Sensitivity of Northeast Pacific Marine Heatwaves to Seasonality of Tropical and North Pacific Dynamics

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February 04, 2026

Overview

REGIONAL DIVERSITY OF MARINE HEATWAVES

Tropical Pacific states associated with
Northeast Pacific marine heatwaves

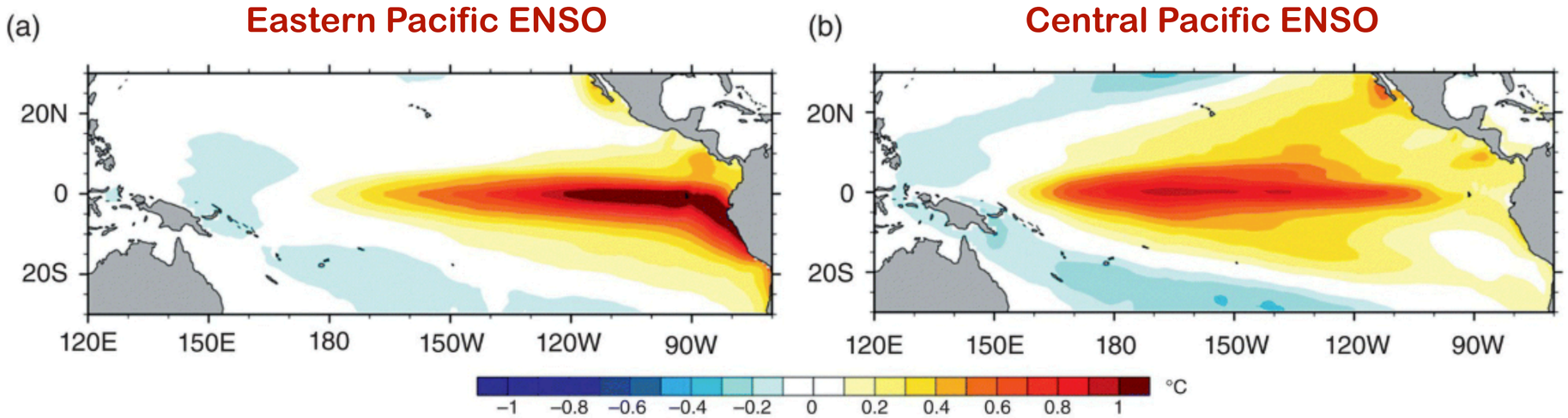
SEASONAL DEPENDENCE AND OCEAN MEMORY

Persistence and reemergence
diagnosed from SSTA autocorrelations

CS-LIM AS A SUPPORTING TOOL

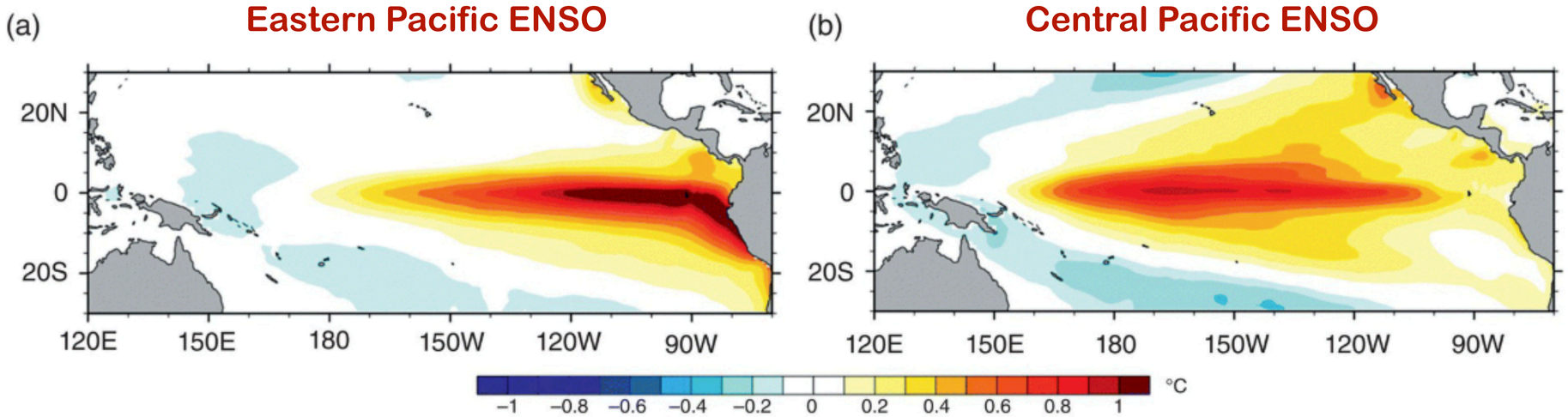
A data-driven framework to sample many
realizations consistent with reanalysis

Northeast Pacific during ENSO flavors



Capotondi, A., et al. (2020). "ENSO diversity." El Niño Southern Oscillation in a changing climate: 65-86.

Northeast Pacific during ENSO flavors



Capotondi, A., et al. (2020). "ENSO diversity." El Niño Southern Oscillation in a changing climate: 65-86.

Definition: Rotated EOFs

$$E = \frac{PC_1 - PC_2}{\sqrt{2}}$$

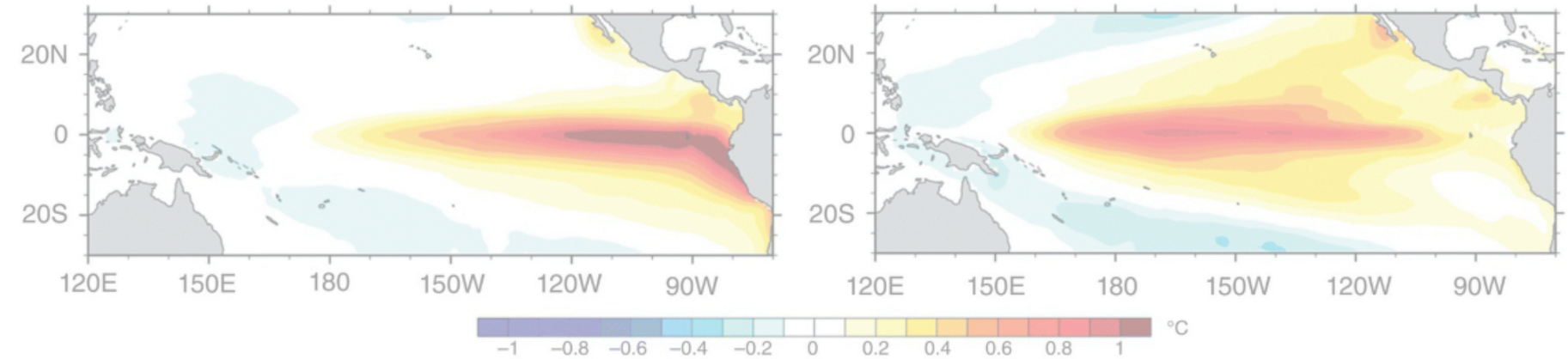
$$C = \frac{PC_1 + PC_2}{\sqrt{2}}$$

Takahashi, K., et al. (2011). "ENSO regimes: Reinterpreting the canonical and Modoki El Niño." GRL 38(10).

Northeast Pacific during ENSO flavors

(a) **Eastern Pacific ENSO**

(b) **Central Pacific ENSO**



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Definition:
Rotated EOFs

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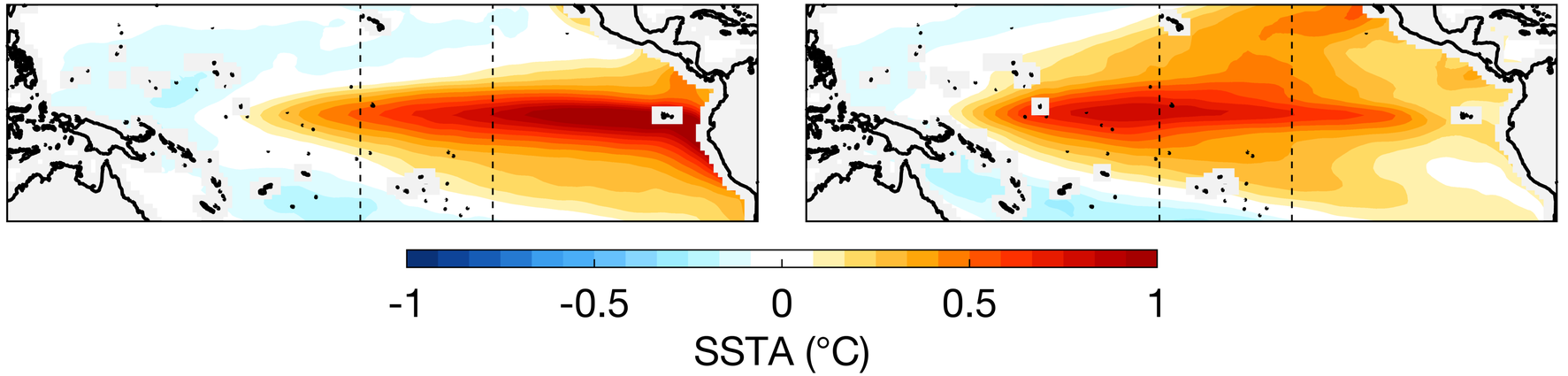
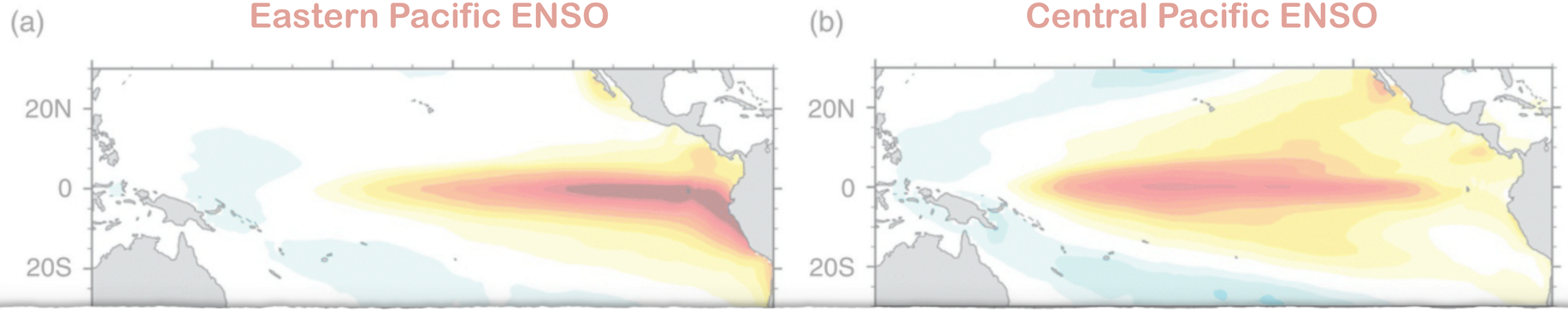
$$PC_1 + PC_2$$

