Dynamical links between the Kuroshio & Oyashio Extensions: A mechanism for enhanced decadal variability in the N Pacific

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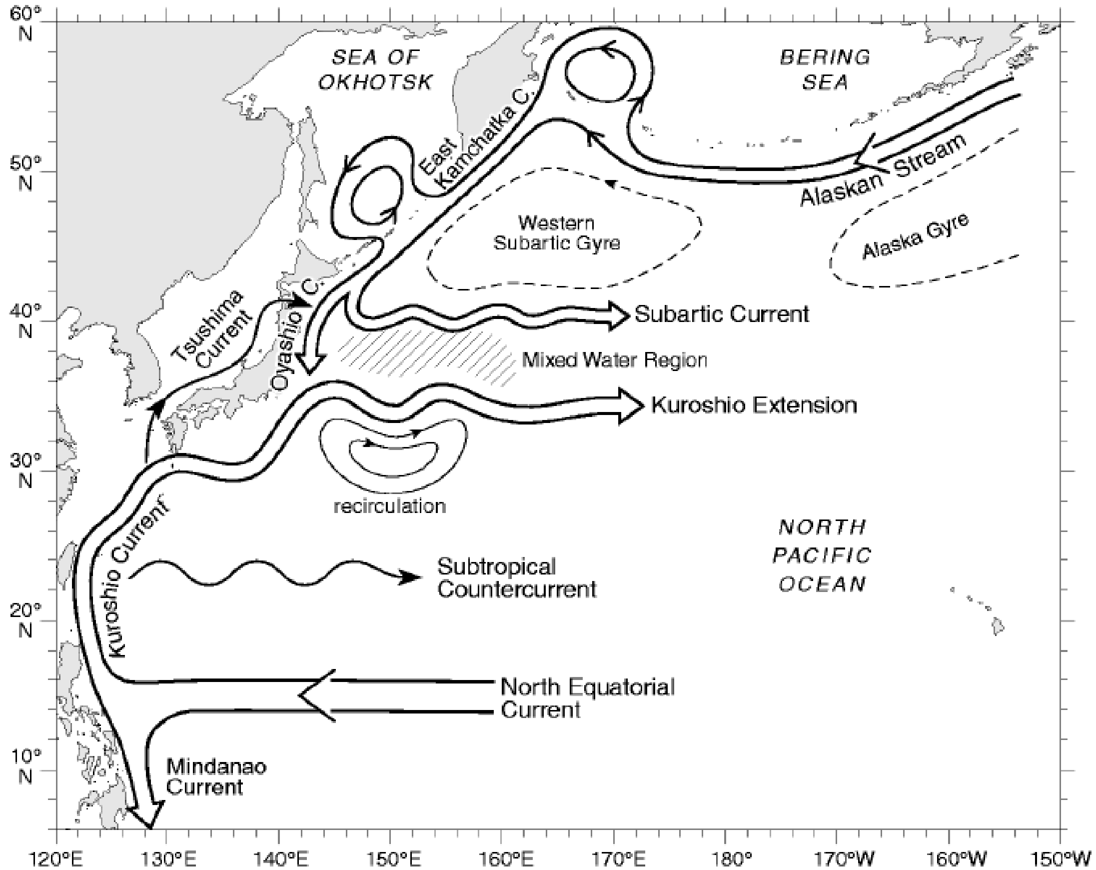
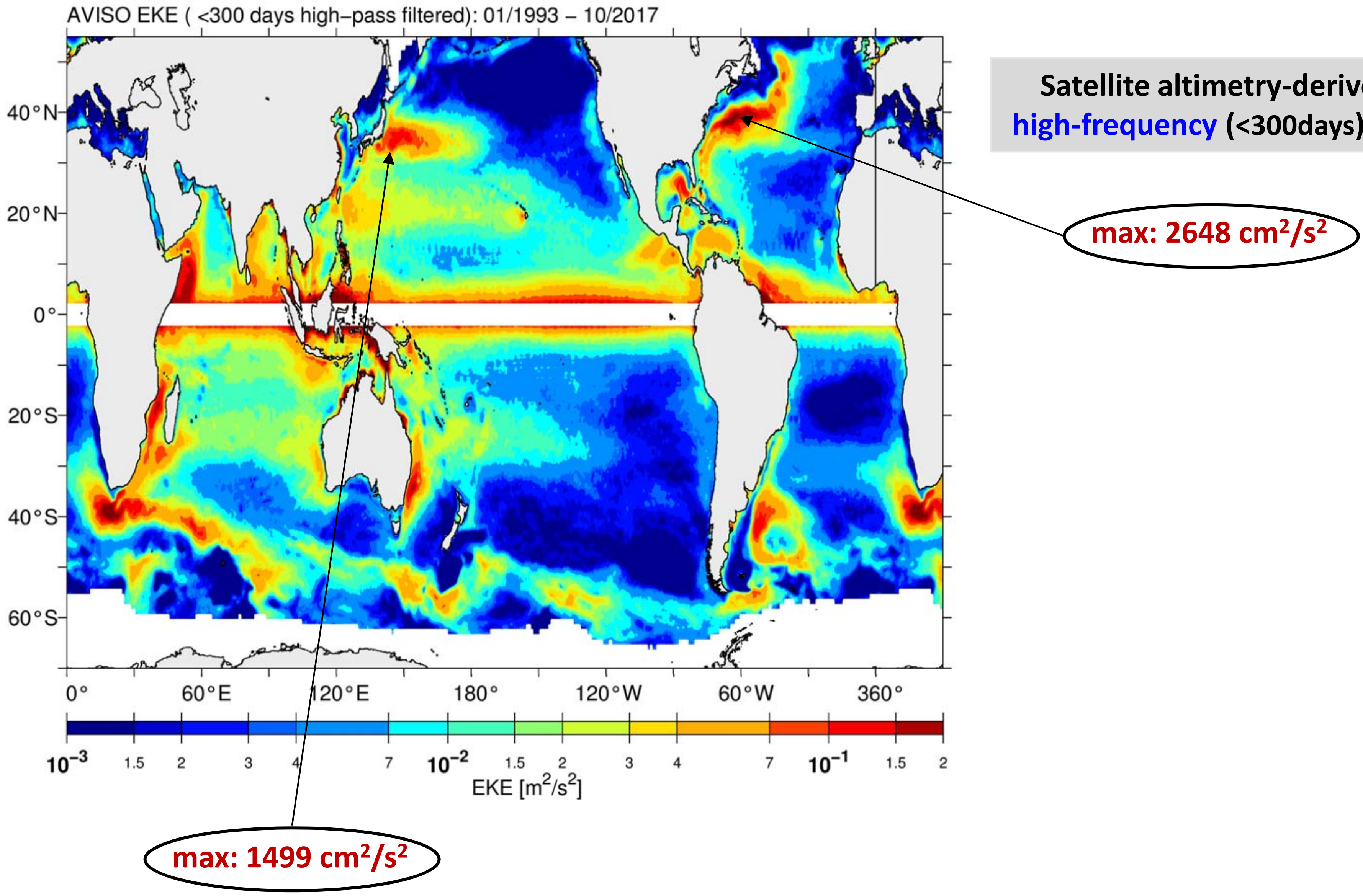


