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Pacific Decadal Variability in CCSM3

Wilbert Weijer[1] and Niklas Schneider[2],
[1]Los Alamos National Laboratory, Los Alamos, NM; [2]University of Hawai'i at Manoa, Honolulu, HI

SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY
UNIVERSITY OF HAWAI'I AT MĀNOA

Introduction

A critical question regarding low-frequency climate variability is whether the climate system contains oscillatory modes that can be resonantly excited. The North Pacific climate system in the CCSM3 shows significant spectral peaks at 17 and 8.5 yr periods, suggesting the resonant excitation of such oscillatory modes (Figure 1). Here we study the dynamics of this resonance.

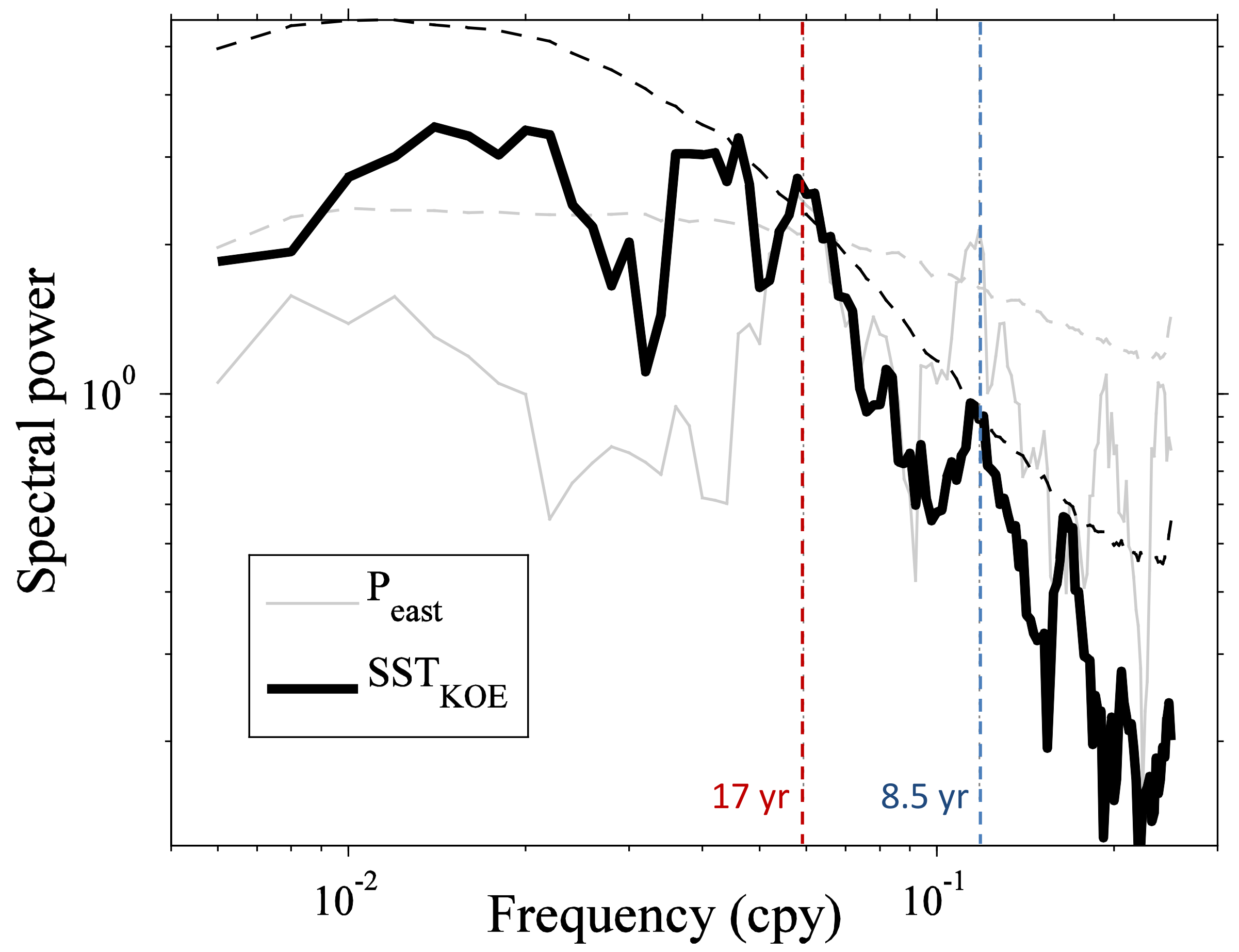

Figure 1: Spectra of ***P_{east}*** *and* ***SST_{KOE}****. The time series share spectral peaks at 17 and 8.5 yr, indicating a basin-wide resonance.*

Data and Analysis Method

Model output used in this study is

- Pre-industrial control integration of the CCSM3
- 500 yr of annually-averaged data

Primary index is ***P_{east}*** which is baroclinic pressure integrated over the upper 500 m, and averaged along the eastern basin boundary (from the equator to the Gulf of Alaska). ***P_{east}*** displays significant spectral peaks at 17 and 8.5 yr periods (Fig. 1), and is coherent with ***SST_{KOE}*** (SST in the Kuroshio-Oyashio Extension (KOE) region). This shows the climatic relevance of this mode and its basin-wide range.

Other variables that play a role in the resonance should:

- be coherent with ***P_{east}*** , and
- display significantly enhanced spectral energy

on these time scales. So we diagnose the coherence, coherence phase, and spectral energy of different variables at 17 and 8.5 yr periodicities. Here we focus on the 17-yr mode.

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Mechanism

A critical ingredient of the 17-yr mode is advection of temperature and salt anomalies across the North Pacific in a spicy combination. At 500 m depth, it takes the mean flow exactly 17 yr to advect spiciness anomalies across the North Pacific (Fig. 2). At depth, Rossby wave activity can be noticed (Fig. 3).

