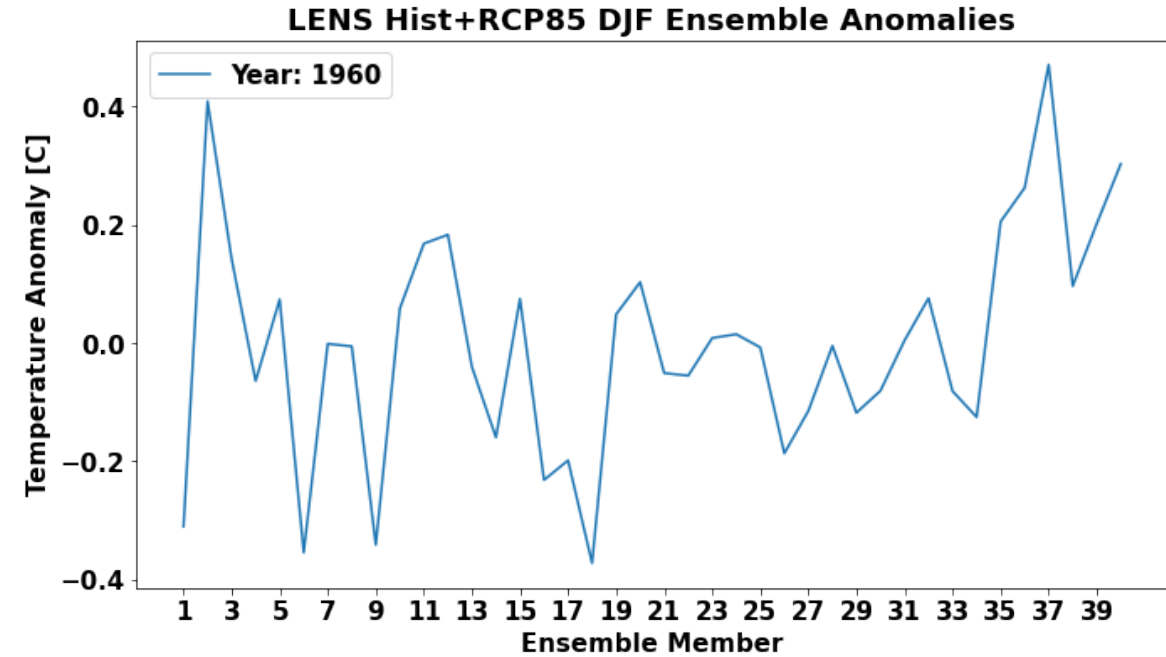
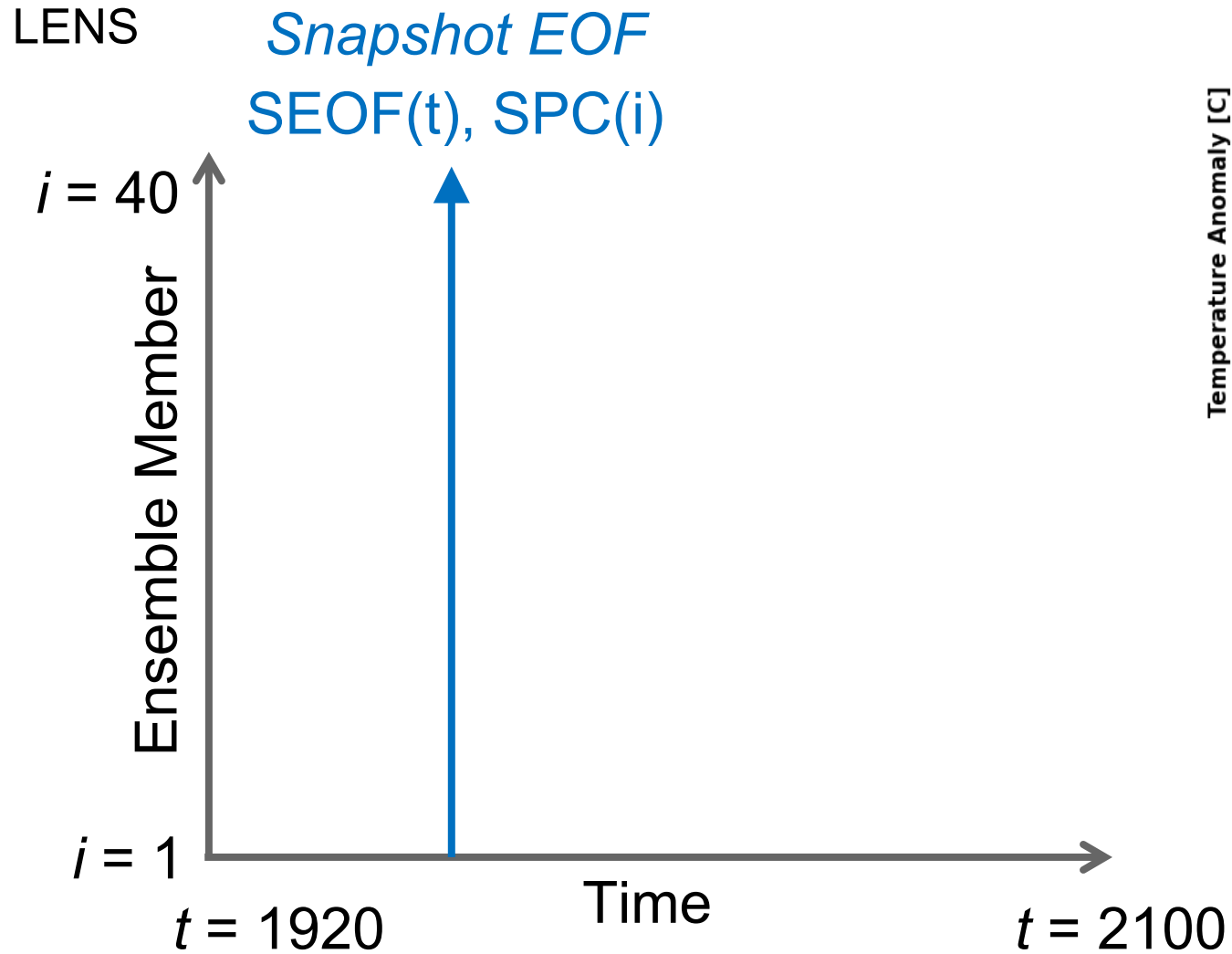
What is a Snapshot EOF?

LENS



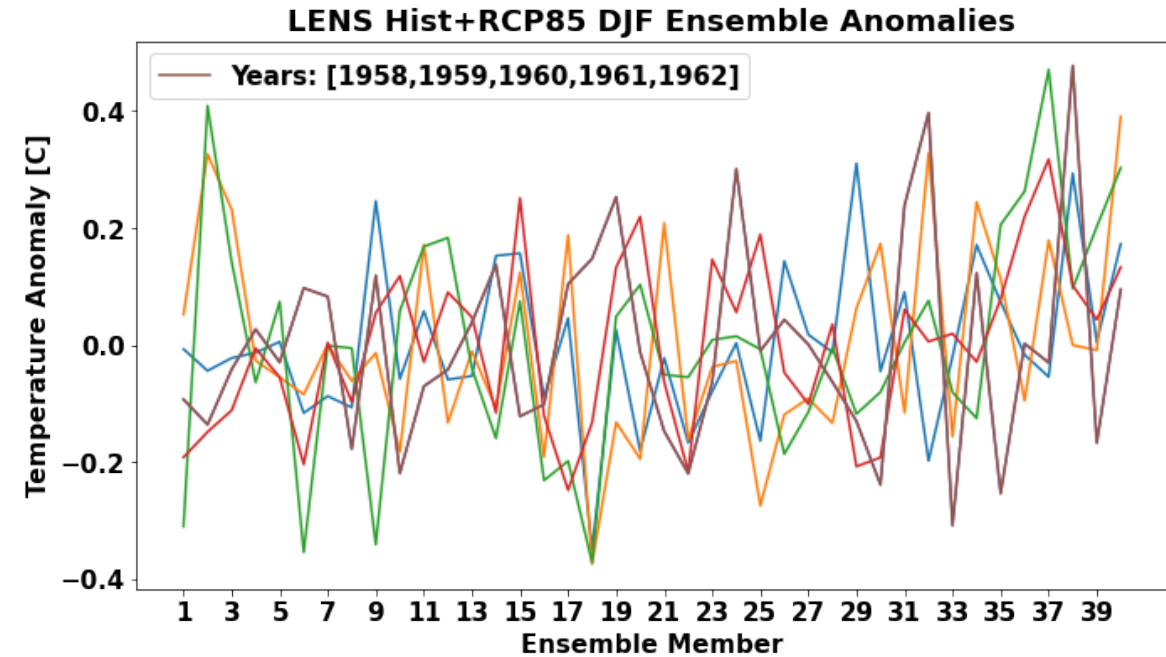
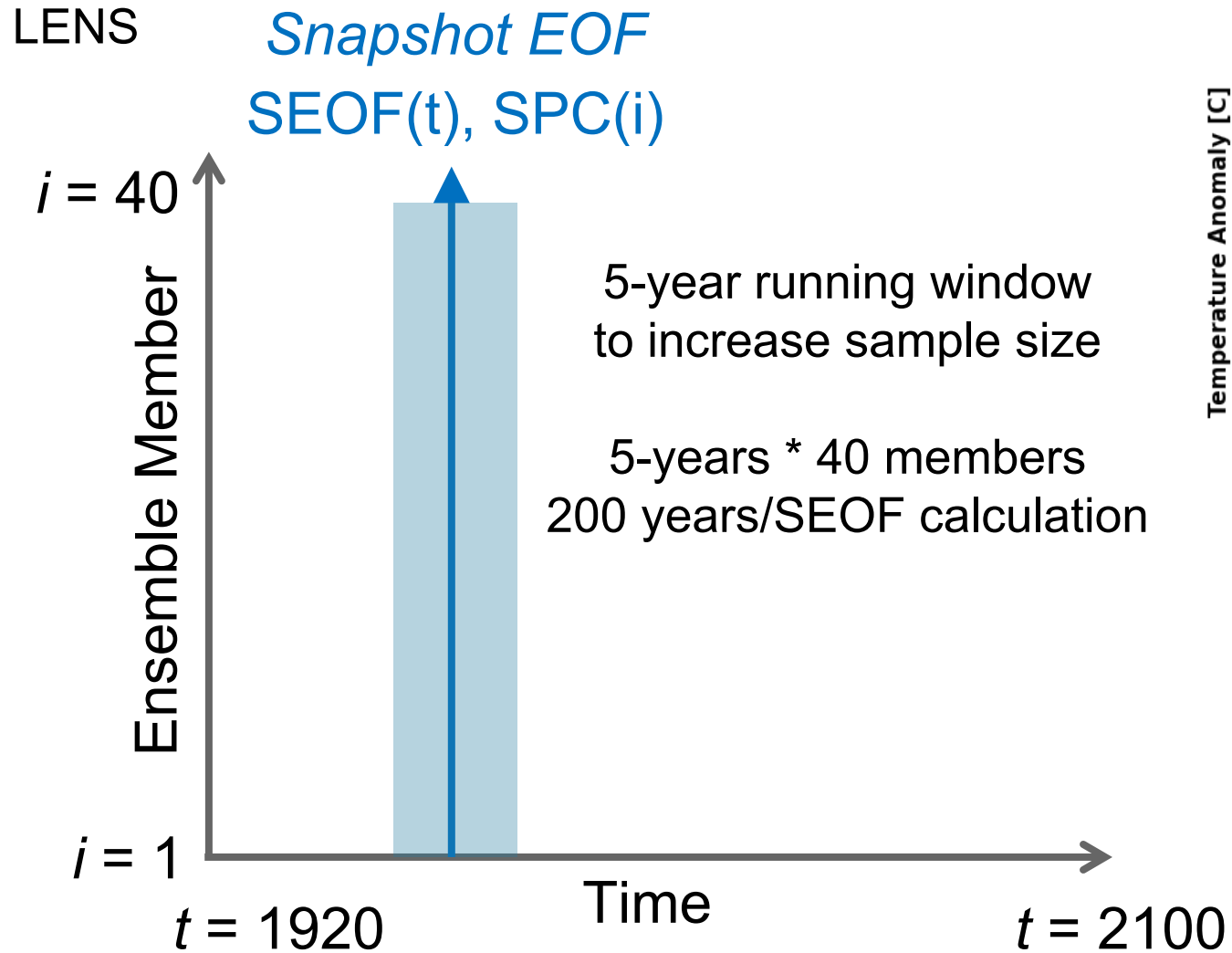
Aperiodic forcing in the time dimension (Anthropogenic GHG forcing, volcanoes, etc)