OSTST Meeting, Miami, FL, 23-27 October 2017

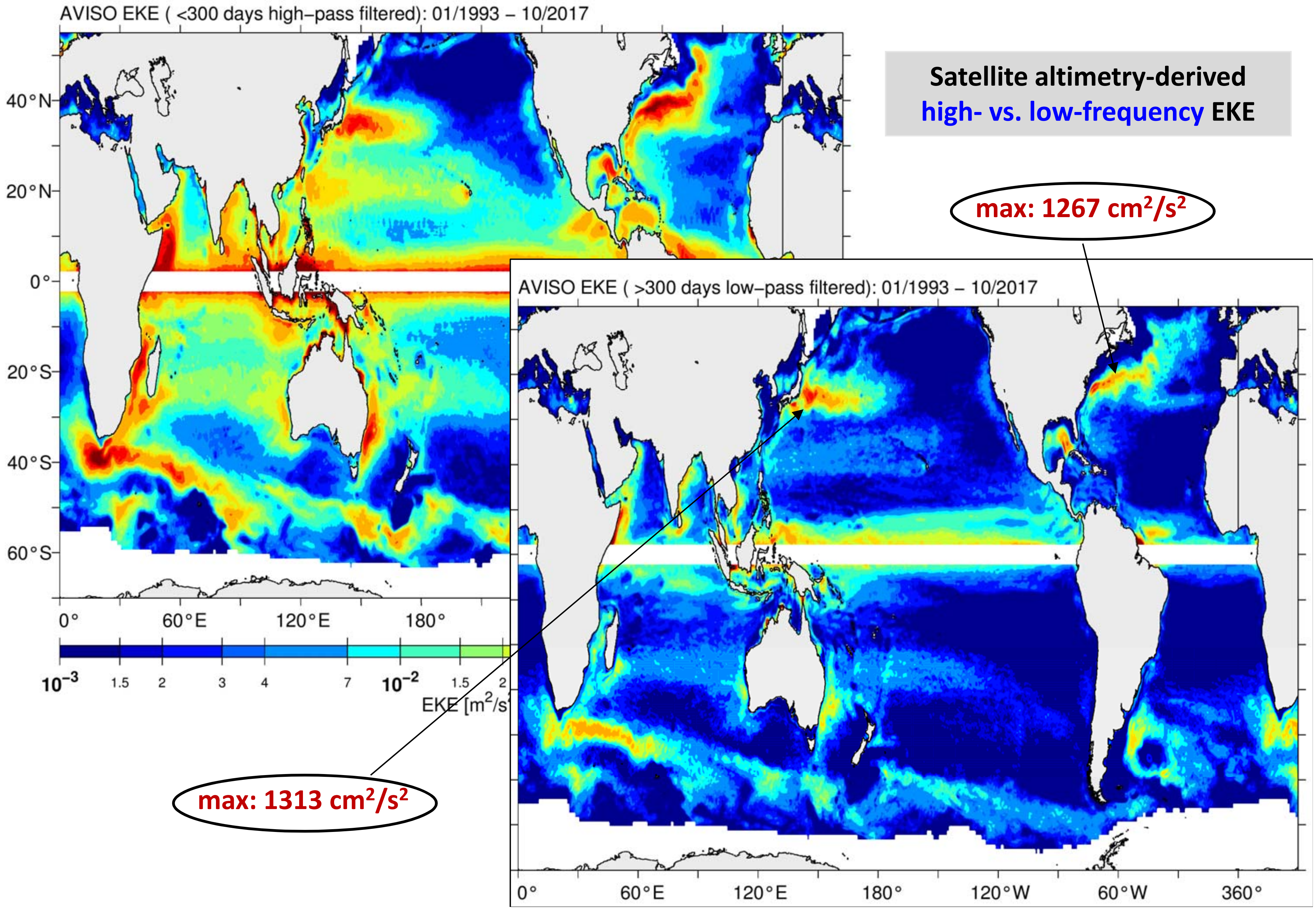
KE has the highest mesoscale eddy variability in the Pacific Ocean