Our figure based on ORAS5 SSTA (1958-2021)



Northeast Pacific during ENSO flavors



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Rotated EOFs

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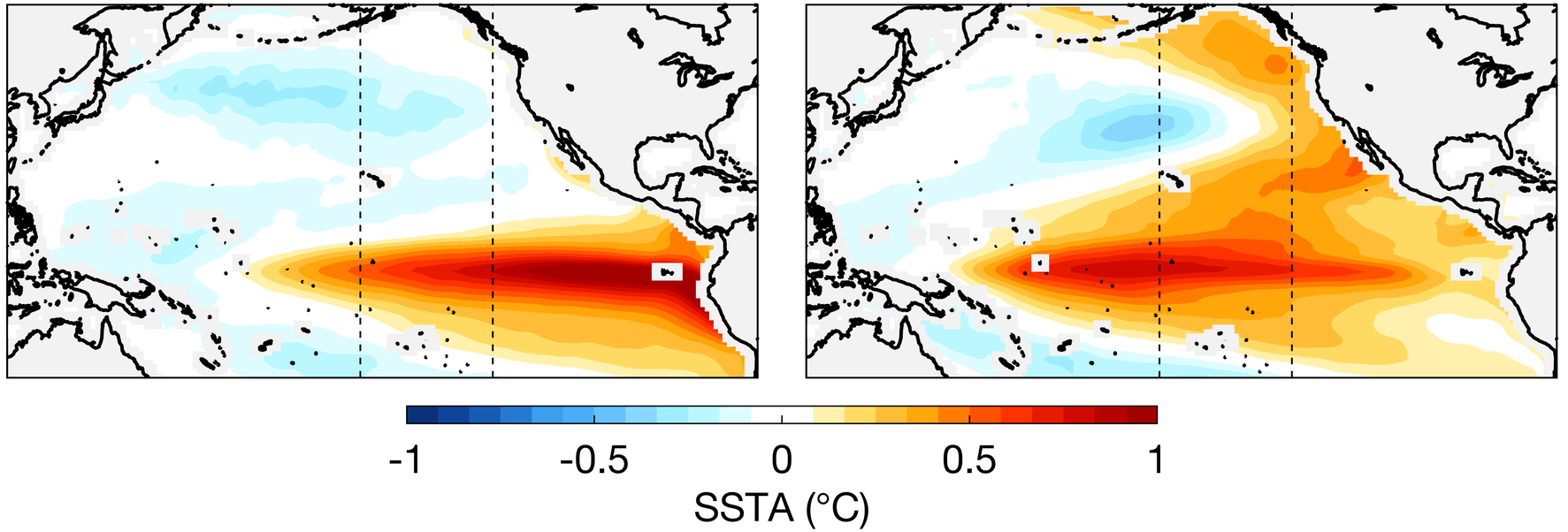
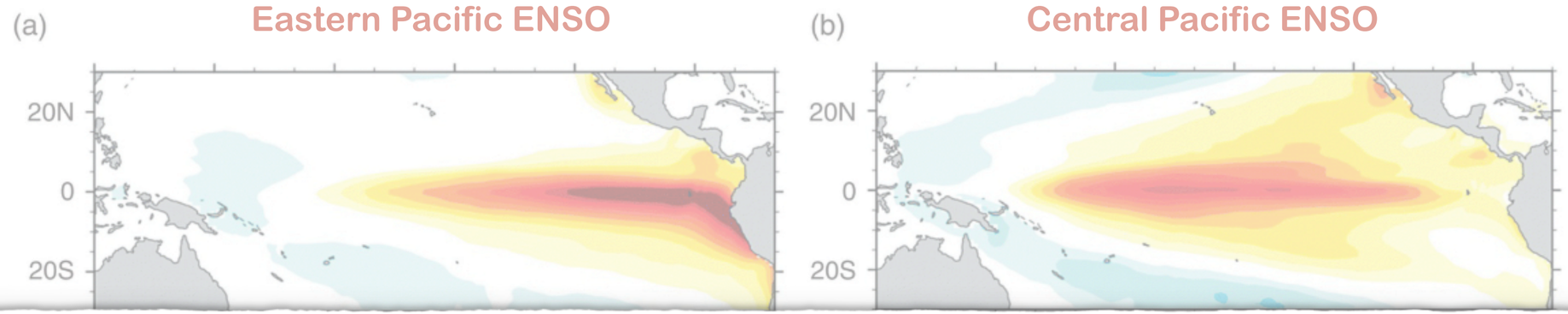
Extend to North Pacific…



Northeast Pacific during ENSO flavors



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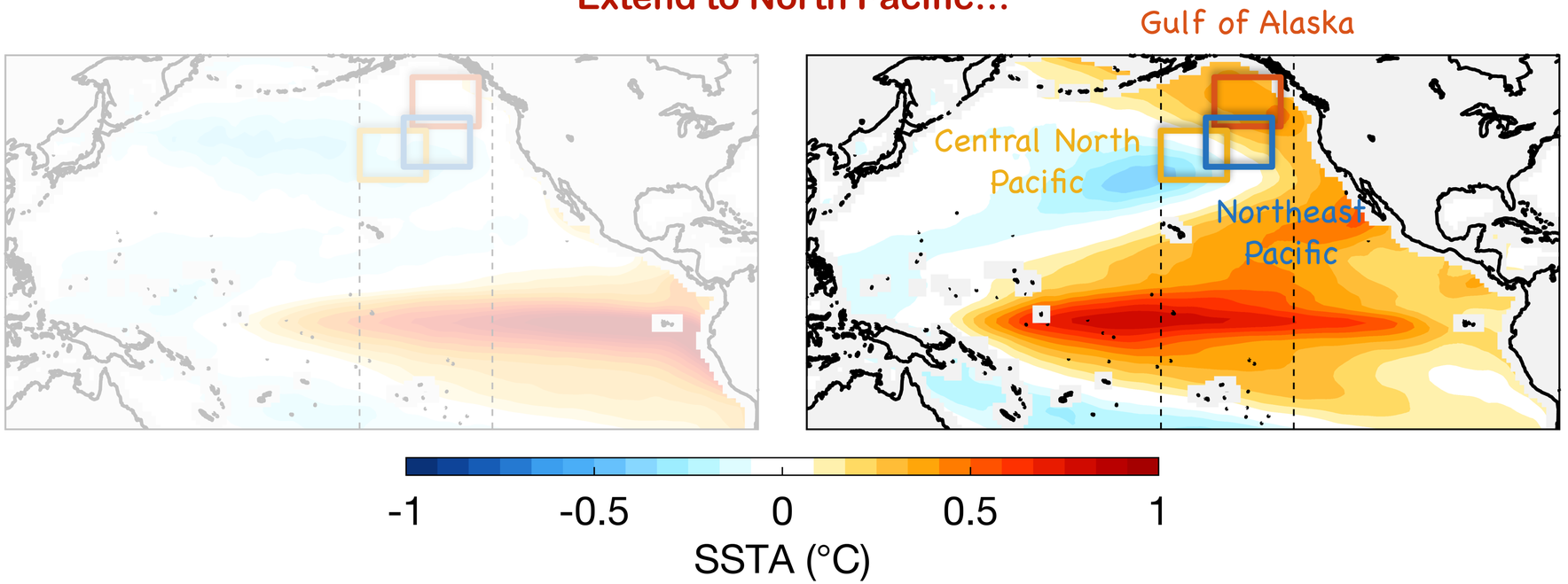
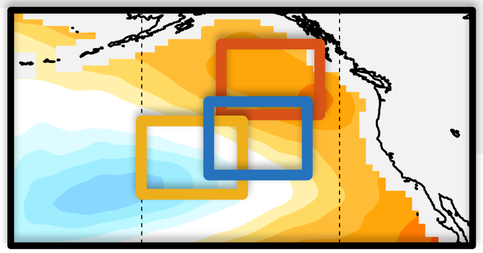
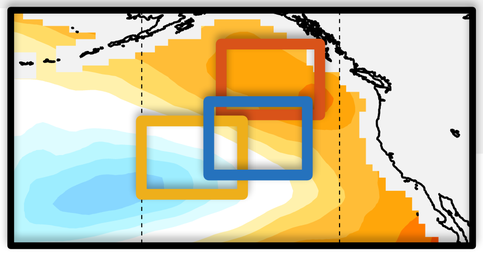