What is a Snapshot EOF?



Zero mean ensemble anomalies,
stationary statistics across the
ensemble dimension

What is a Snapshot EOF?

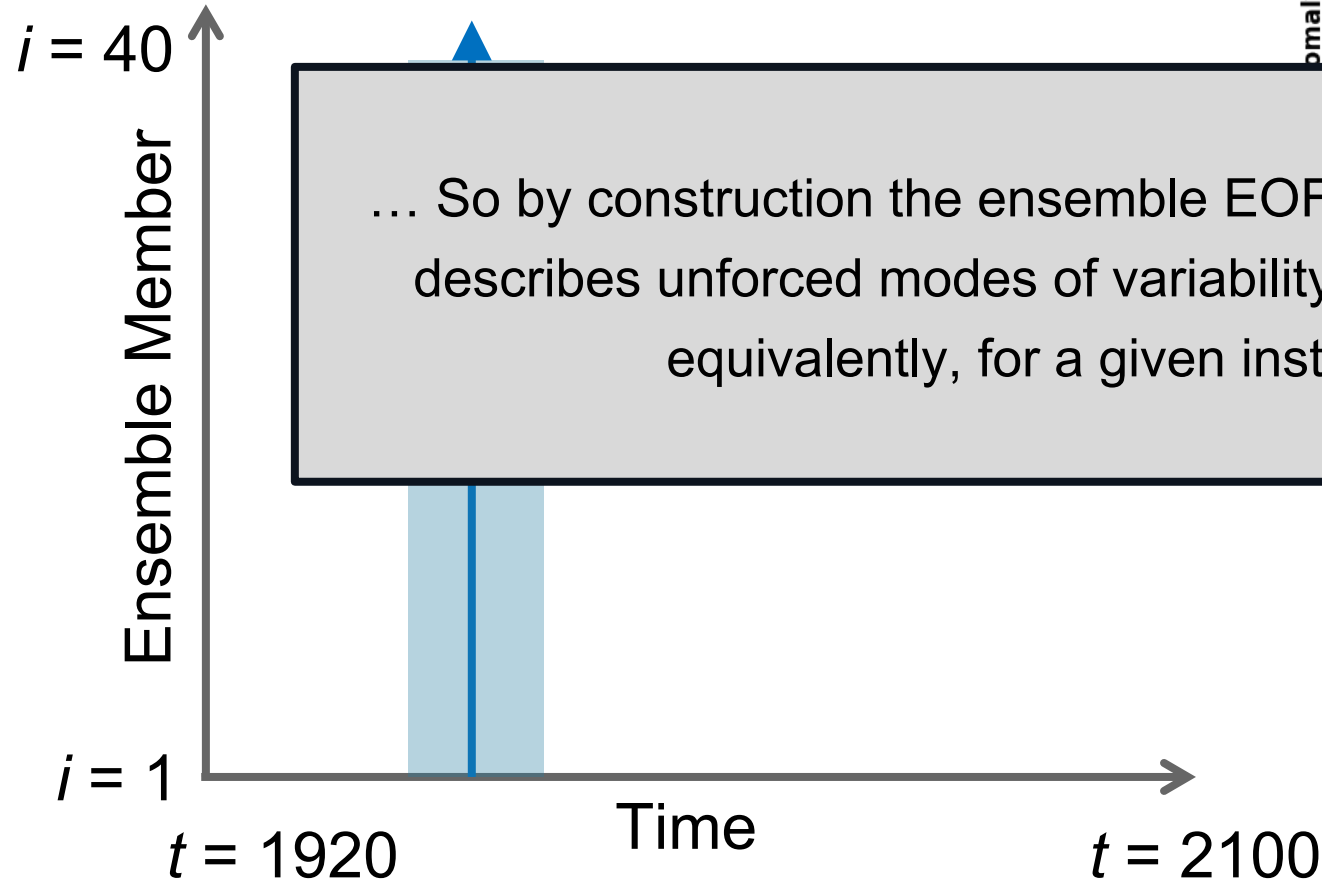


Zero mean ensemble anomalies,
stationary statistics across the
ensemble dimension

What is a Snapshot EOF?

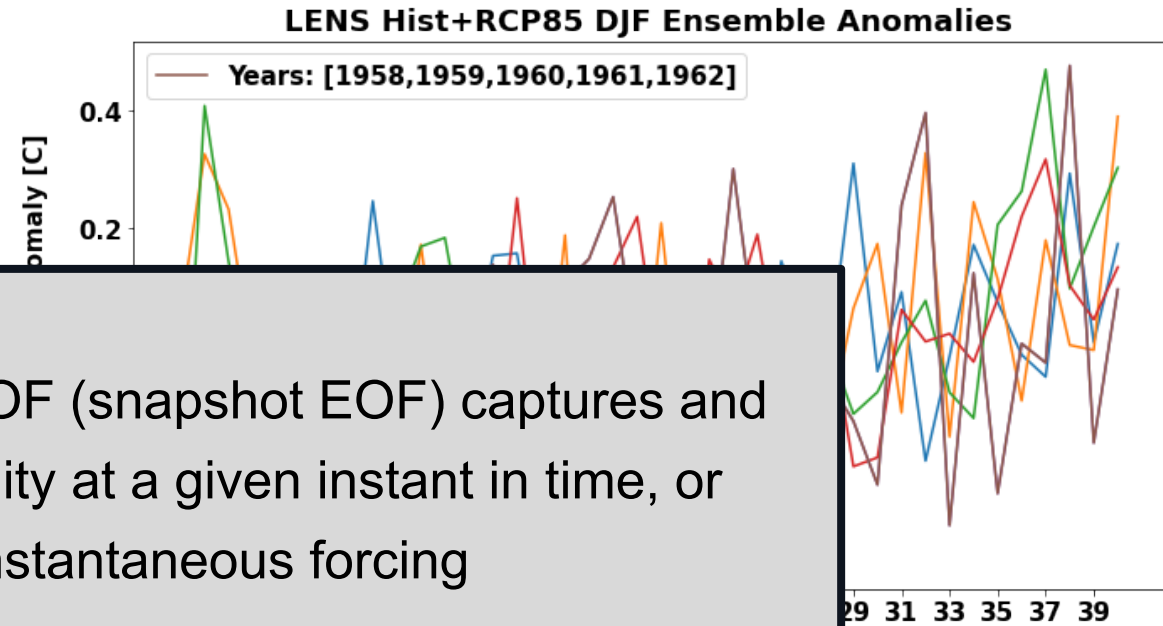
LENS

Snapshot EOF
SEOF(t), SPC(i)