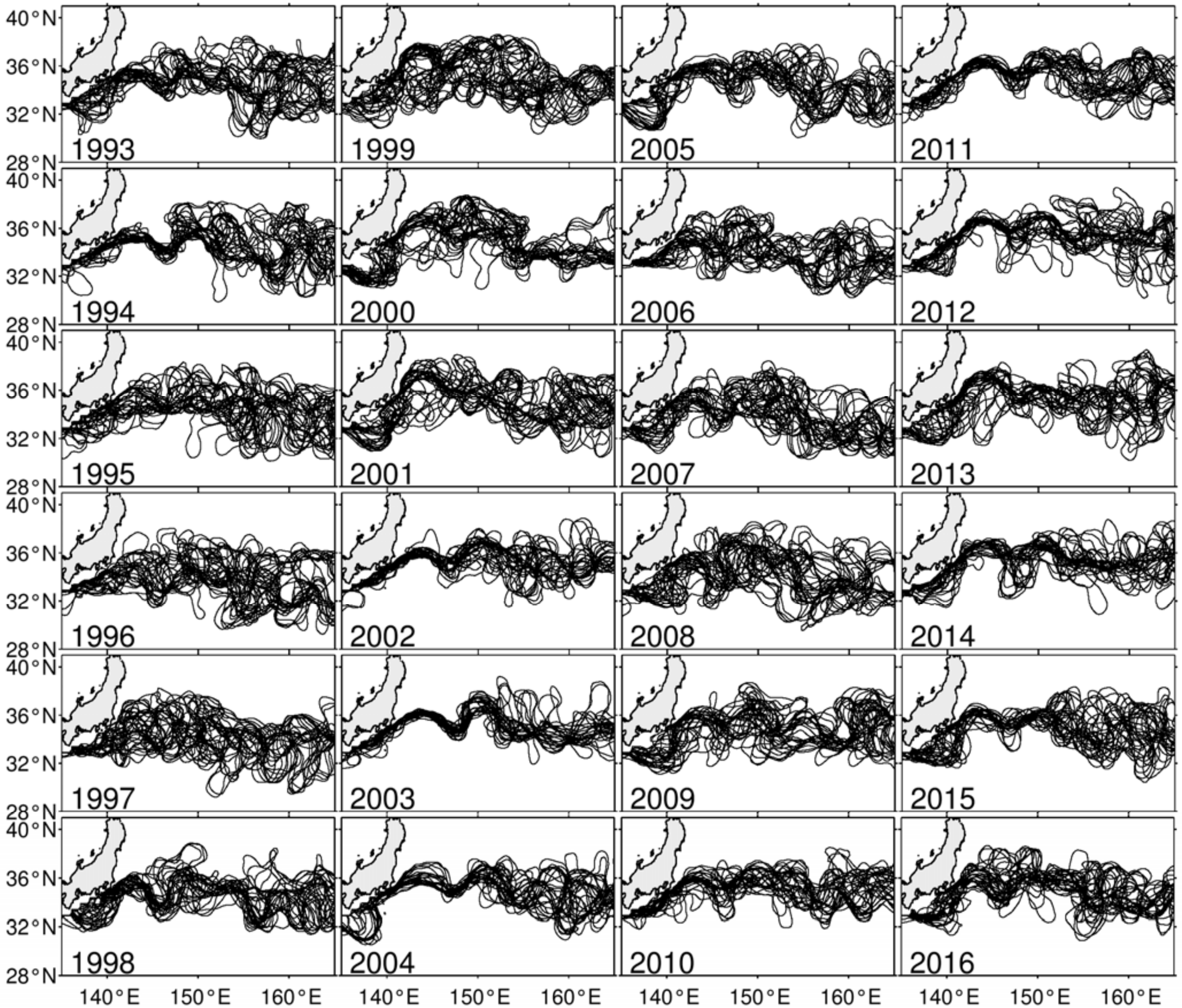
Satellite altimetry-derived
high-frequency (<300days) EKE