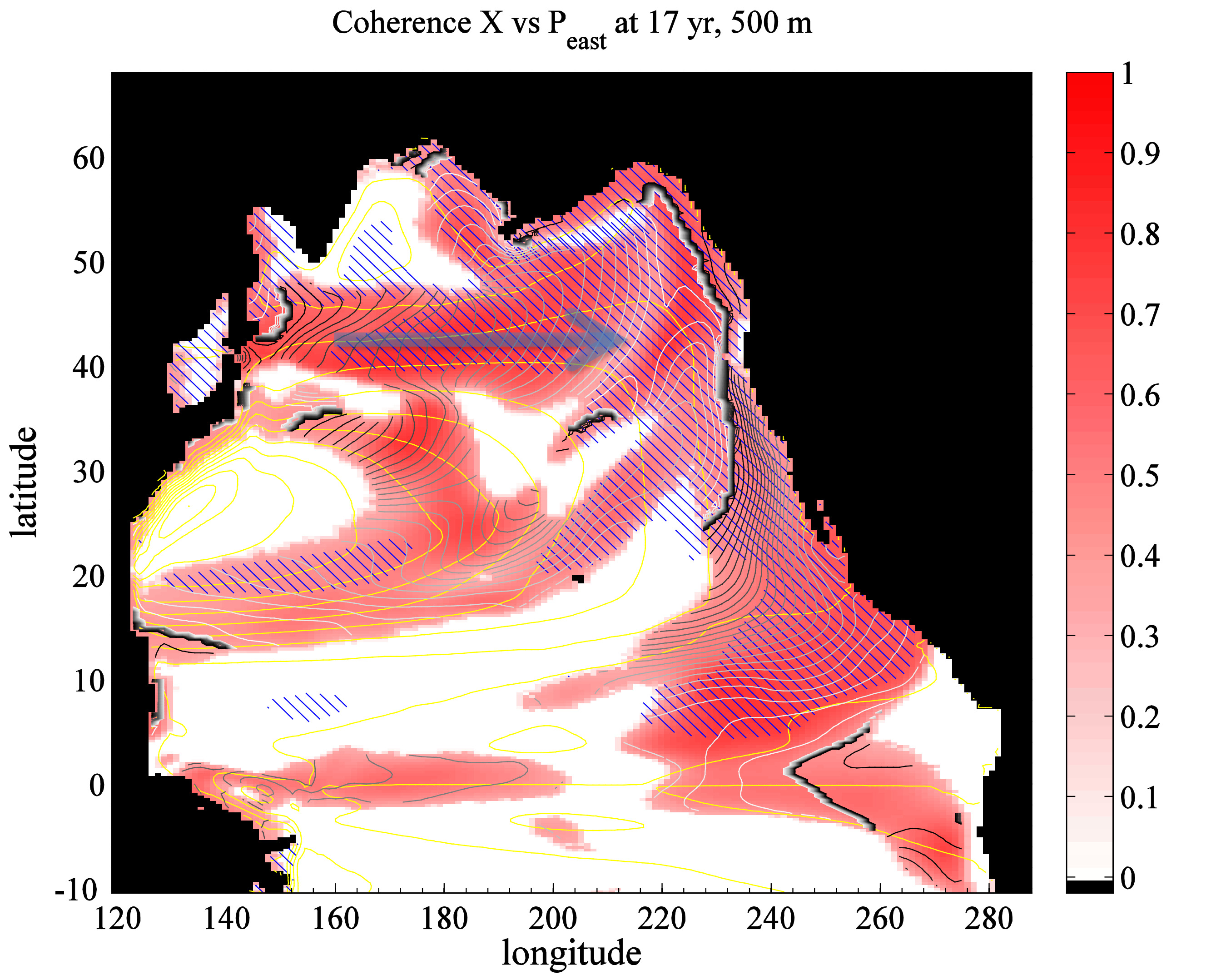

Figure 2: (Squared) coherence (shading) and coherence phase (contours) at 17 yr between spiciness ***X*** *at 500 m and* ***P_{east}*** *(wherever significant). Contours range from black (360°) to white (0°) with 15° interval, with* ***X*** *leading* ***P_{east}*** *; so phase propagates from black to white. Blue hatching indicates where* ***X*** *displays significantly enhanced power at this time scale, compared to red noise. Yellow contours show approximate stream function at that level (assuming divergence free flow).*