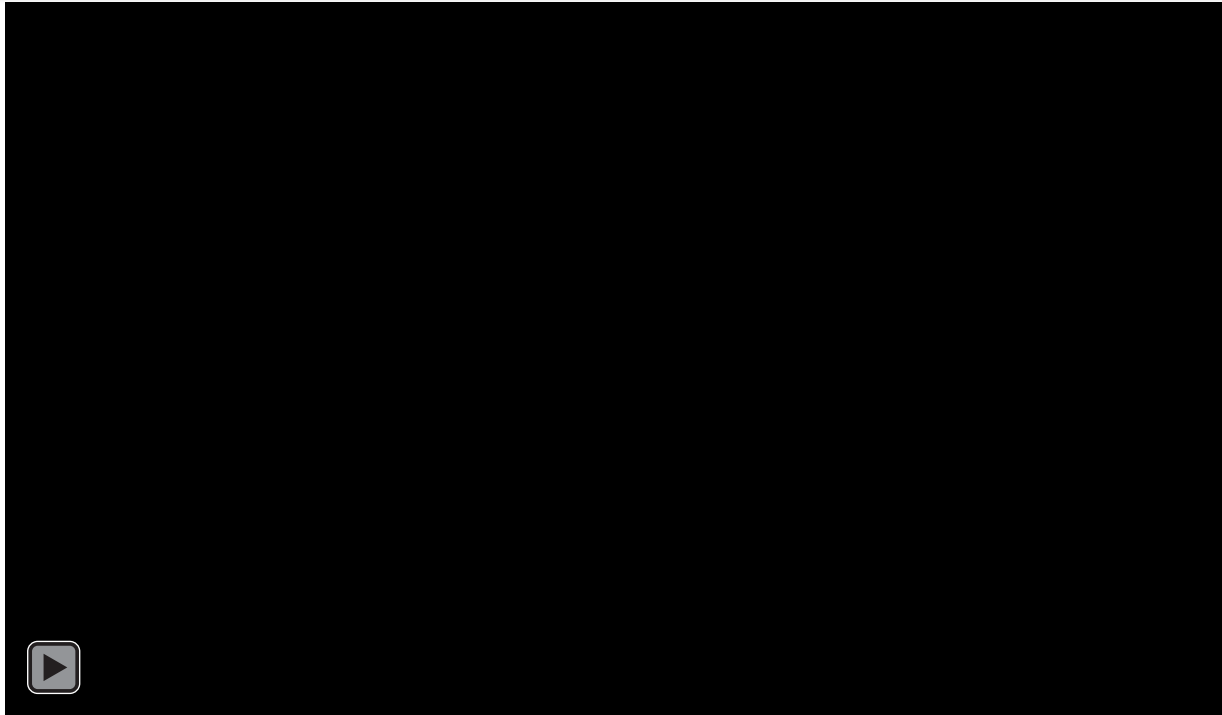


... So by construction the ensemble EOF (snapshot EOF) captures and describes unforced modes of variability at a given instant in time, or equivalently, for a given instantaneous forcing

Zero mean ensemble anomalies,
stationary statistics across the
ensemble dimension

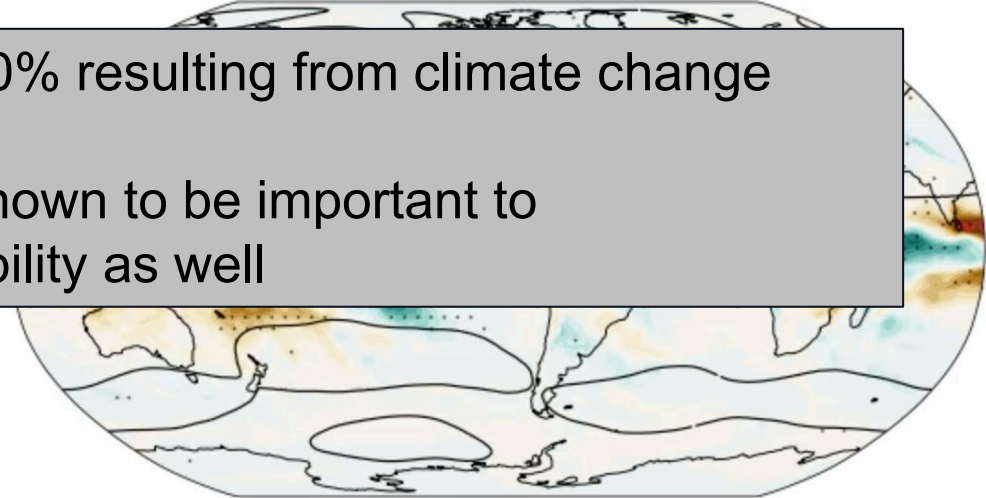


Results

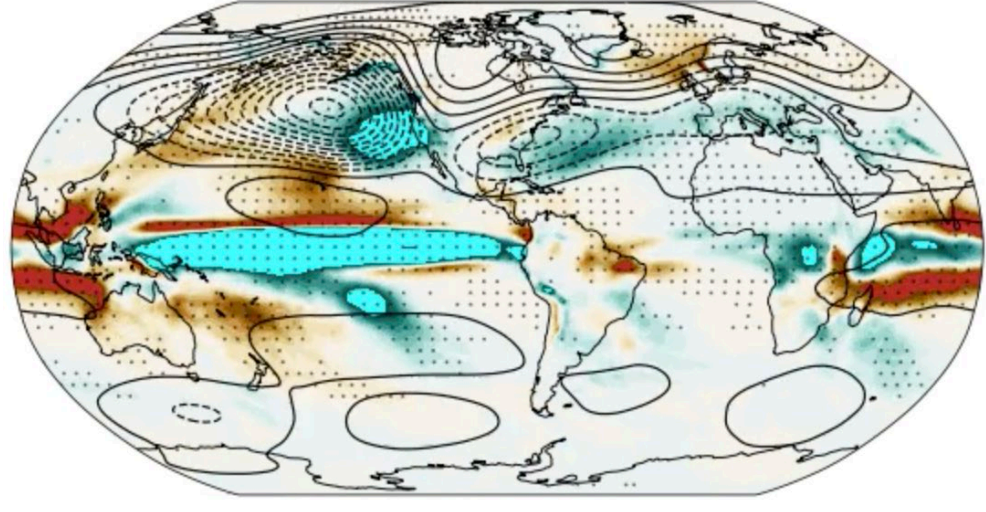


at 30% resulting from climate change
known to be important to
variability as well