KE has the highest low-frequency circulation variability in world oceans

Satellite altimetry-derived
high- vs. low-frequency EKE

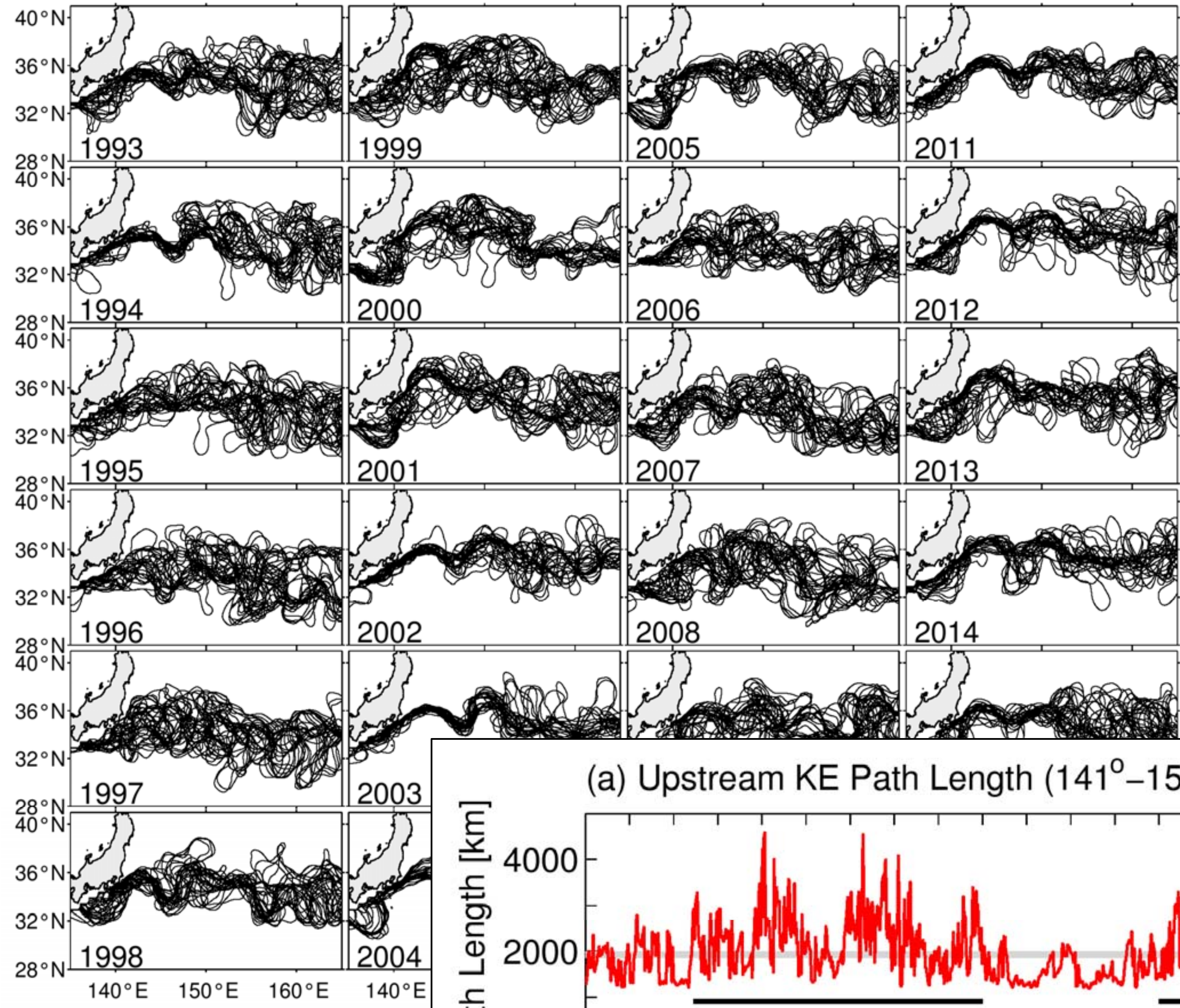


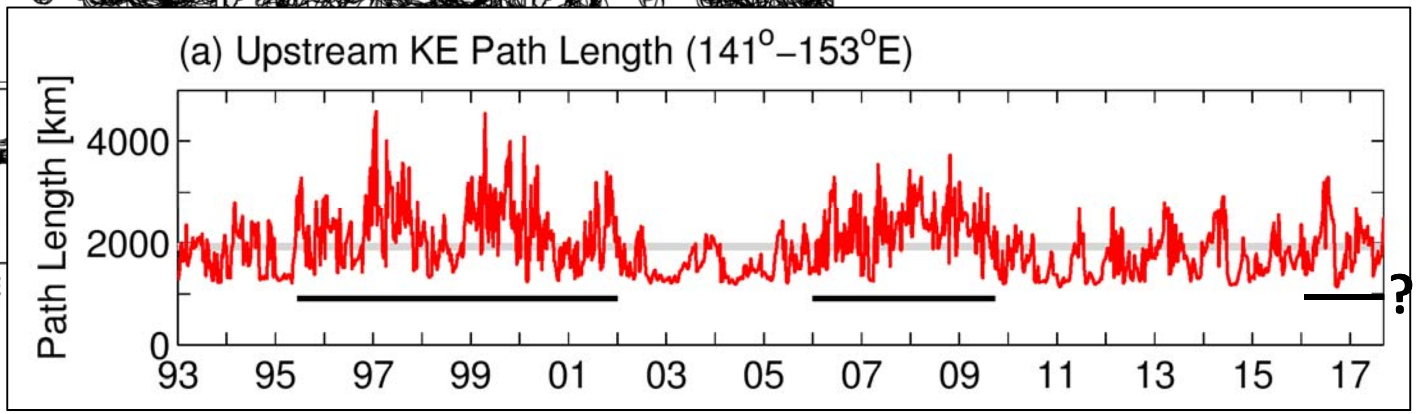
Yearly maps of bi-weekly paths of the Kuroshio/KE jet