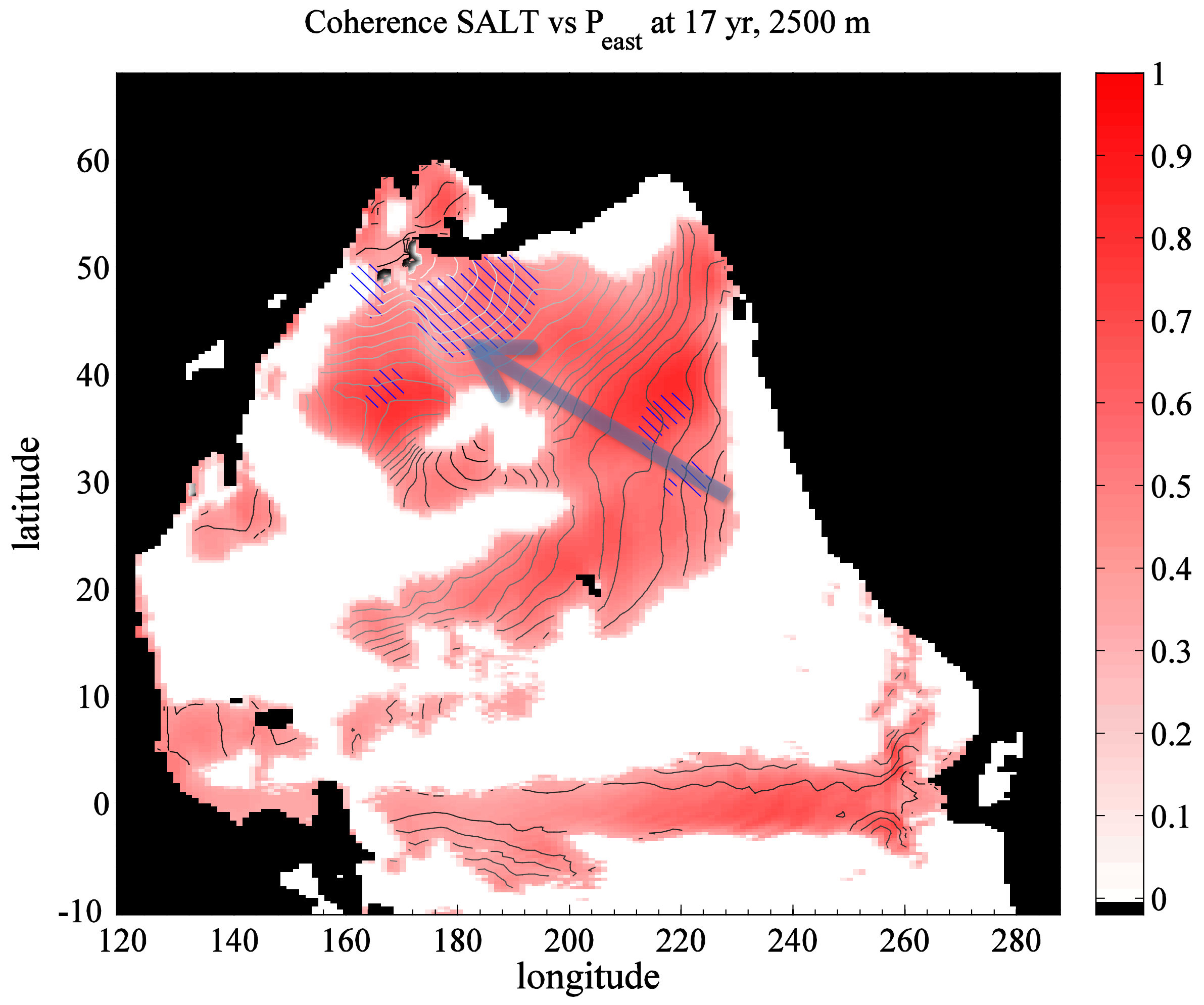

Figure 3: As Fig. 2, but for salinity at 2500 m depth.

Open questions

Several key elements of the resonances are still unclear:

How does the spicy signal generate a pressure anomaly along the eastern basin boundary?

- Damping of the thermal signal by surface fluxes, exposing the salinity signal?
- An atmospheric response to the SST anomalies that forces coastal upwelling?

How is the signal transmitted back to the KOE region?

- Barotropic gyre adjustment (Fig. 4)?
- Baroclinic Rossby waves?
- Boundary trapped waves?

How is a new spicy signal generated?

- Meridional displacement of the KOE?
- Strengthening of the subpolar and subtropical gyres?

What role does the atmosphere play in the resonance?

- Active amplification of the oceanic signal?
- Passive forcing though advective resonance?

How are the 17 and 8.5 yr cycles related?