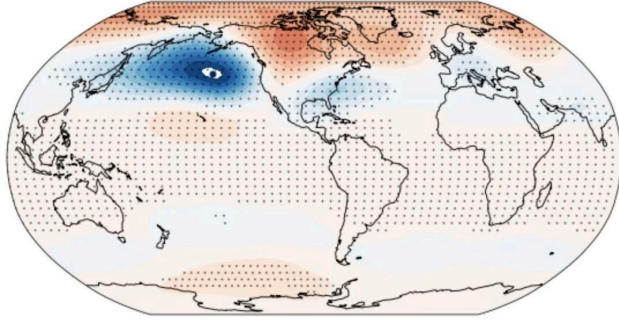
EOF1 | SEOF#1 | 1923



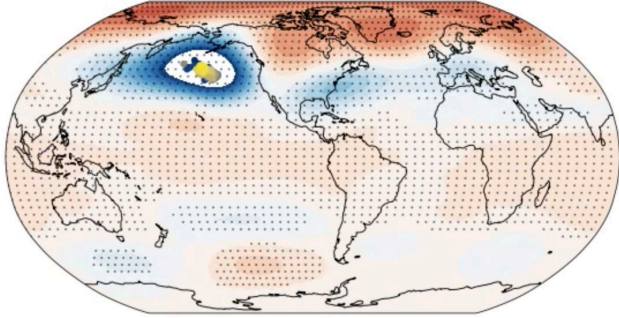
EOF1 | SEOF#176 | 2098



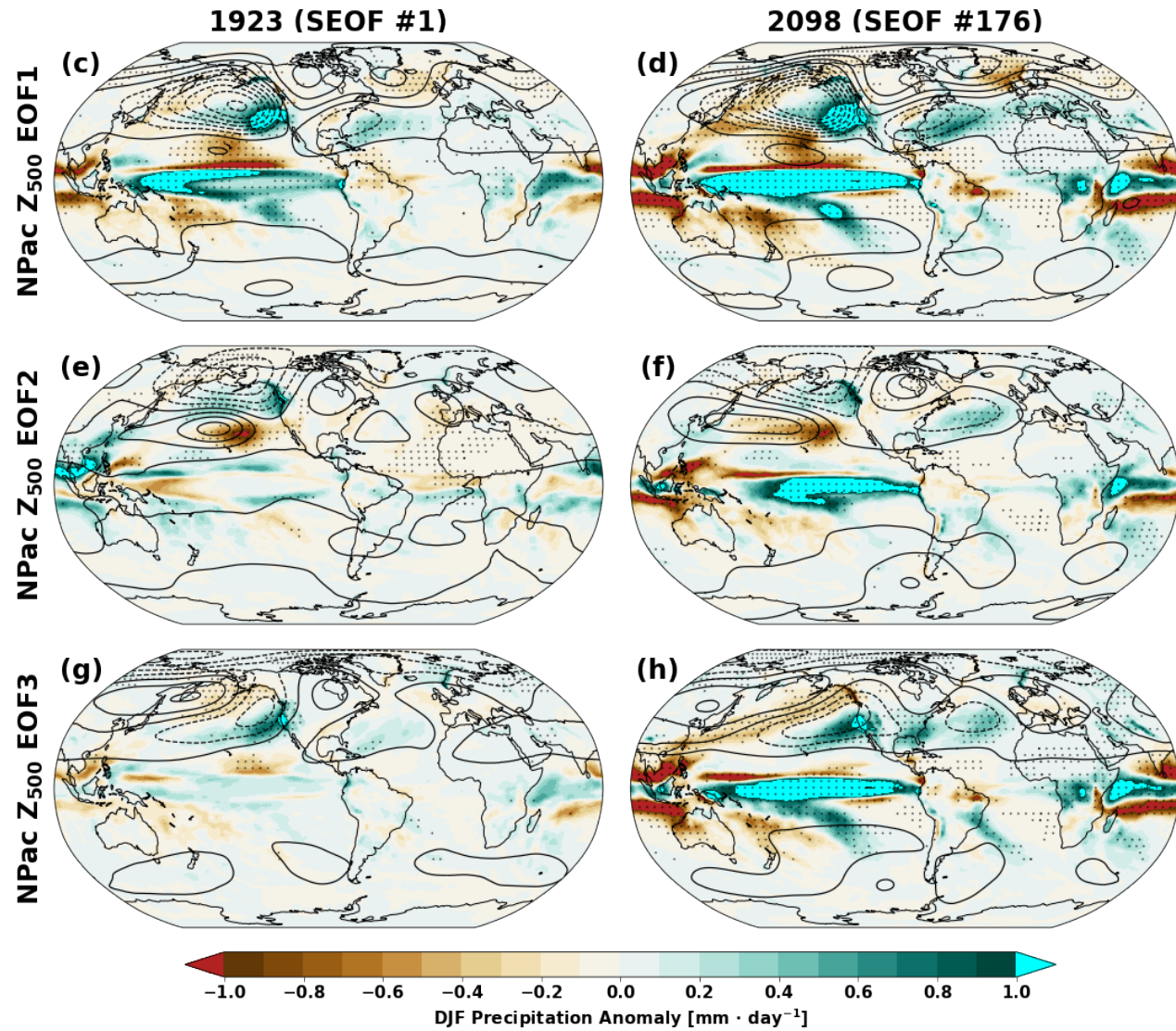
EOF1 | SEOF#1 | 1923-01-01



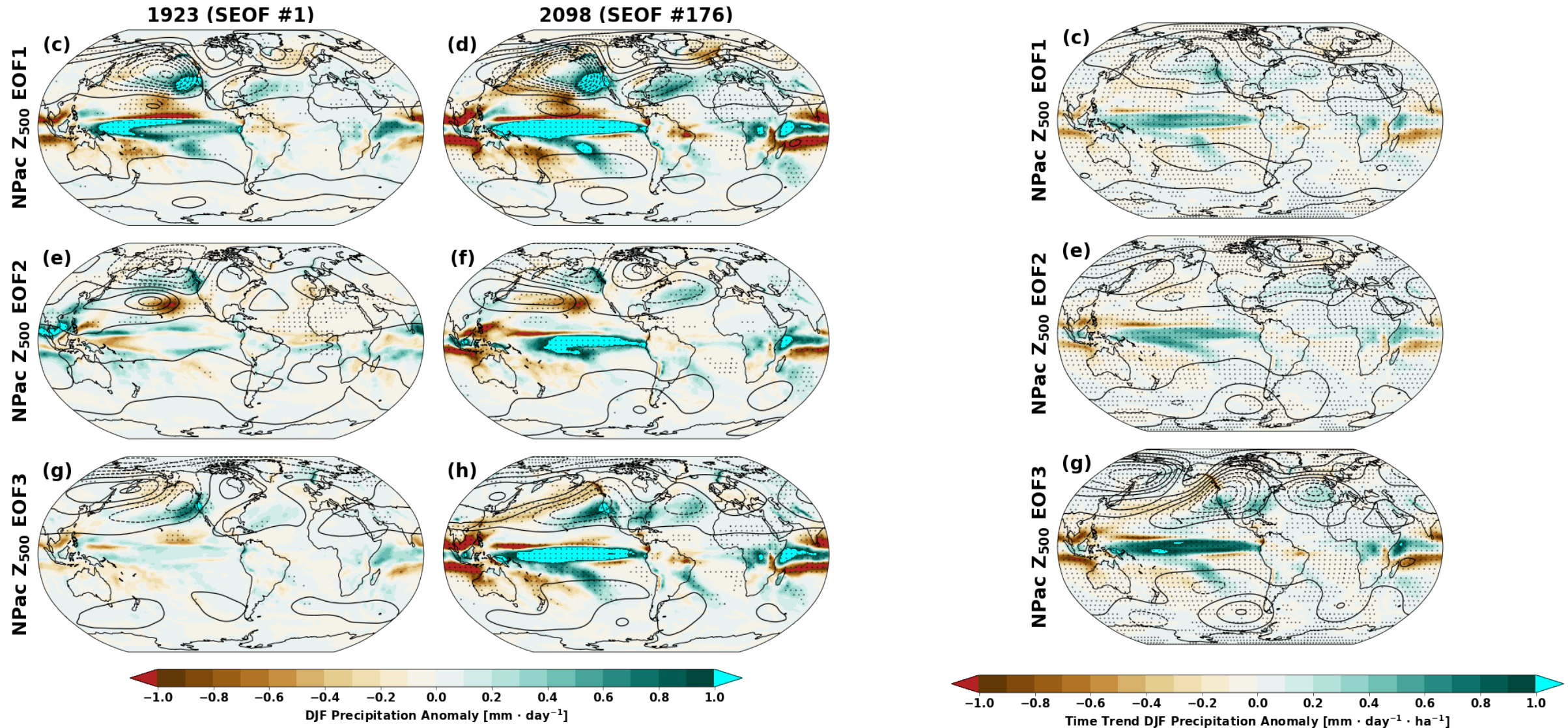
EOF1 | SEOF#176 | 2098-01-01



Results



Results

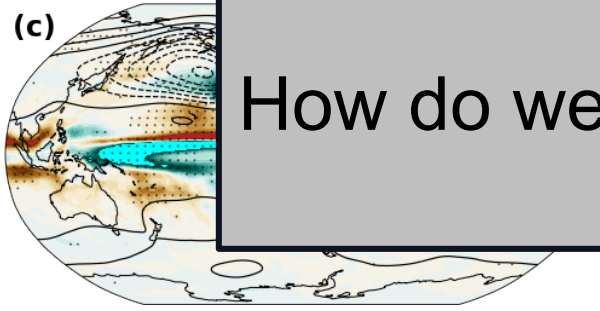


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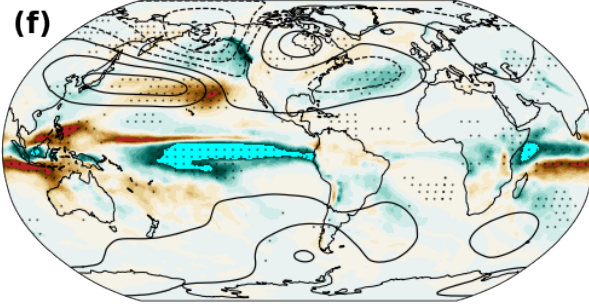
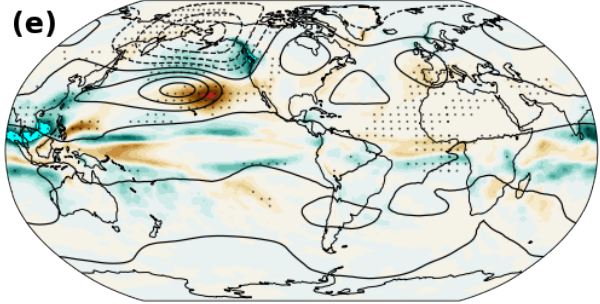
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How do we control for variability originating in the tropics?

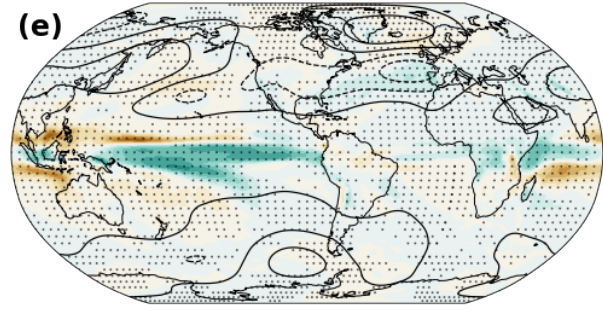
NPac Z₅₀₀ EOF1



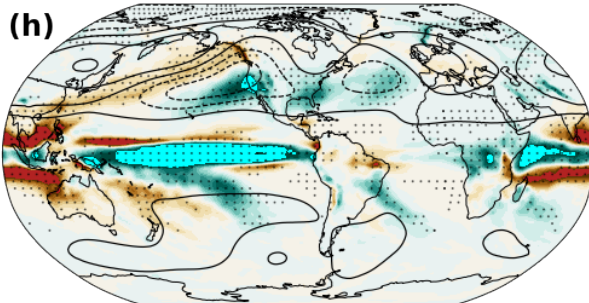
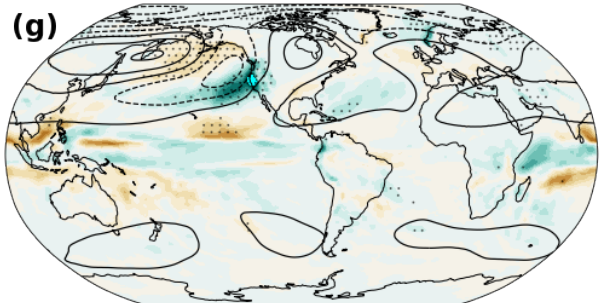
NPac Z₅₀₀ EOF2



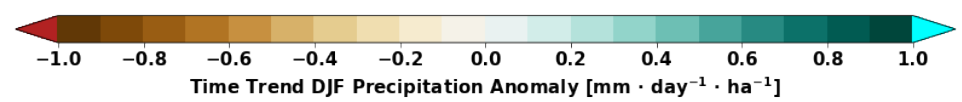
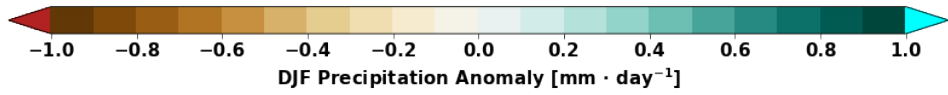
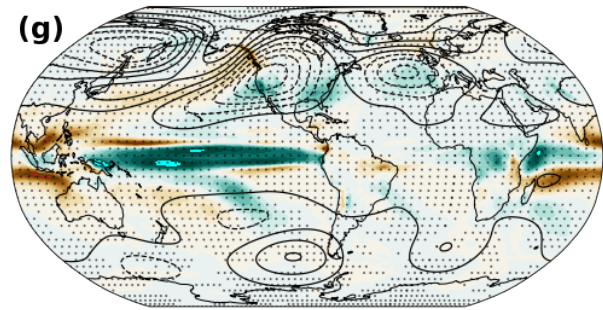
NPac Z₅₀₀ EOF2