Alternation between stable versus unstable states

Yearly maps of bi-weekly paths of the Kuroshio/KE jet

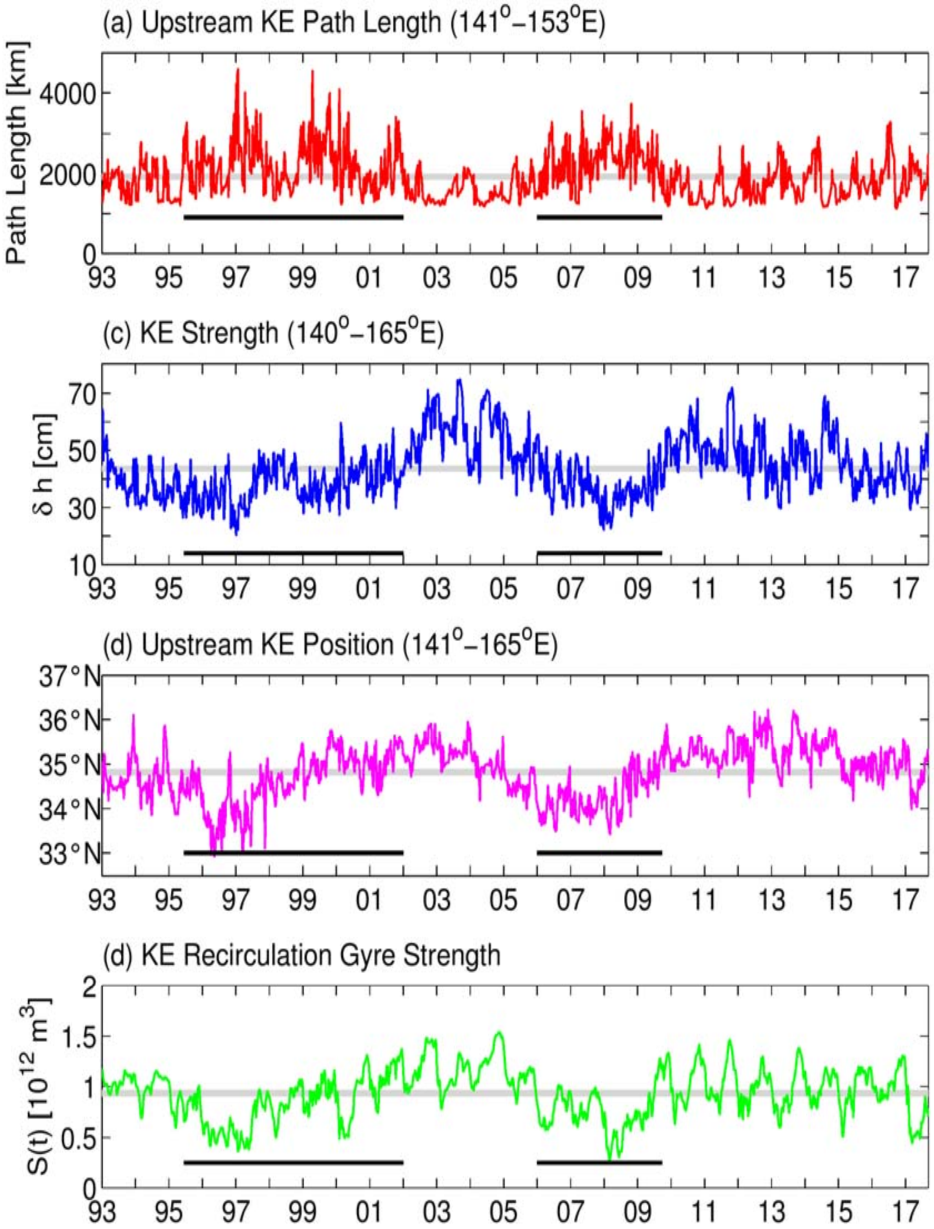




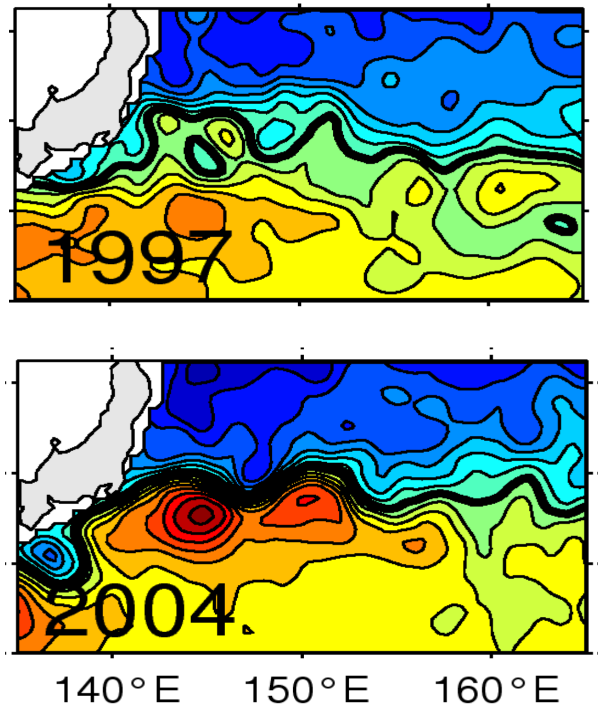