Northeast Pacific indices and marine heatwaves



Regions relative to CP ENSO pattern

Northeast Pacific indices and marine heatwaves



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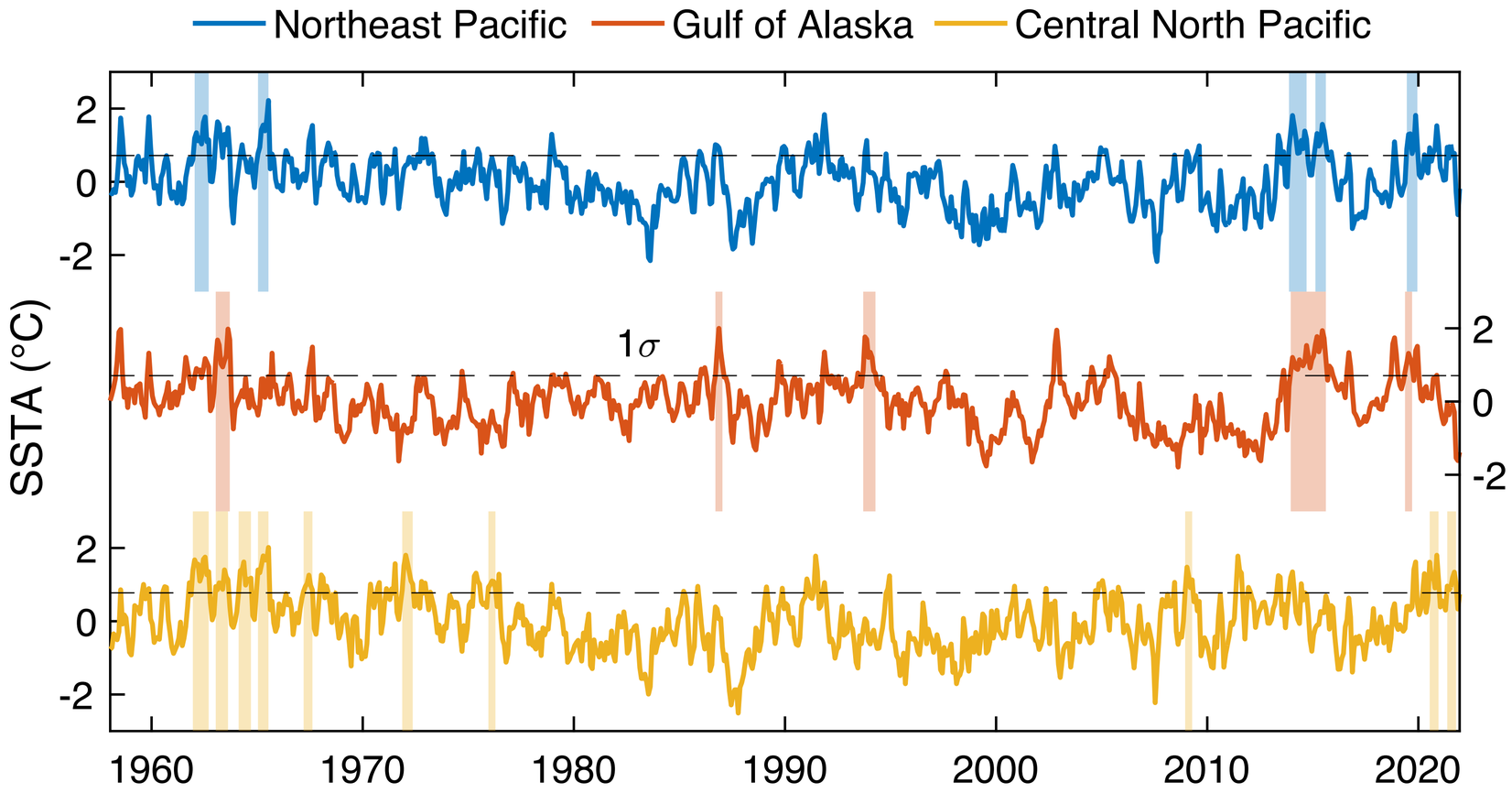


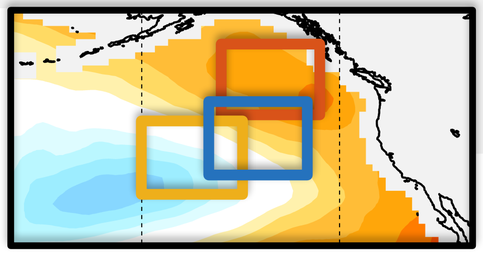
Marine heatwaves:

- **Marked by shading**
- **Defined as events**

  $\geq 1\sigma, \geq 5$ **months**

Xu, T., et al. (2021). "The Continuum of Northeast Pacific Marine Heatwaves and Their Relationship to the Tropical Pacific." GRL **48**(2): 2020GL090661.

Northeast Pacific marine heatwaves and ENSO flavors



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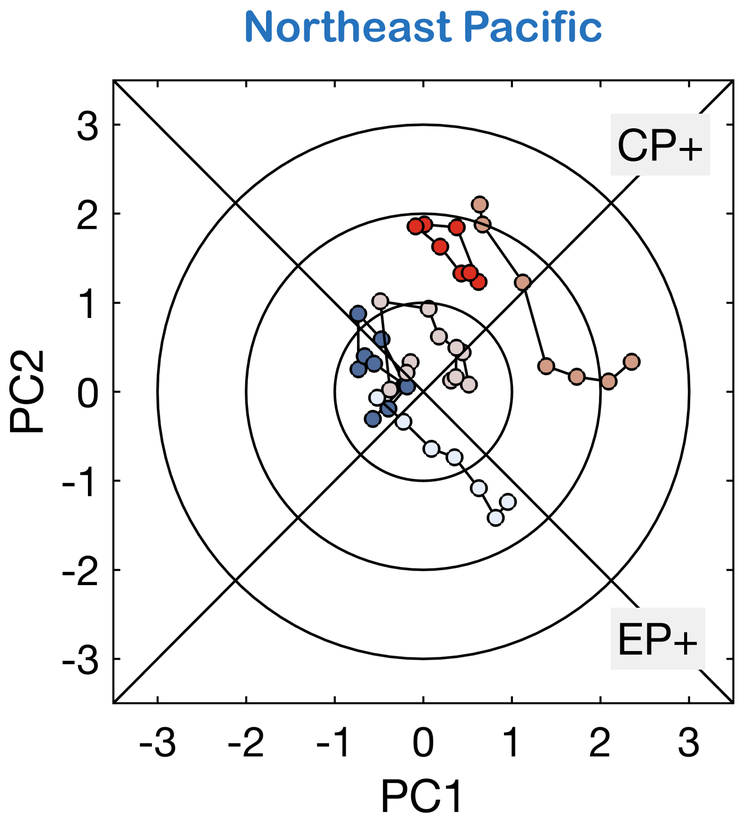
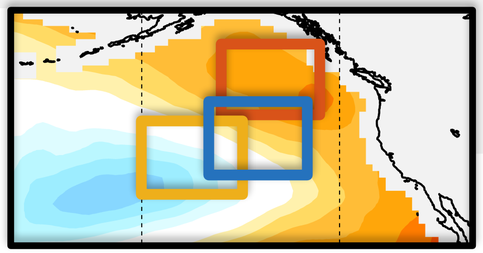
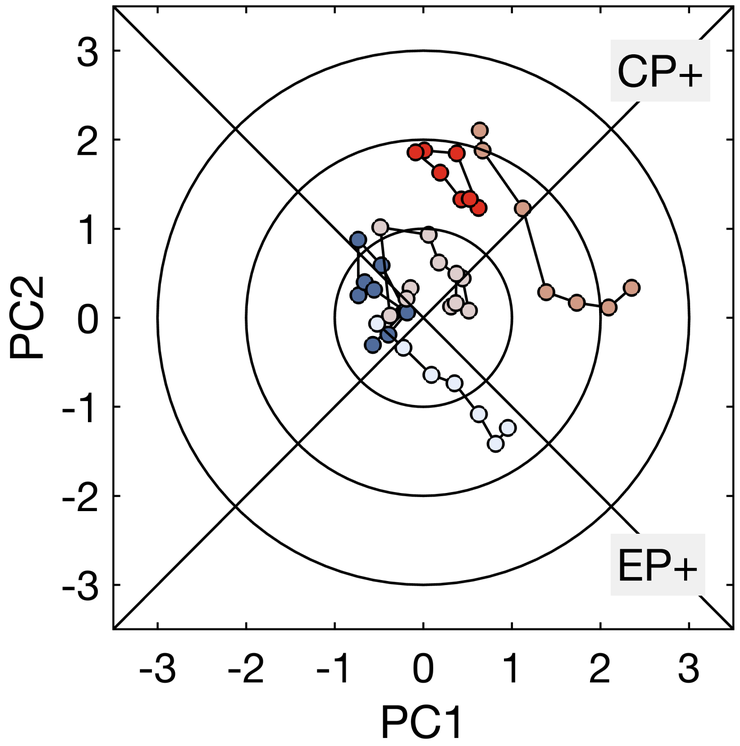