NPac Z₅₀₀ EOF3



NPac Z₅₀₀ EOF3



Results

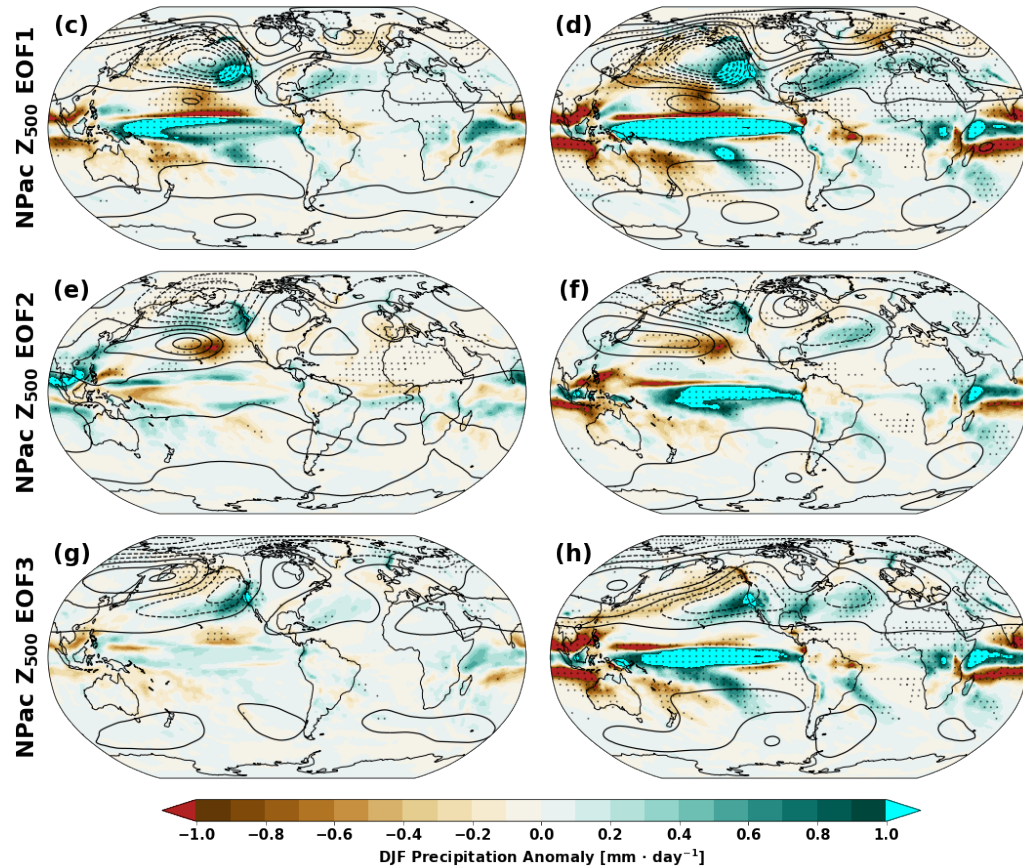
How do we control for variability originating in the tropics?

- The SST perturbation associated with ENSO is largest source of tropical variability
 - Calculate the first EOF/SEOFs of tropical SST variability (“ENSO”)
 - Include all modes of variability into a single multiple linear regression model

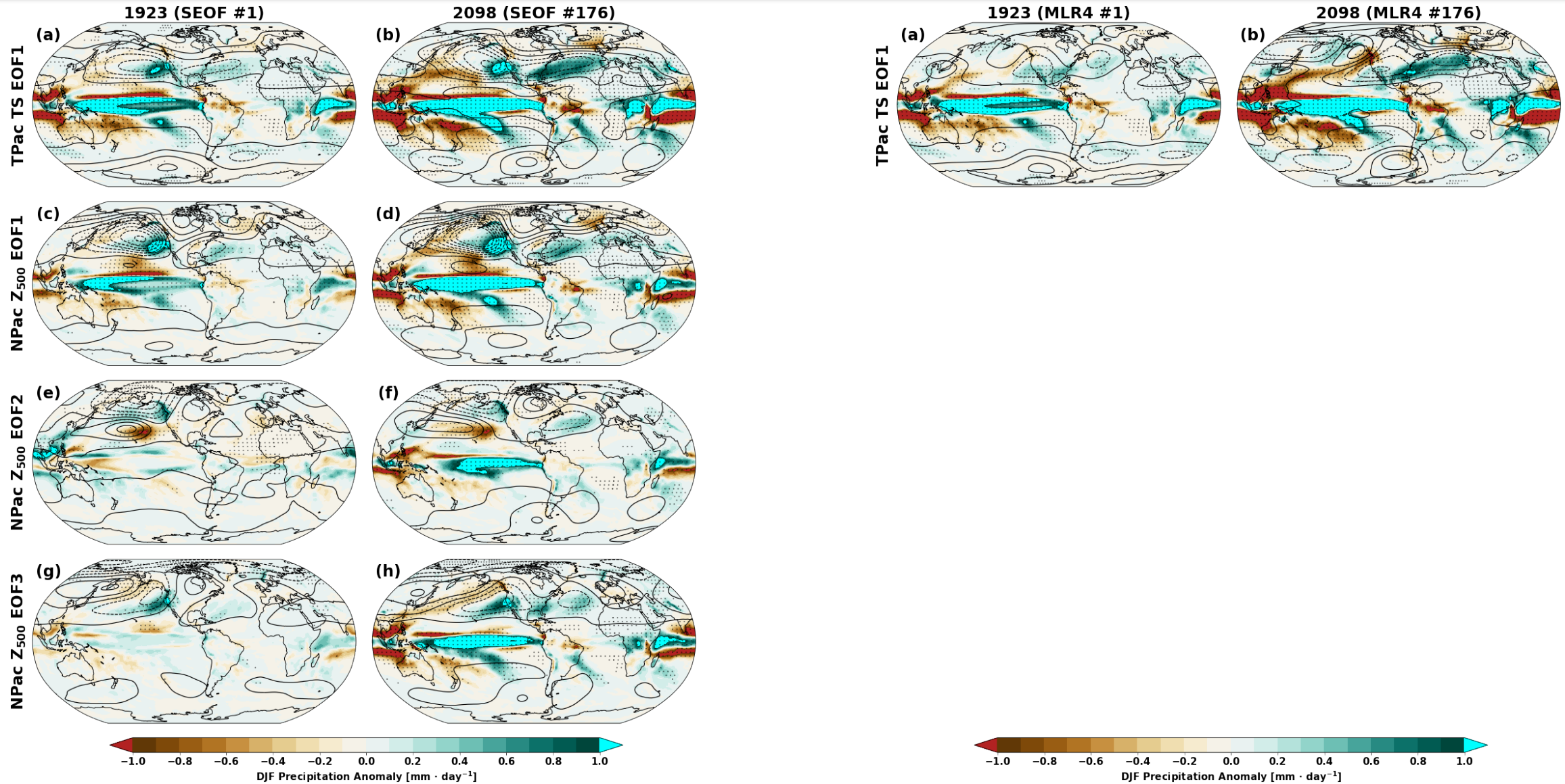
Relative contributions from each mode

$$f_t(\dots) = \mu_{0,t} + \underbrace{\mu_{1,t} \cdot TPac_PC1_t}_{\text{Tropical}} + \underbrace{\mu_{2,t} \cdot NPac_PC1_t + \mu_{3,t} \cdot NPac_PC2_t + \mu_{4,t} \cdot NPac_PC3_t}_{\text{Extratropical}}$$