Stable yrs: 1993-94, 2002-04, 2010-15

Unstable yrs: 1996-2001, 2006-09

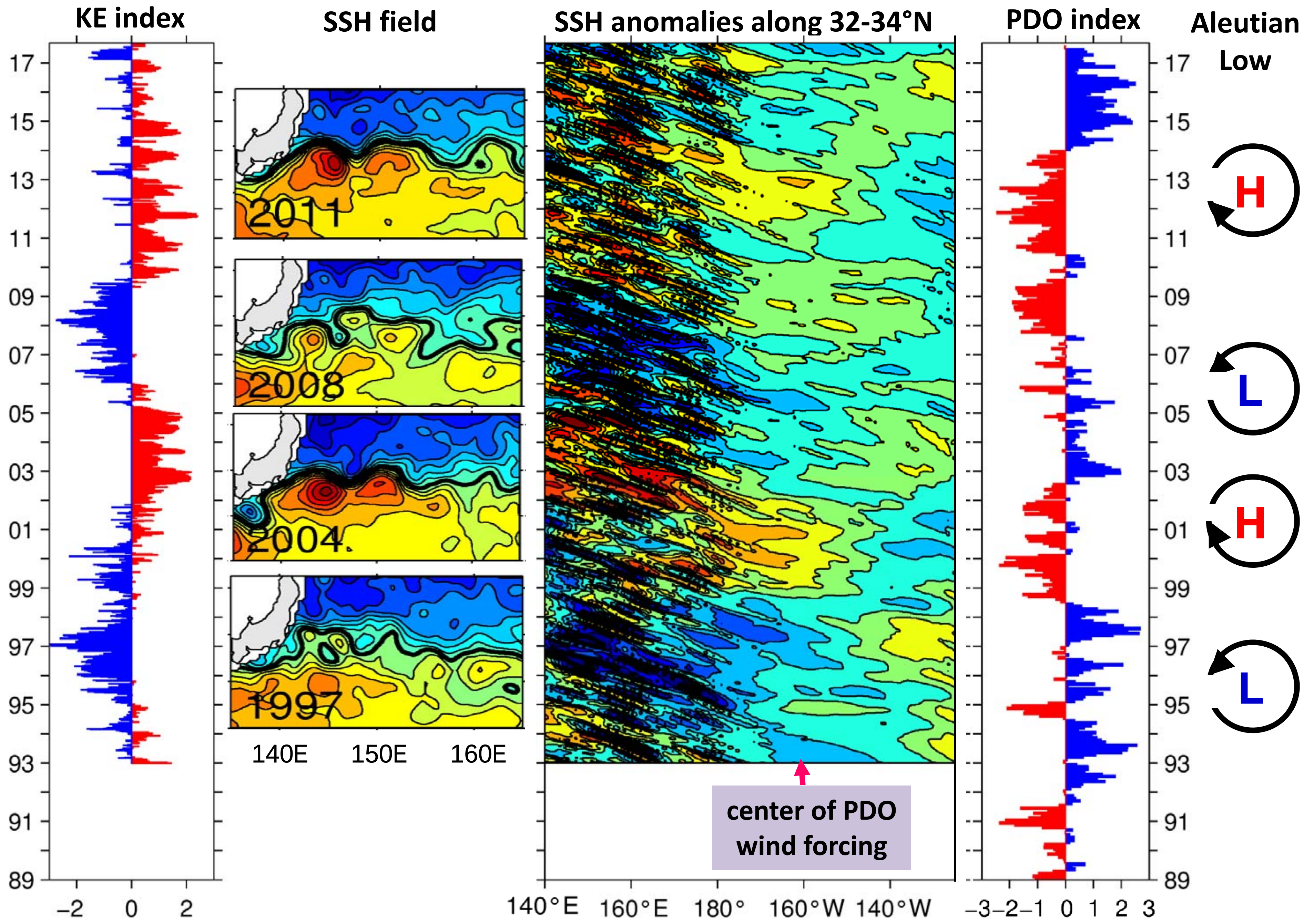
Other dynamical quantities representing the decadal KE variability