Northeast Pacific marine heatwaves and ENSO flavors

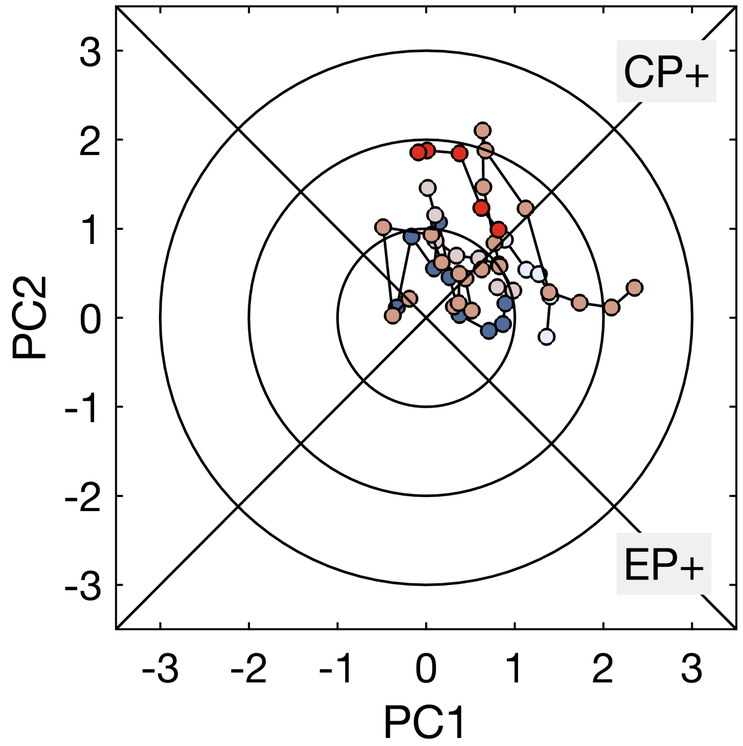


Regions relative to CP ENSO pattern

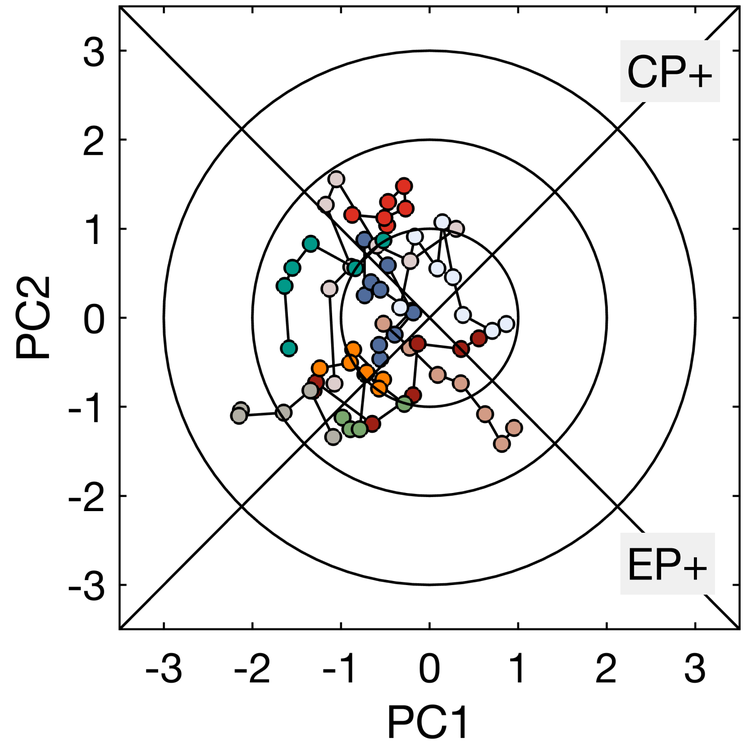
Northeast Pacific



Gulf of Alaska



Central North Pacific



Northeast Pacific marine heatwaves and ENSO flavors

CP ENSO pattern

Linear Inverse Model (LIM)

$$\frac{\mathrm{d}\mathbf{x}}{\mathrm{d}t} = \mathbf{L}\mathbf{x} + \xi$$

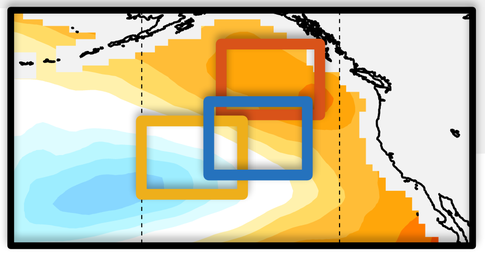
$\mathbf{x}$ - the state variable $\mathbf{L}$ - linear dynamical operator ξ - white noise

- Data-driven stochastic model trained on SSTA and SSHA reanalysis
- Generates realizations with statistics consistent with reanalysis
- Cyclostationary (CS) framework captures seasonal dependence

Penland, C. & Sardeshmukh, P. D. (1995). The optimal-growth of tropical Sea-surface temperature anomalies. j. cli*m.* **8**, 1999–2024.

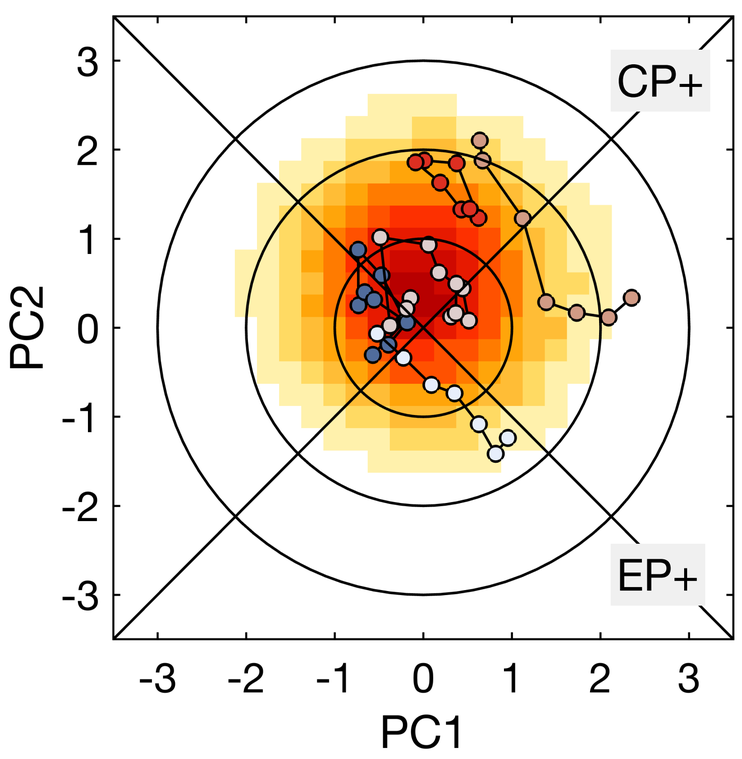
Shin, S. I., et al. (2021). "Impact of Annual Cycle on ENSO Variability and Predietability." Journal of Climate **34**(1): 171-193.

Northeast Pacific marine heatwaves and ENSO flavors



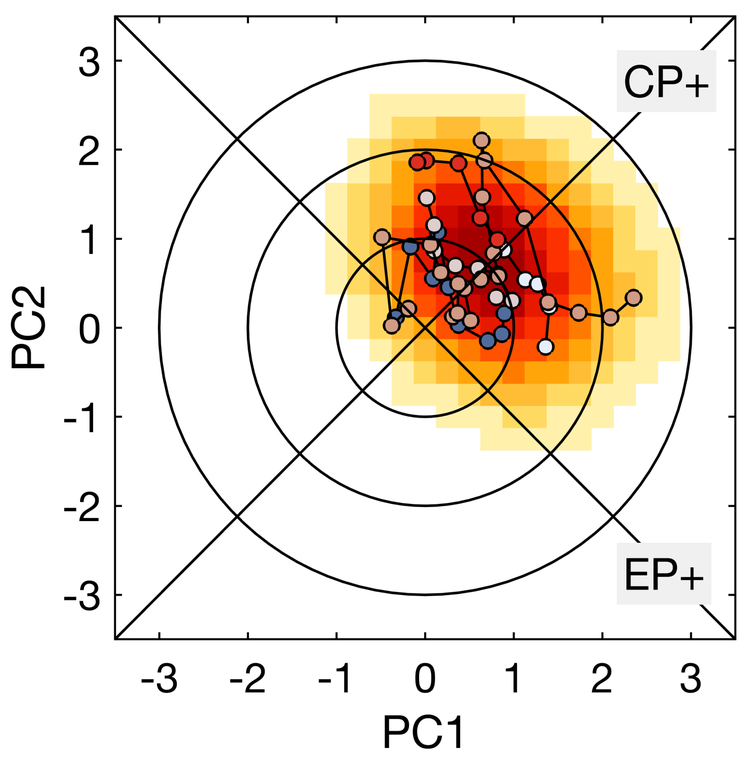
Regions relative to CP ENSO pattern

Northeast Pacific



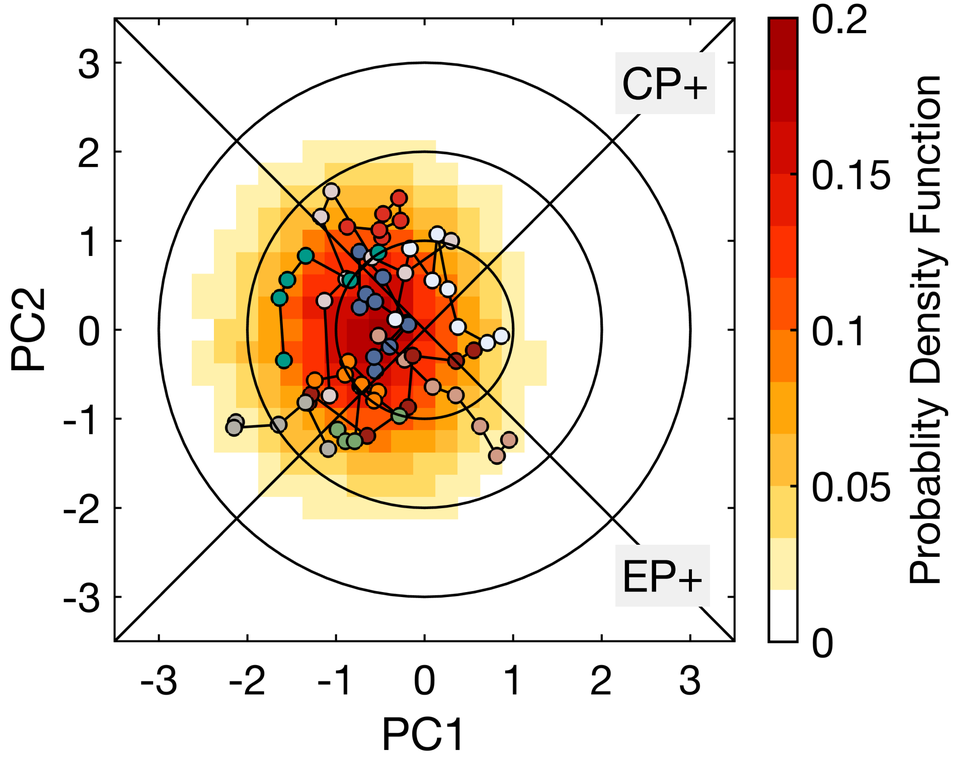
Relatively Gaussian distribution centered near the origin