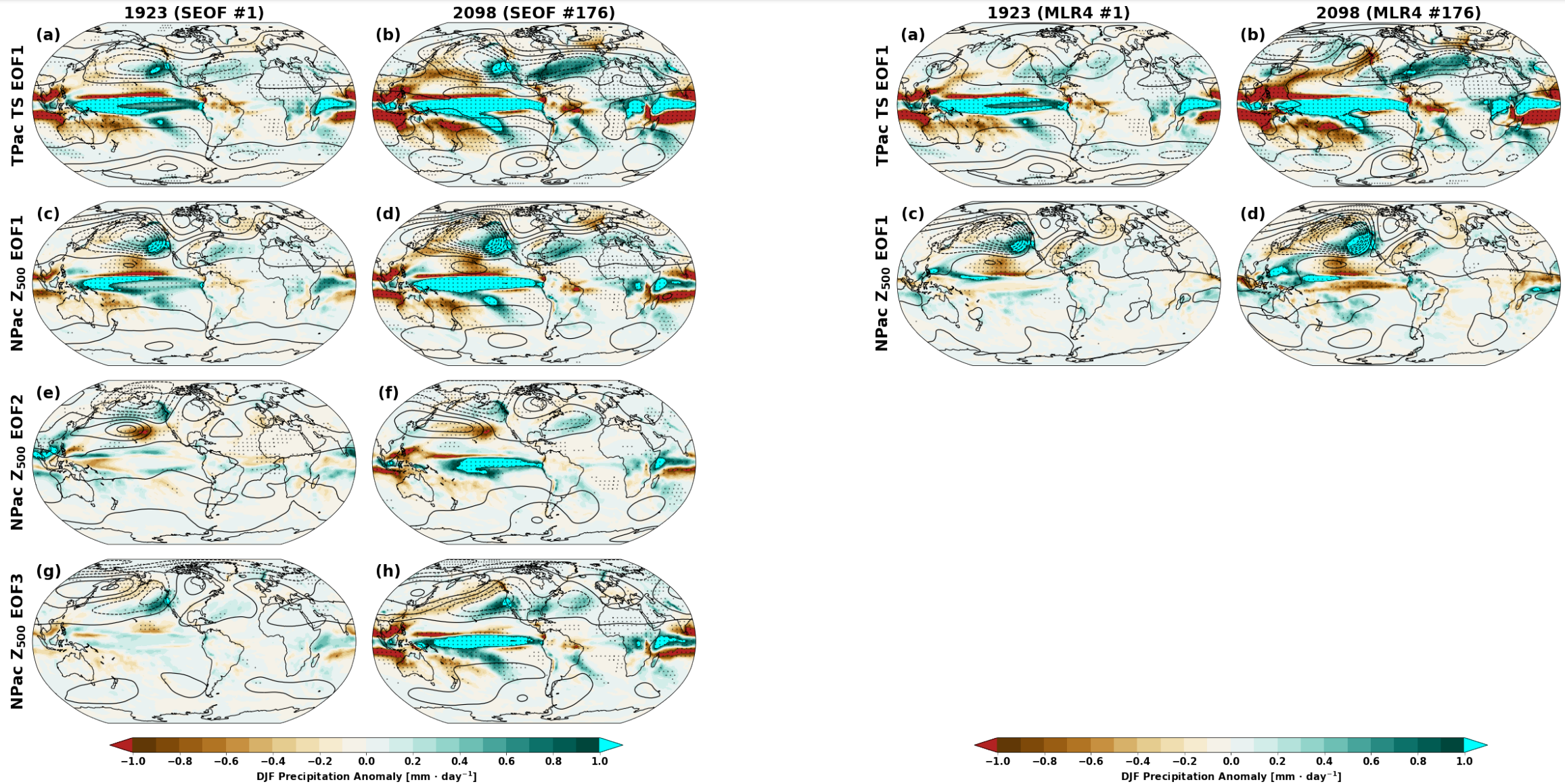
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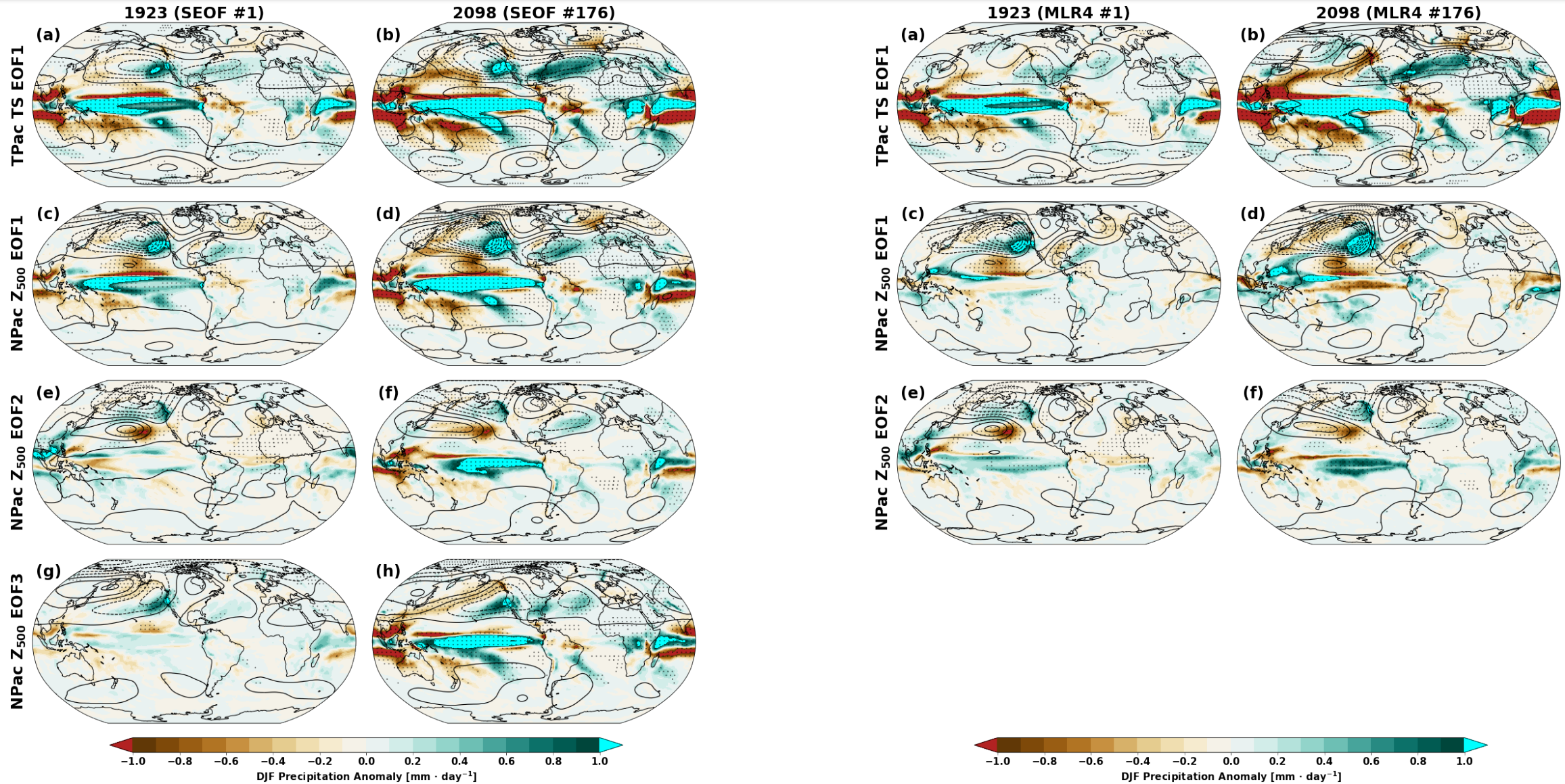
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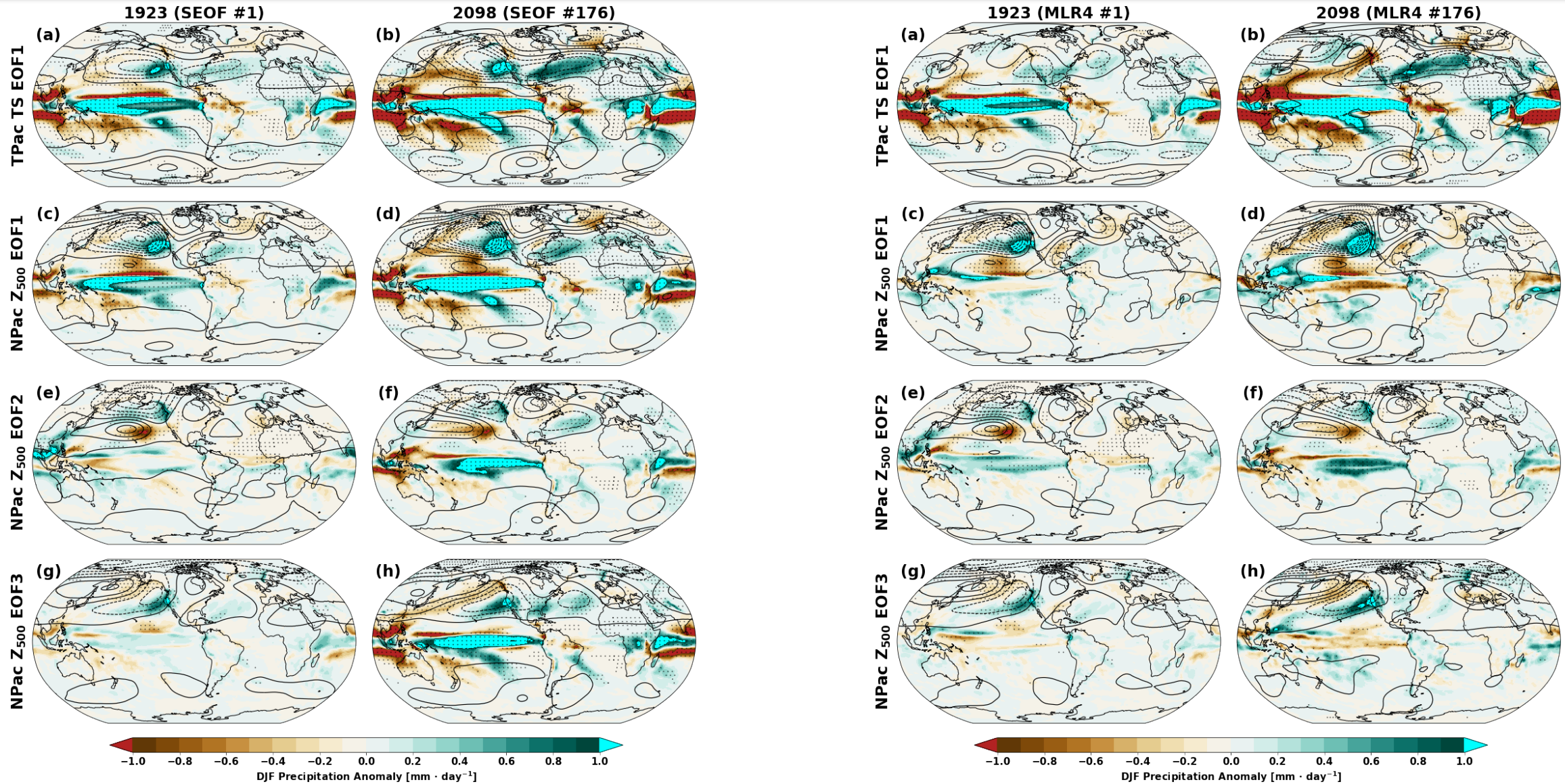
Results