Typical yearly SSH patterns in unstable vs. stable states

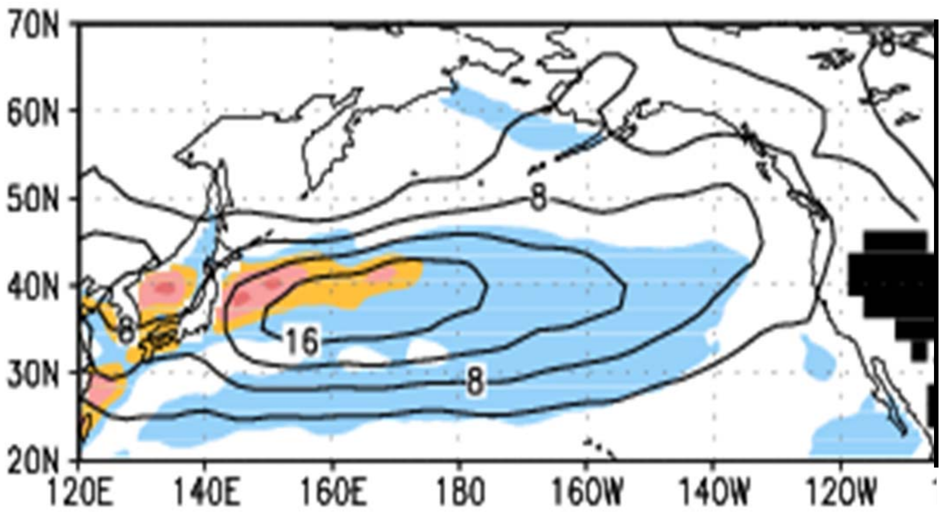


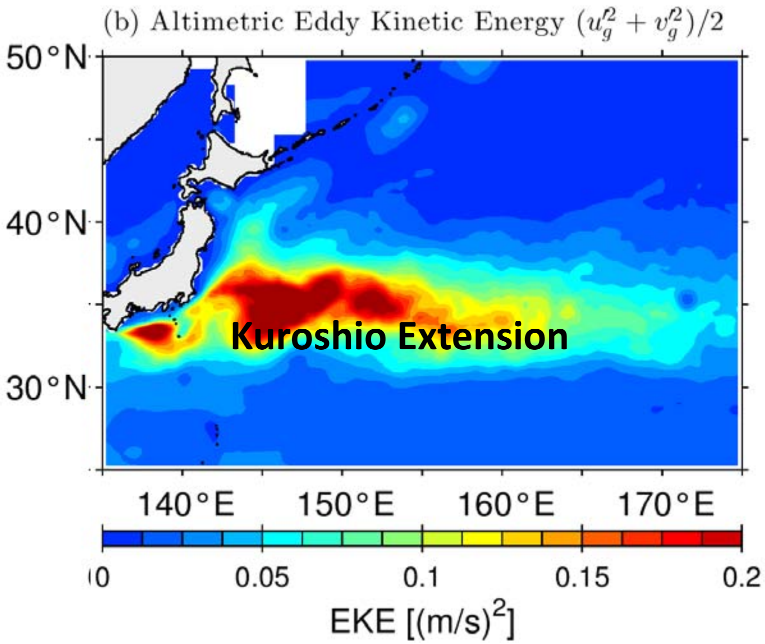
Connections between PDO forcing, cross-basin SSH adjustment & KE state

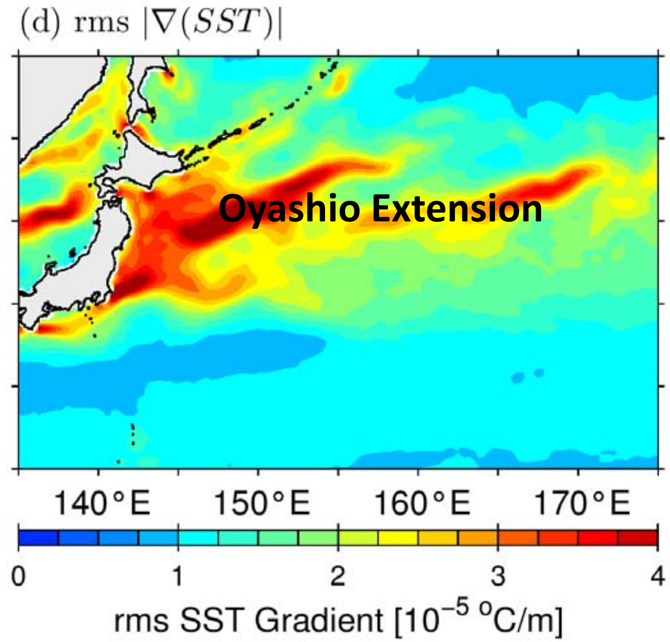


SST gradient variations are associated with OE that is aligned with storm-tracks

JF rms 850mb v'T' of stormtrack variability (Nakamura et al. 2004)