Gulf of Alaska



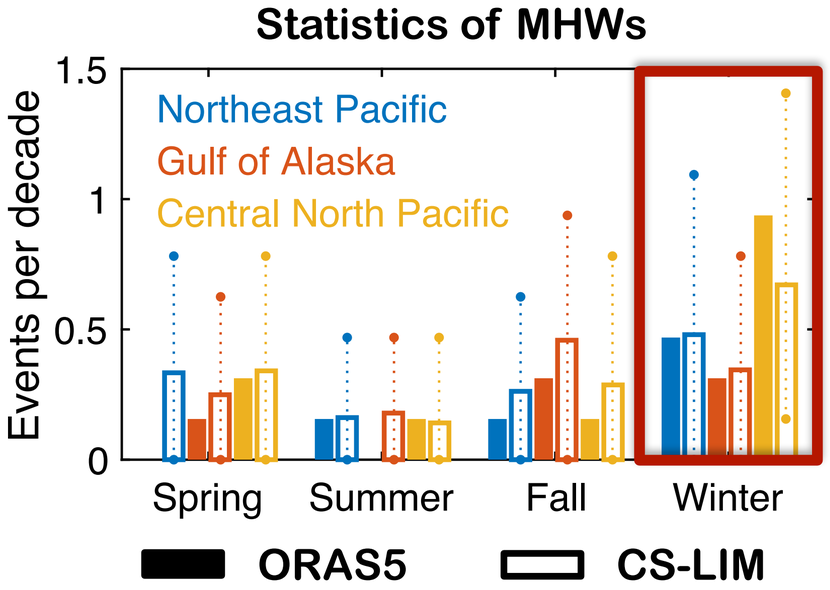
Cluster around the positive CP axis

Central North Pacific



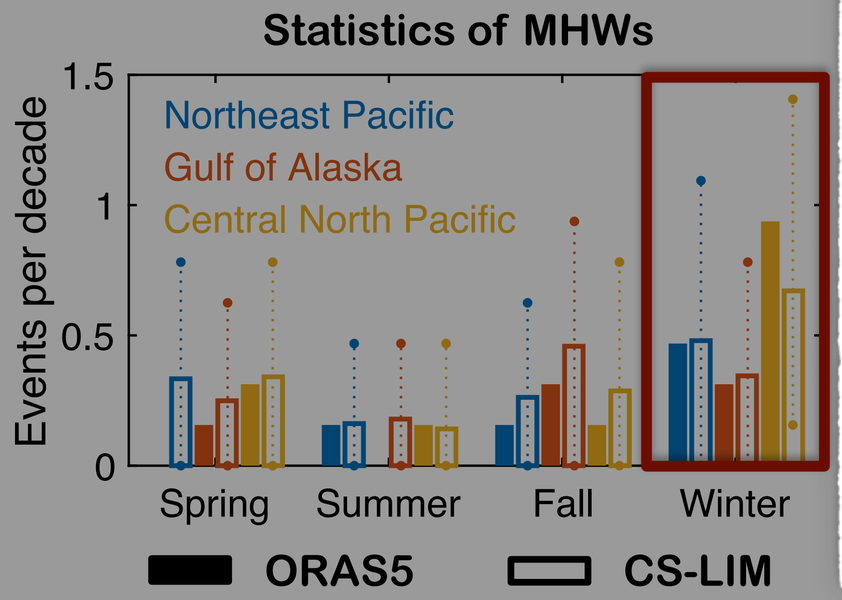
Cluster around the negative PC1

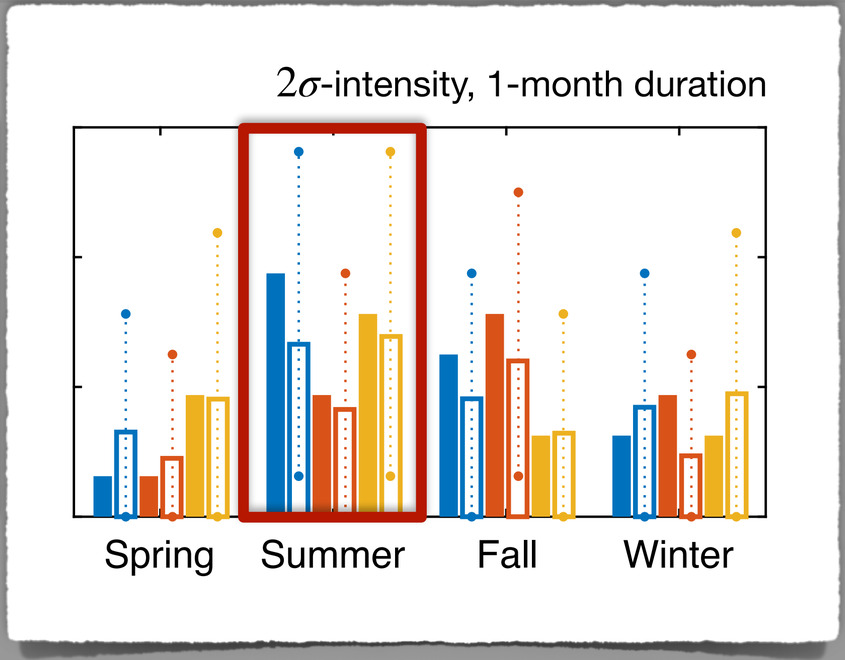
Seasonal variations of Northeast Pacific marine heatwaves



Long-lasting but moderately intense NEPac MHWs tend to start in winter

Seasonal variations of Northeast Pacific marine heatwaves





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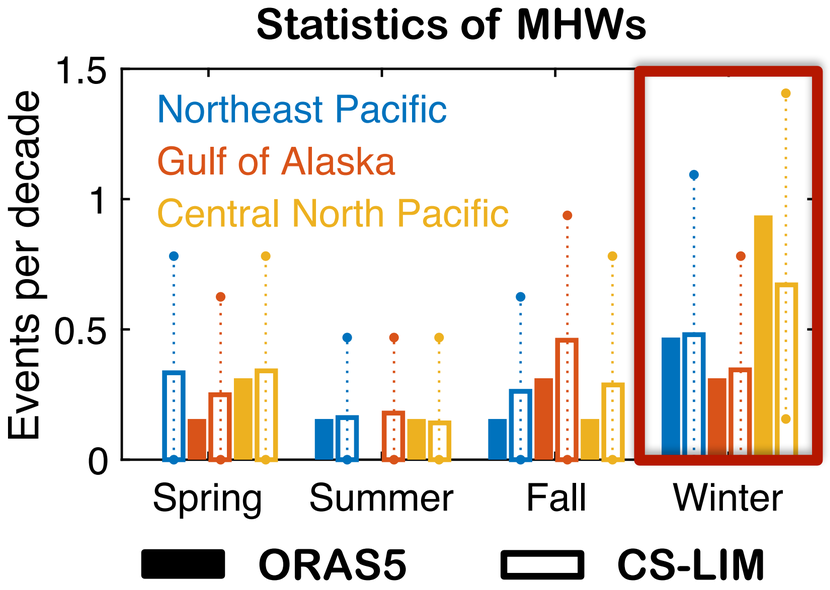