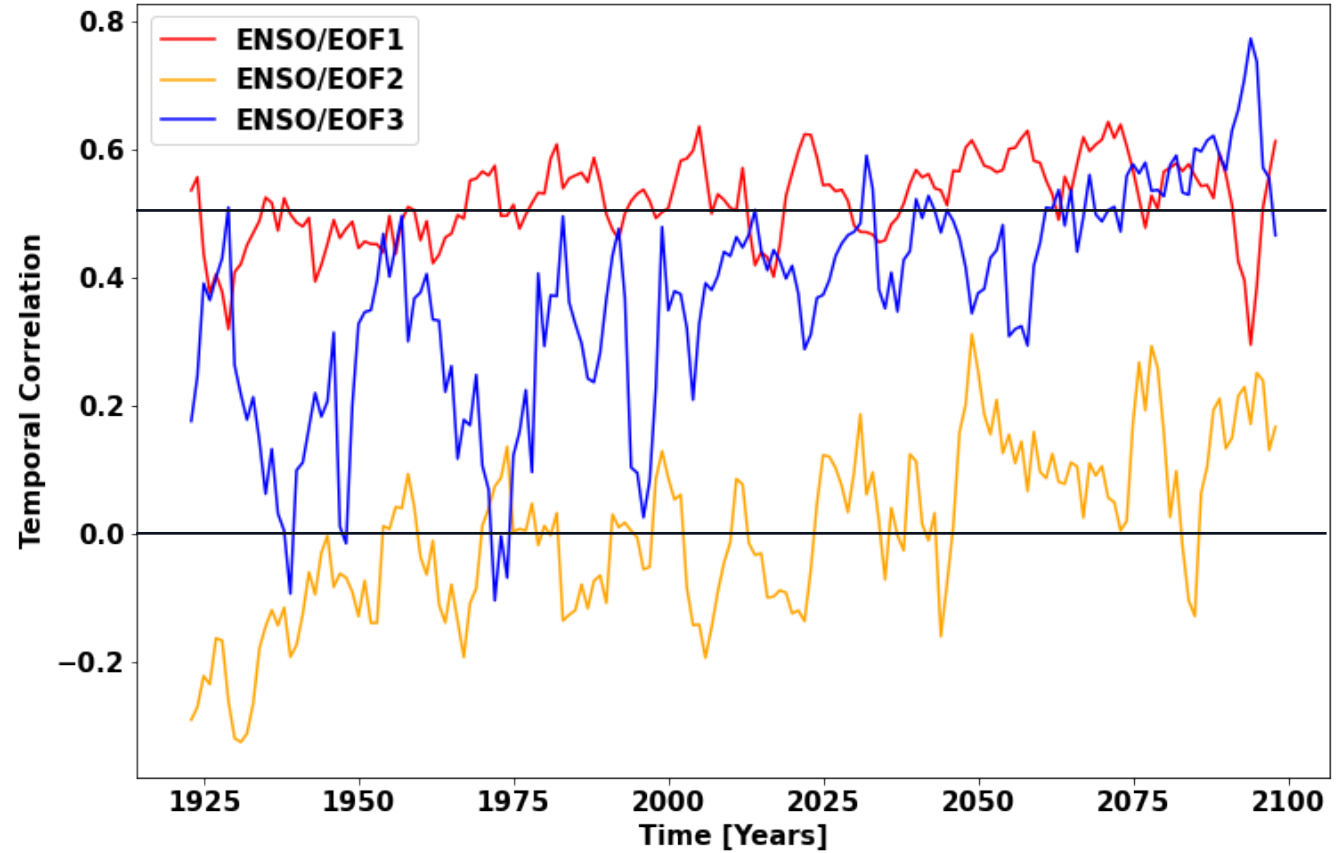
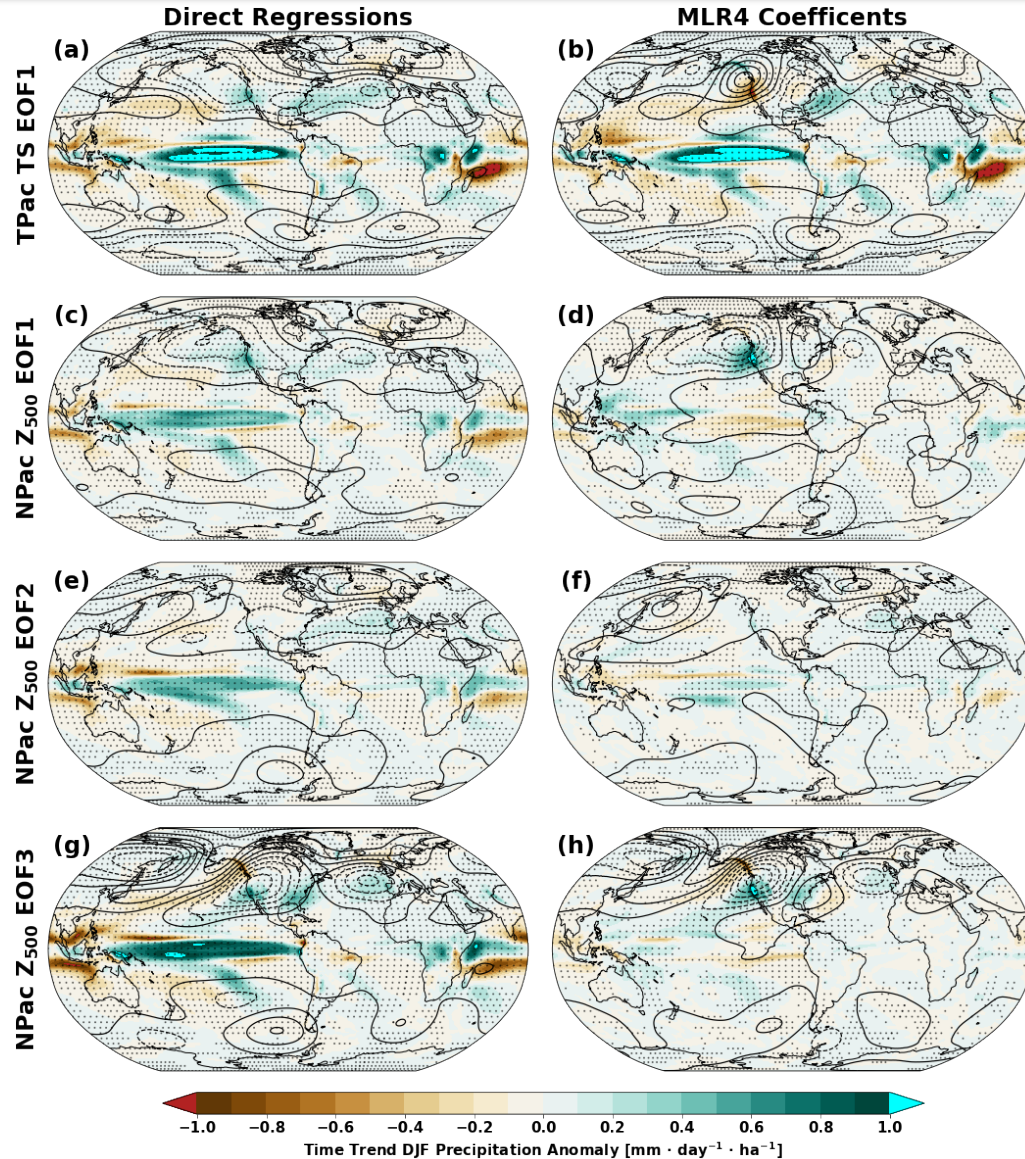
Results



Results



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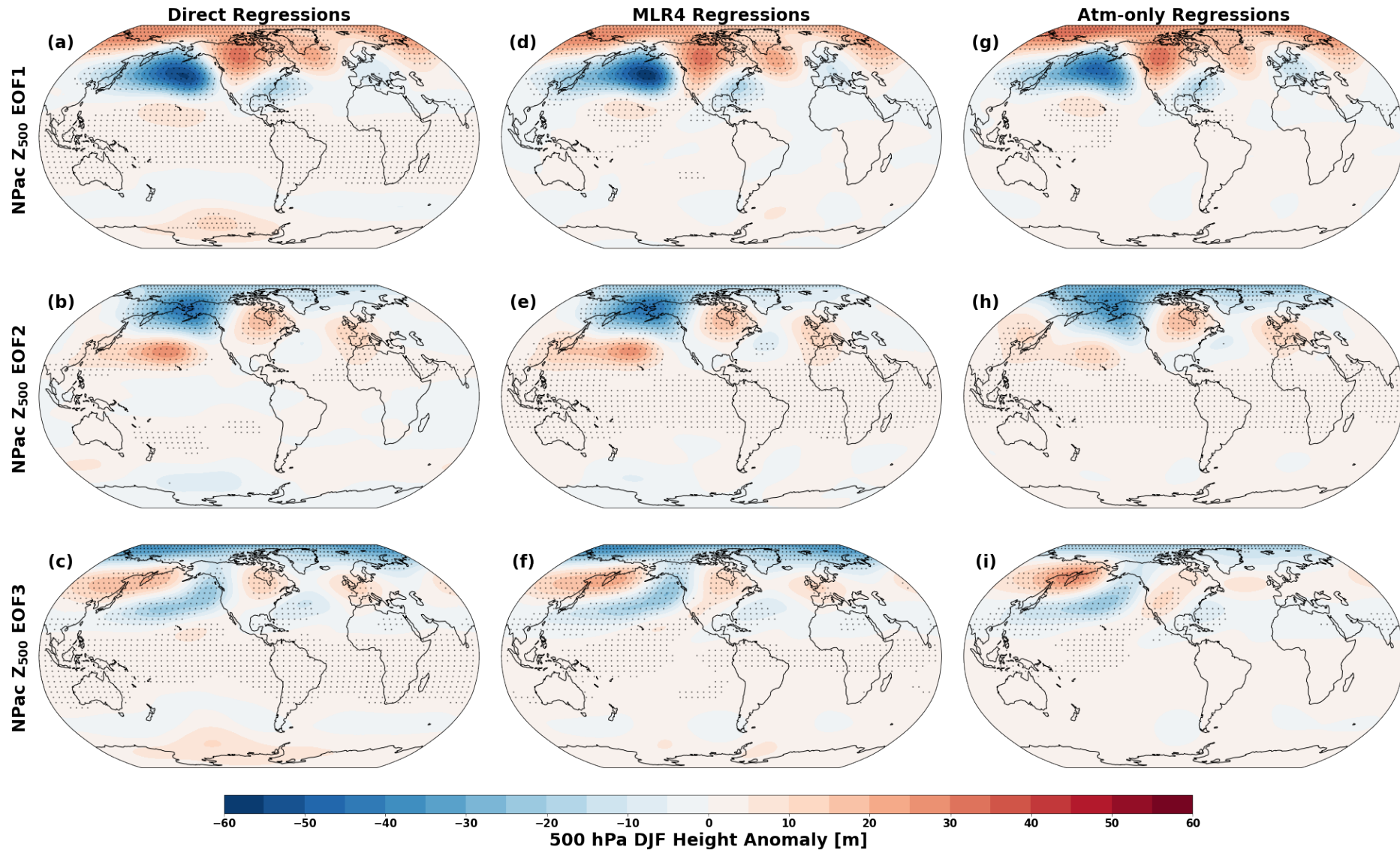
Summary

1. We were able to employ an ensemble-based EOF framework to isolate modes of north Pacific atmospheric variability and subsequently use a multiple linear regression model to partition variability intrinsic to the extratropical atmosphere from variability arising from tropical ocean forcing
2. Both the PNA and EOF3 show a substantial strengthening by the end of the 21st century resulting from external forcing indicative of greater western U.S. hydroclimate variability
3. The tropical SST perturbation associated with ENSO shows a spatial transition with enhanced effects across the south and southeastern U.S. and a greatly enhanced trans-Atlantic teleconnection
4. The ENSO/PNA correlations (interactions) remain high increasing slightly by end of century, however, the changes in ENSO appear to preferentially excite EOF3 whereby it becomes as important as the PNA leading to enhanced subtropical moisture transport