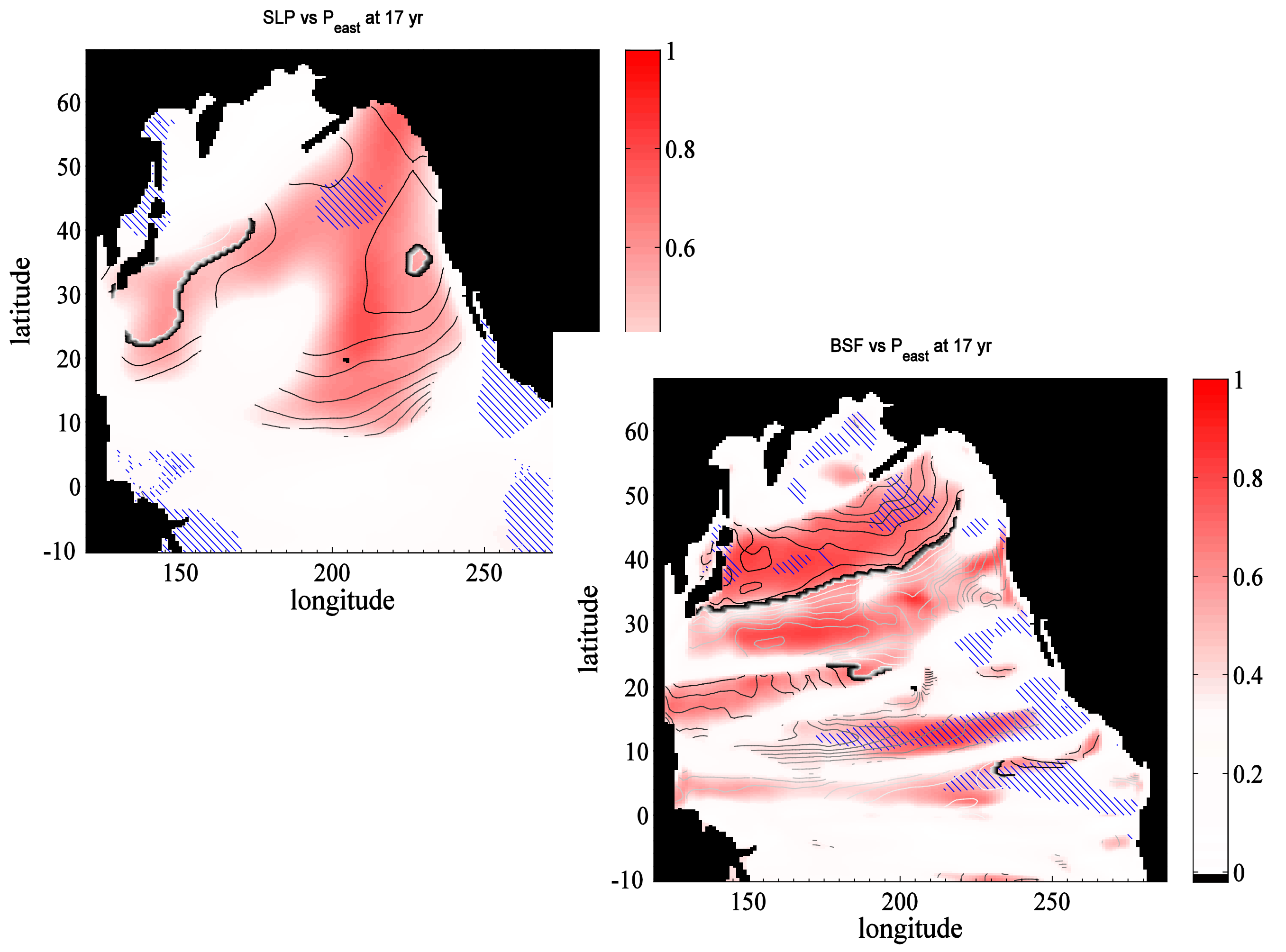

Figure 4: As Fig. 2, but for sea level pressure (SLP) and barotropic stream function (BSF). Large regions exist that fluctuate coherently with ***P_{east}****, but without enhanced spectral power.*

Conclusions

- North Pacific climate in the CCSM3 displays significantly enhanced power at 17 and 8.5 yr time scales
- Ocean dynamics play a critical role
- Time scale seems to be set by eastward advection, rather than westward Rossby wave propagation