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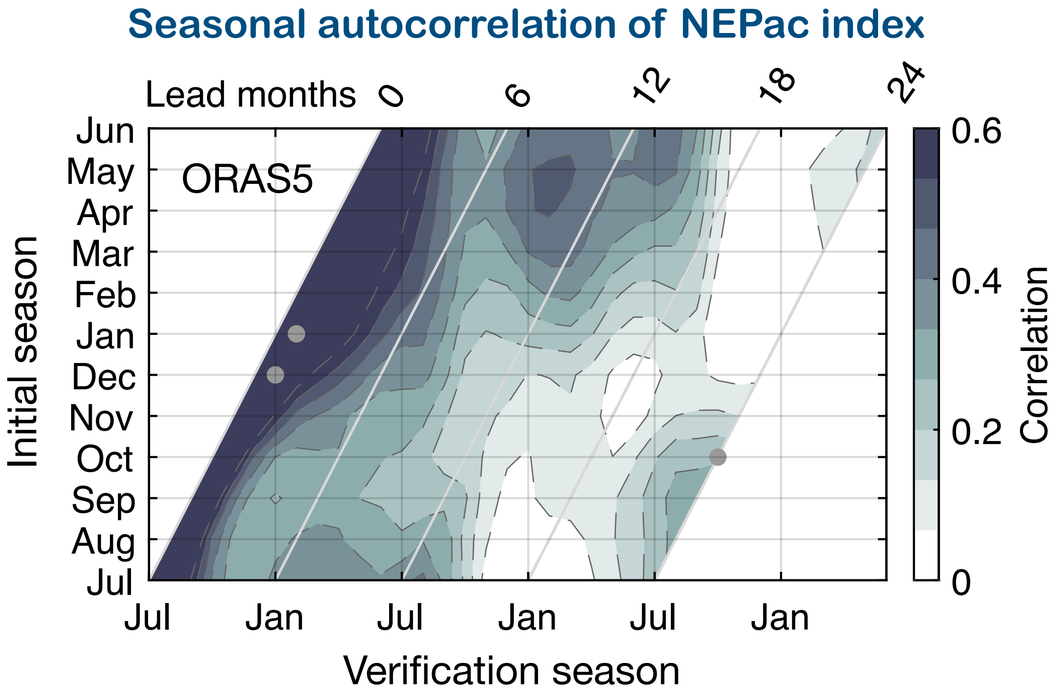

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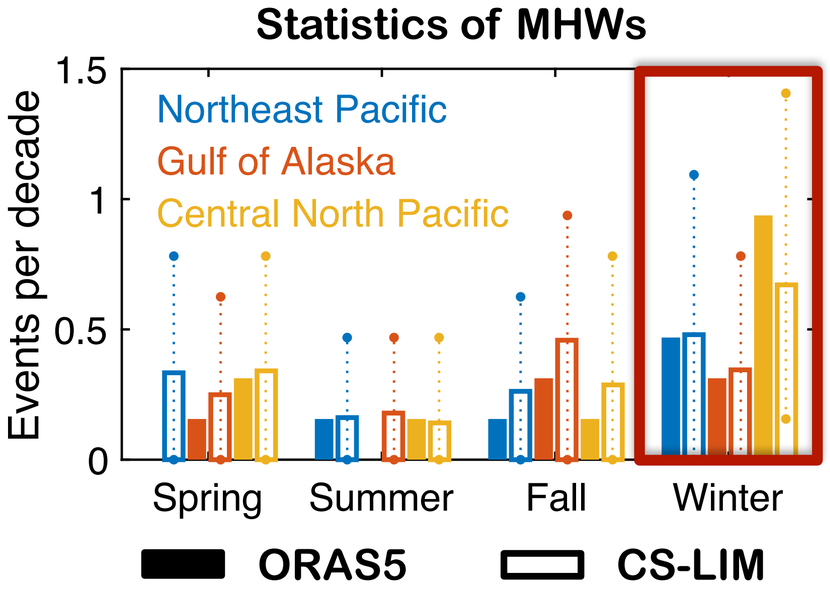

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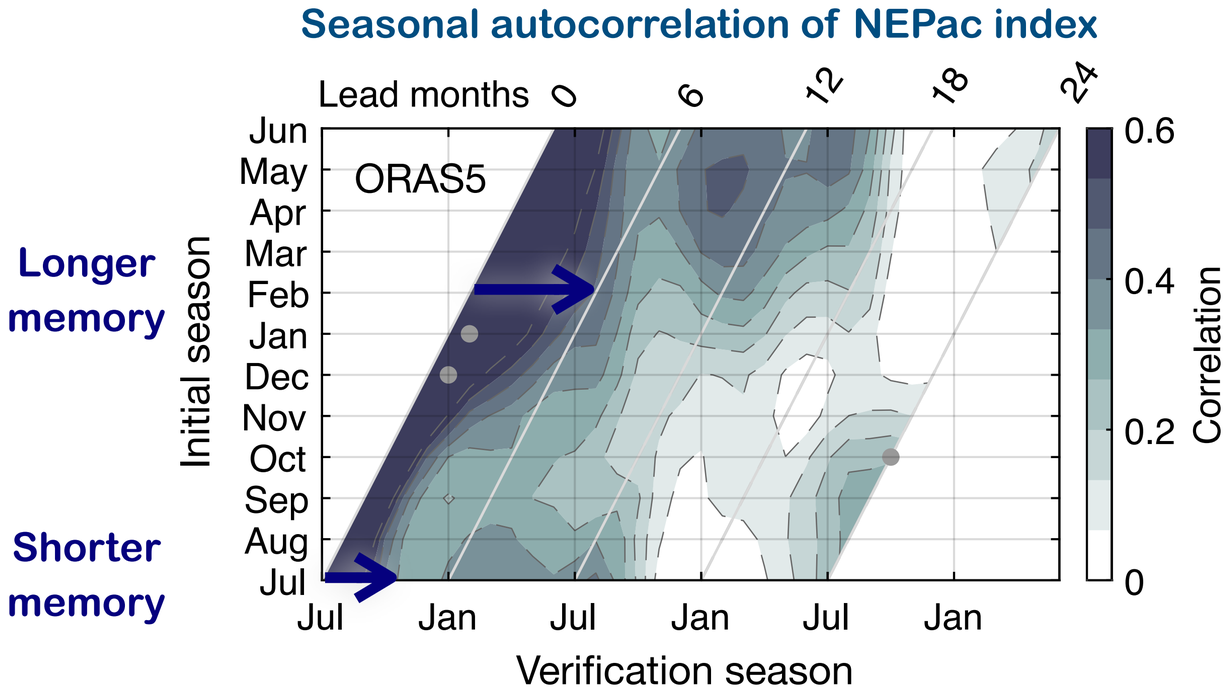

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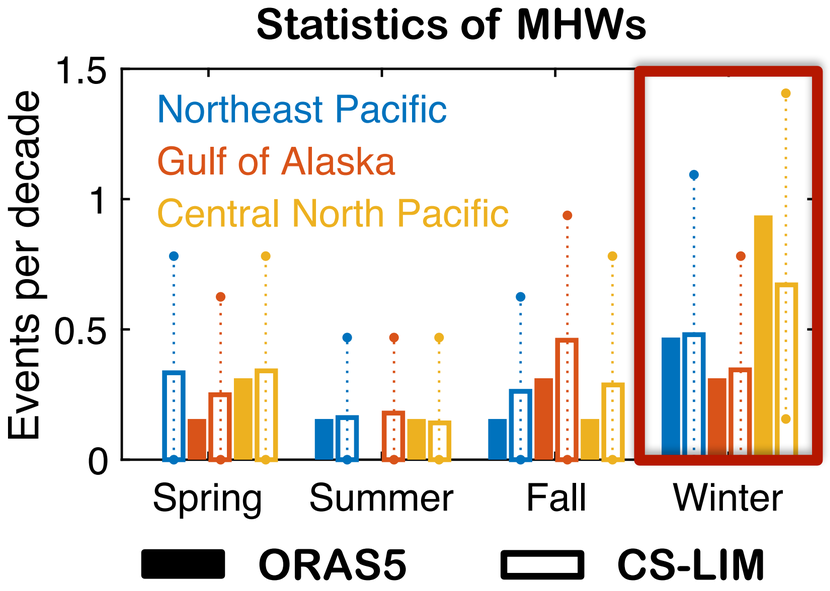