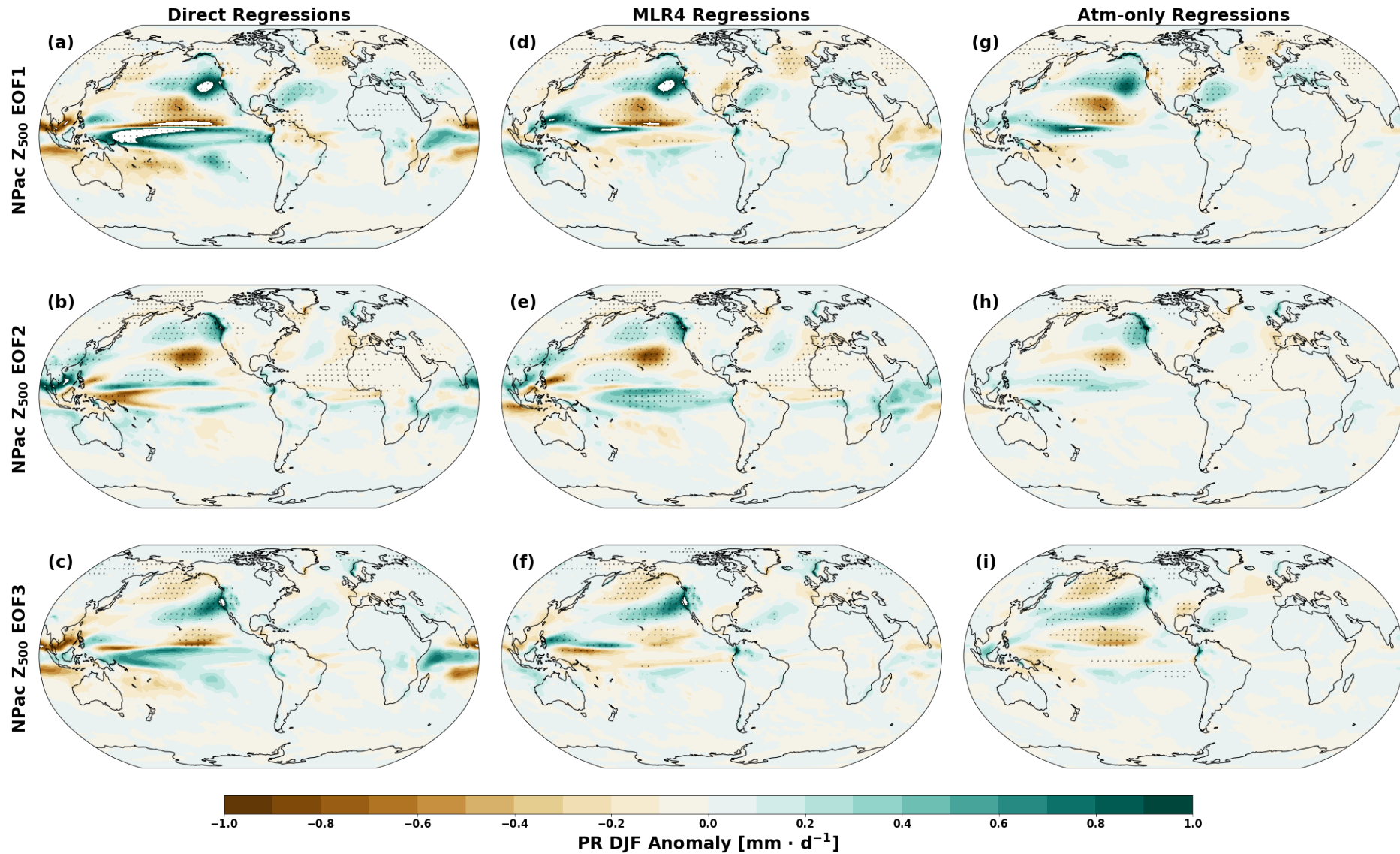
Questions

1. We were able to employ an ensemble-based EOF framework to isolate modes of north Pacific atmospheric variability and subsequently use a multiple linear regression model to partition variability intrinsic to the extratropical atmosphere from variability arising from tropical ocean forcing
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Backup Slides

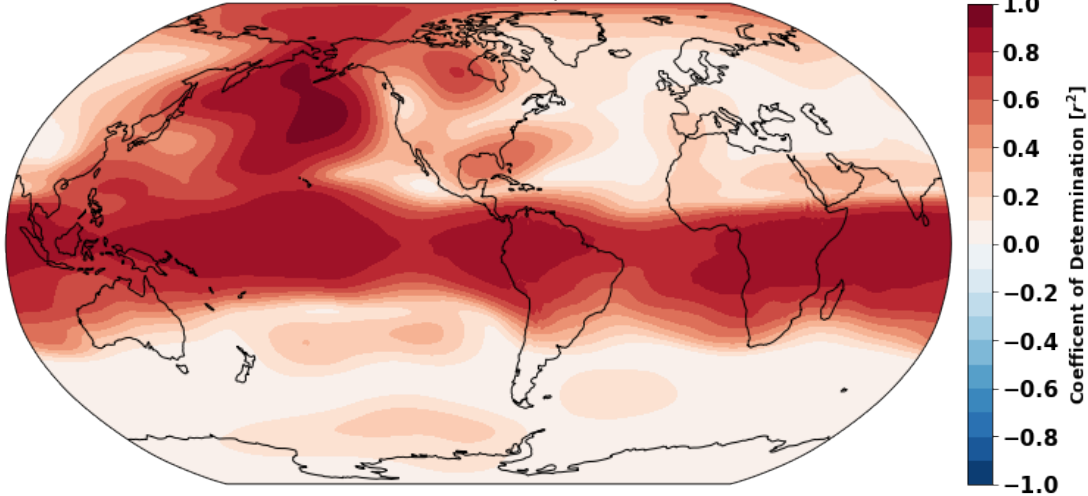


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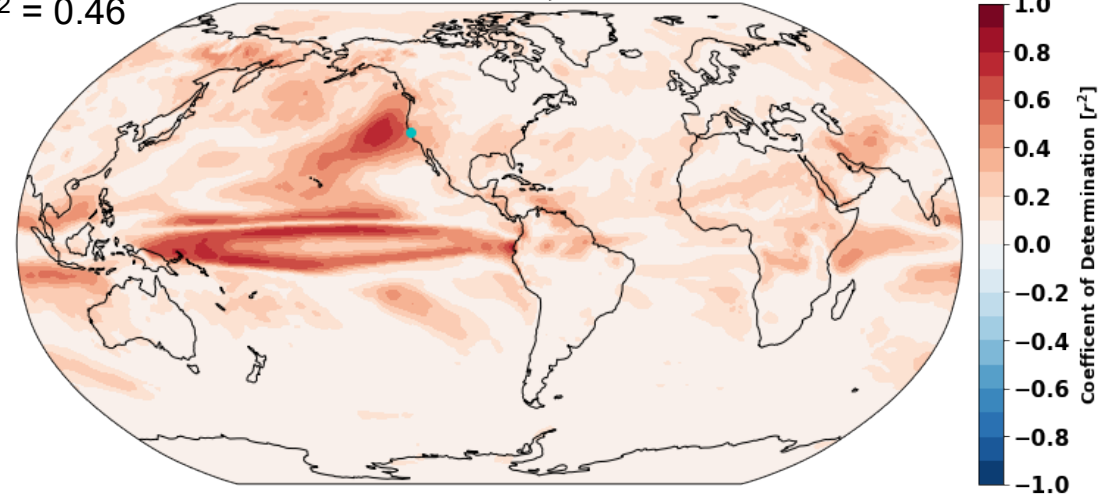


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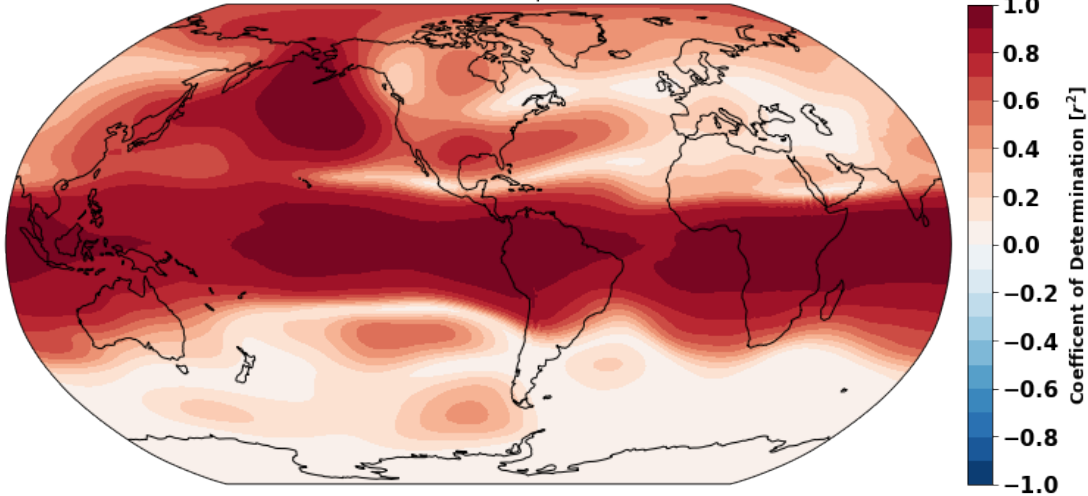
Z500 MLR4 Model Scores | SEOF1 - 1923



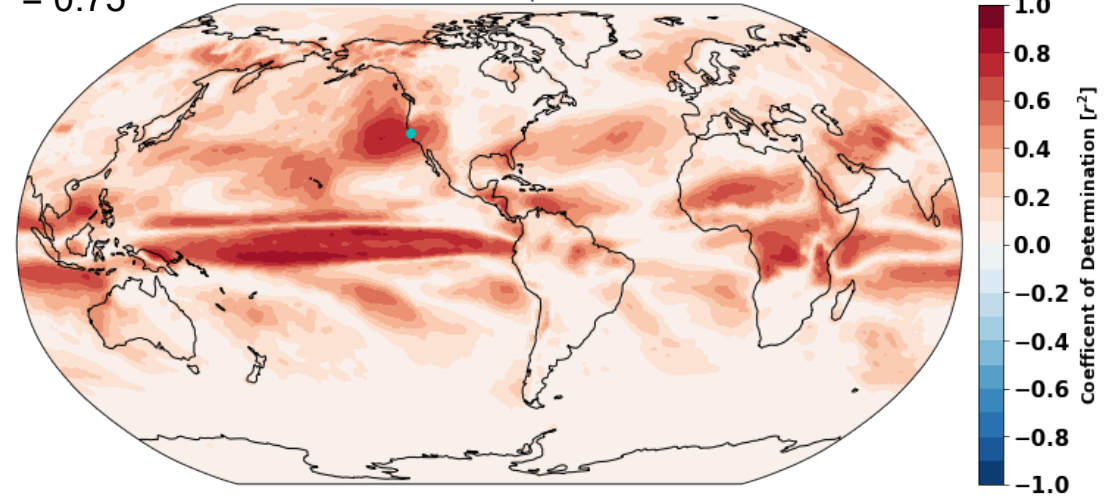
PR MLR4 Model Scores | SEOF1 - 1923
 $R^2 = 0.46$



Z500 MLR4 Model Scores | SEOF176 - 2098



PR MLR4 Model Scores | SEOF176 - 2098
 $R^2 = 0.75$



Field Variance Explained