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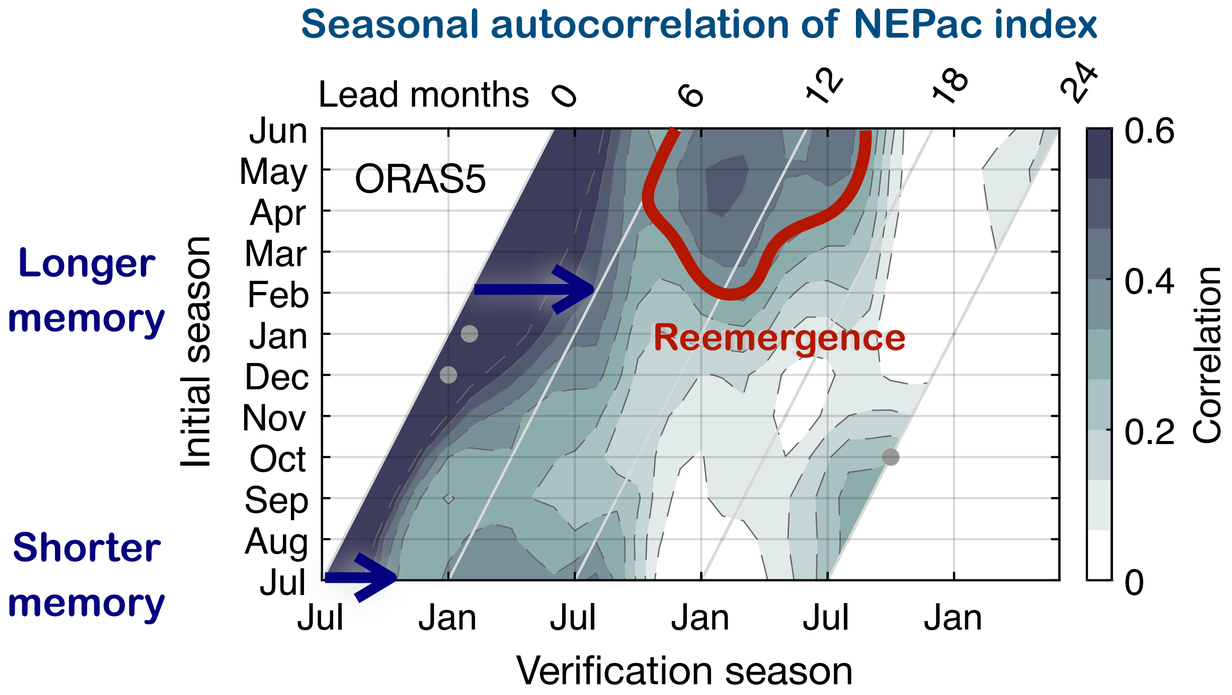
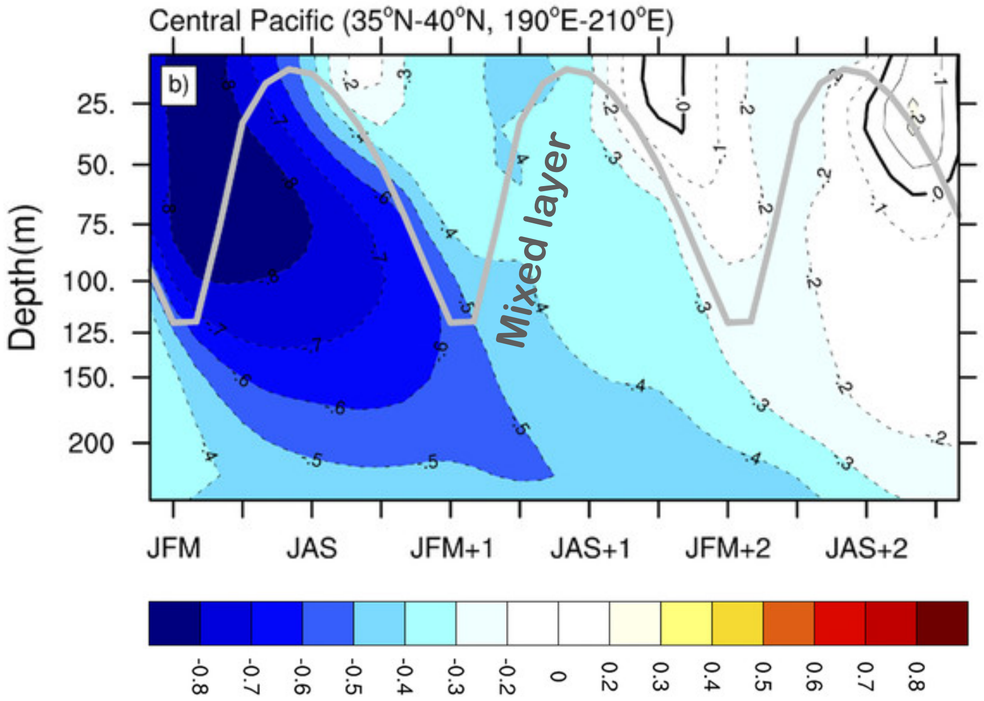


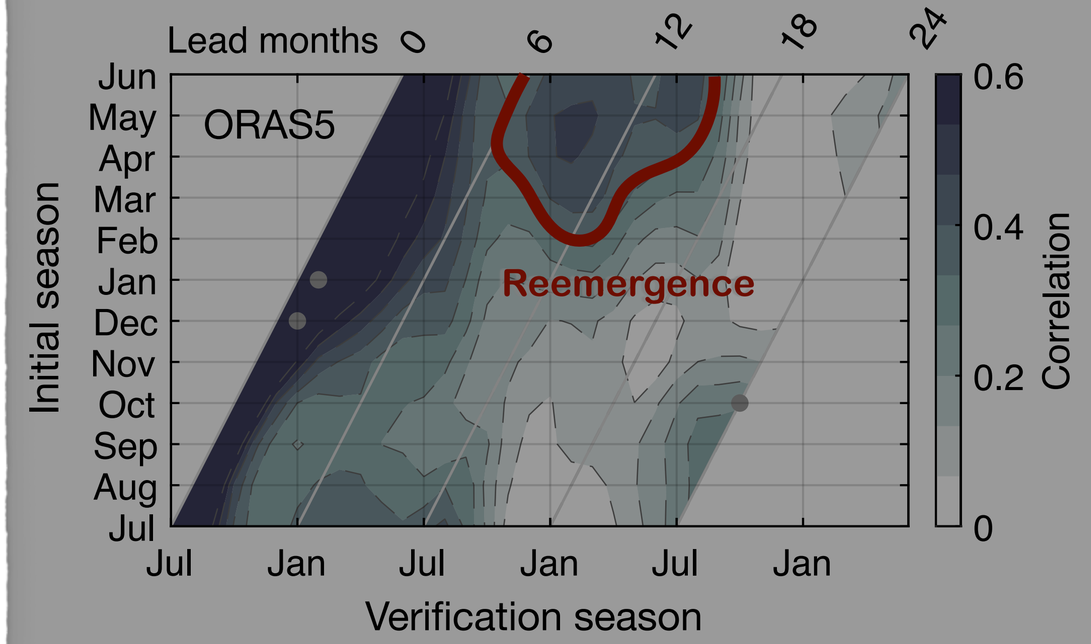
Seasonal variations of Northeast Pacific marine heatwaves

Anomalous heat trapped beneath the mixed layer "reemerge" at the surface in the following winter



Newman, M., et al. (2016). "The Pacific Decadal Oscillation, Revisited." Journal of Climate **29**(12): 4399-4427.

Seasonal autocorrelation of NEPac index



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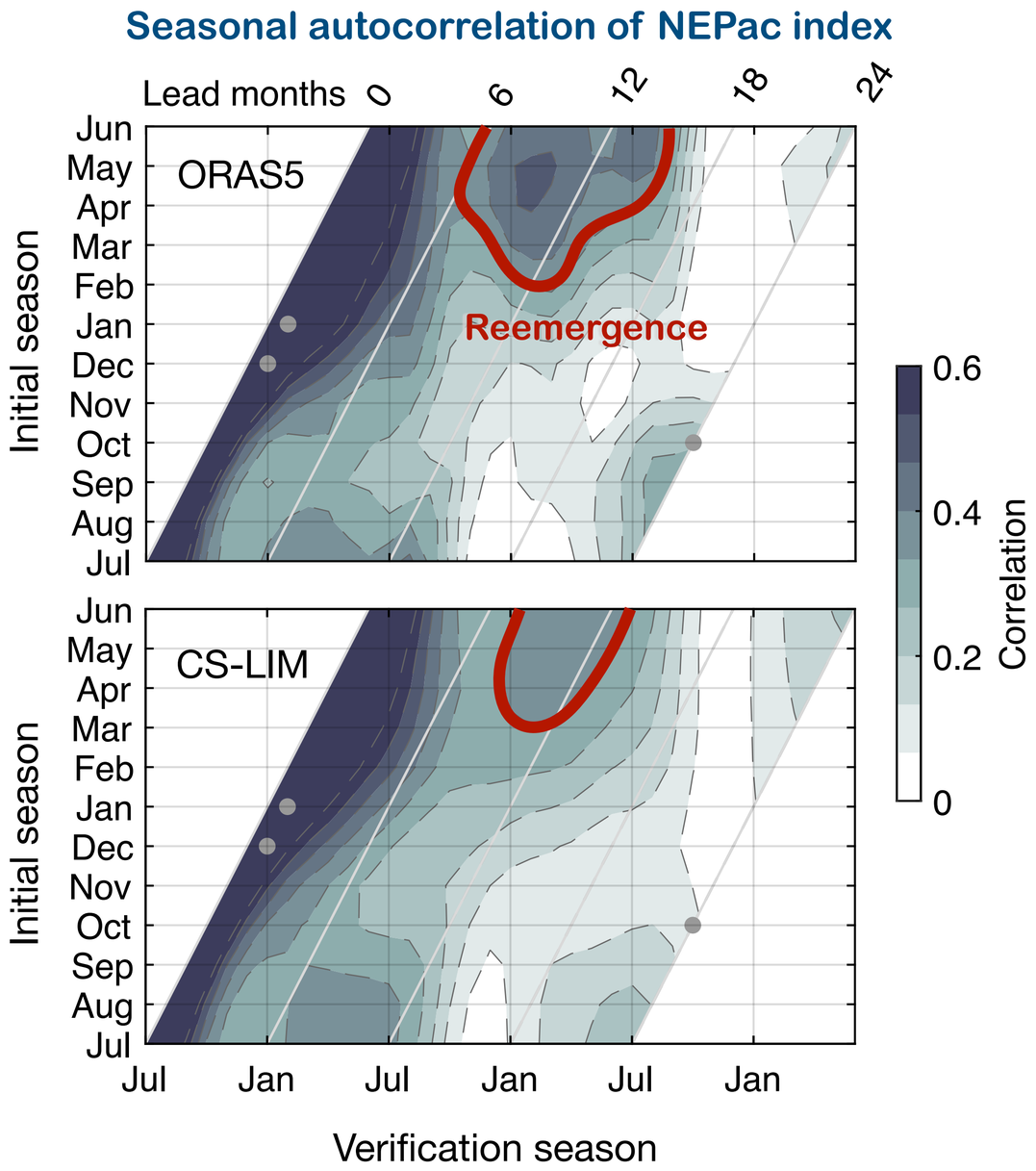

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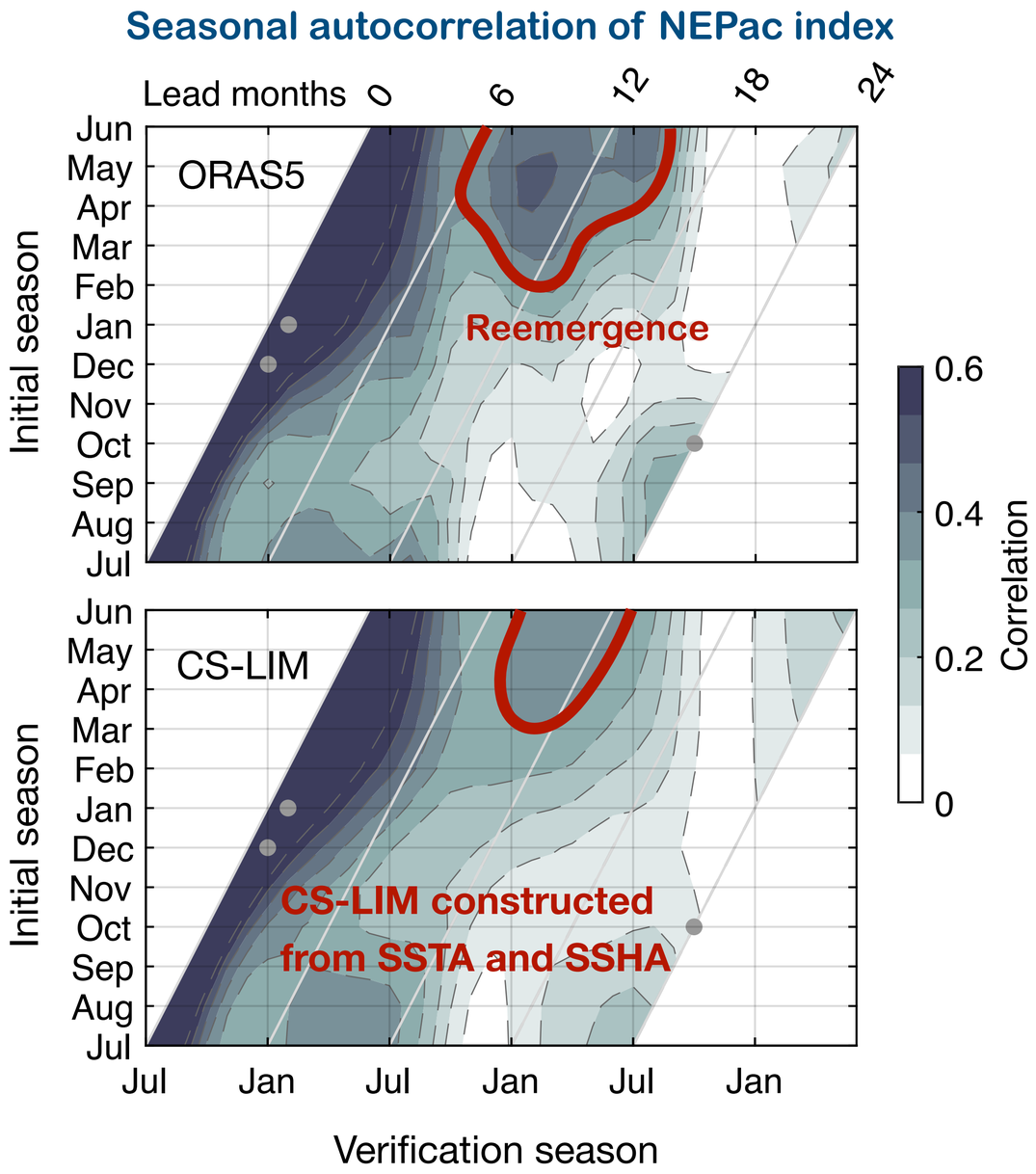
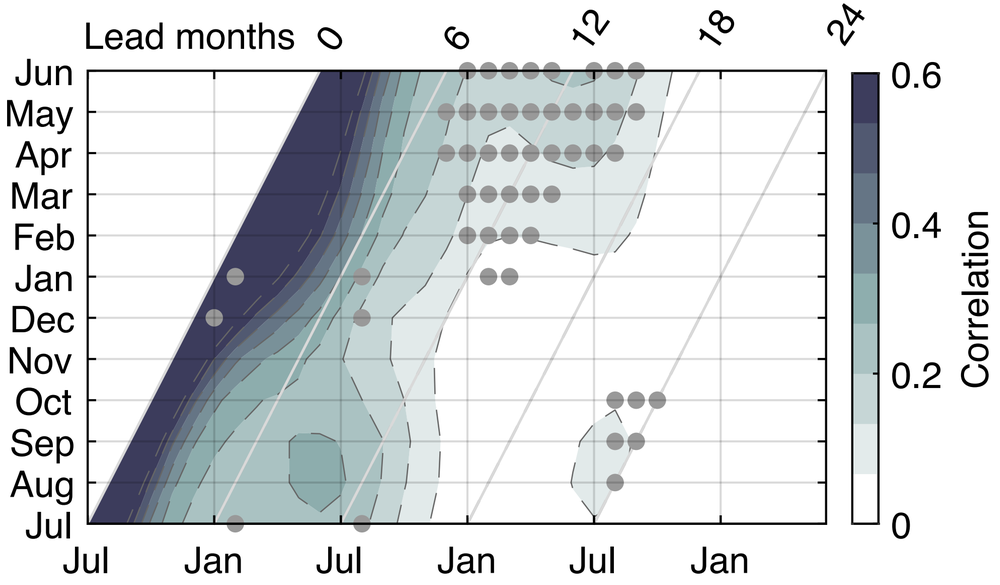


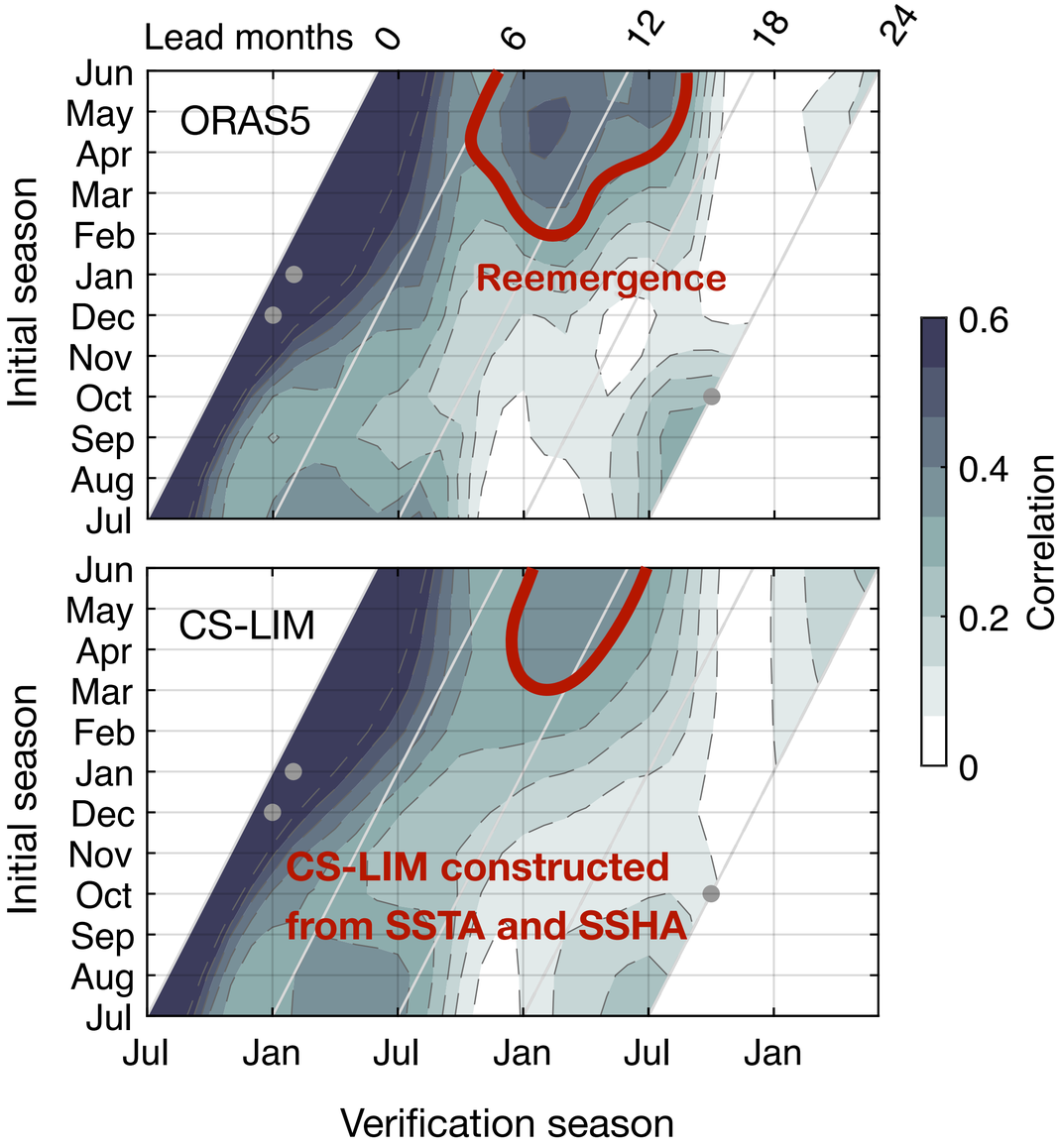
Seasonal variations of Northeast Pacific marine heatwaves

CS-LIM constructed only from SSTA



Gray dots mark where the CS-LIM significantly differs from ORAS5

Seasonal autocorrelation of NEPac index



Conclusion & Takeaways

1. Northeast Pacific marine heatwaves occur year-round but winter-onset events are more frequent.
2. Different regions of Northeast Pacific are associated with different types of ENSO teleconnections.
3. Seasonal ocean memory, including reemergence-like behavior, contributes to wintertime persistence and recurrence of marine heatwaves.
4. The relative importance of tropical forcing and North Pacific processes varies by region and season, producing distinct marine heatwave “flavors”.

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