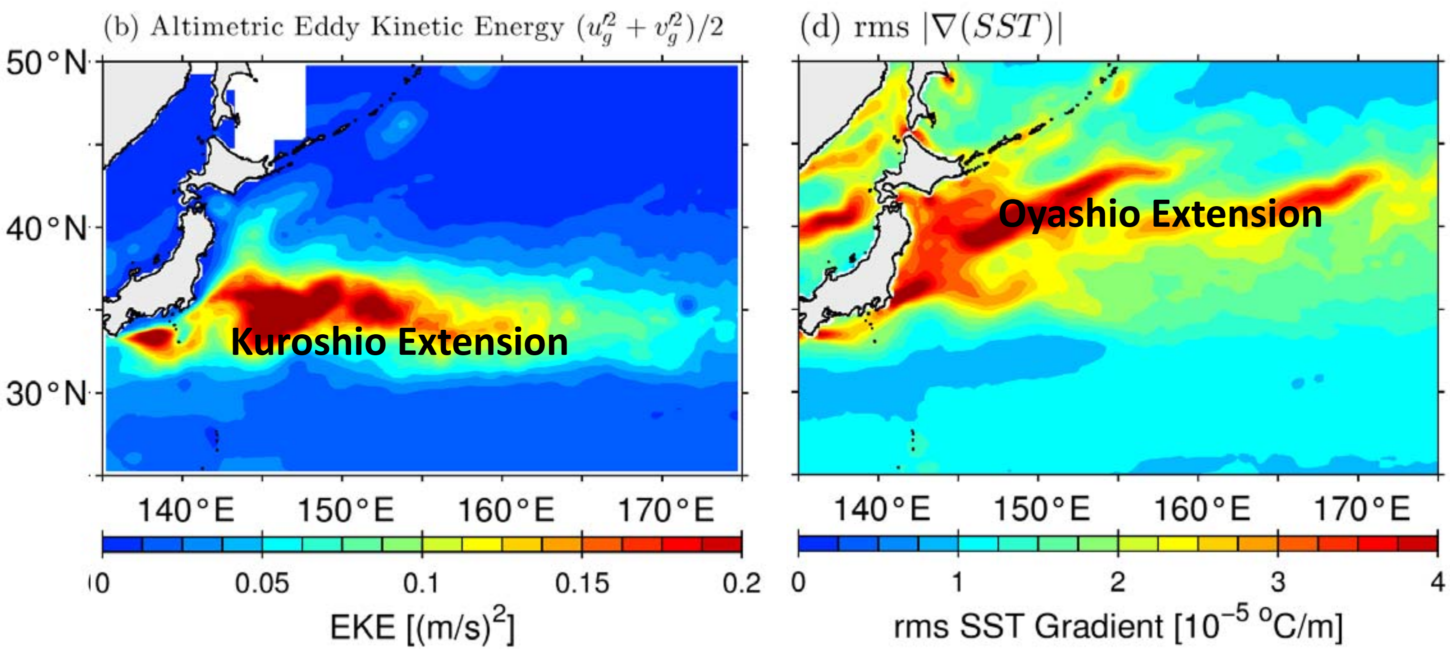


Questions:

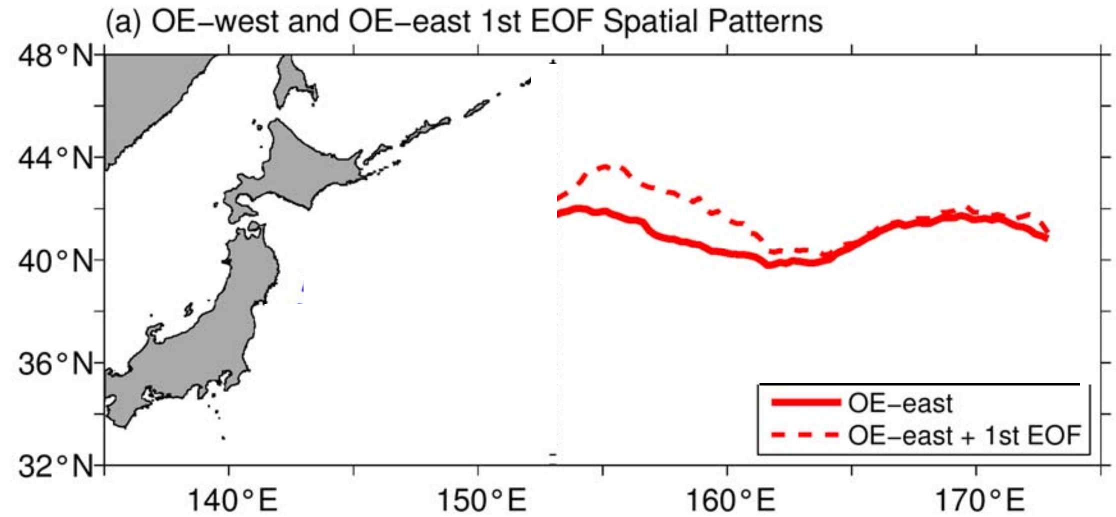
Q1: What are the dominant signals of the OE front ?
Are they related to the decadal KE variability ?

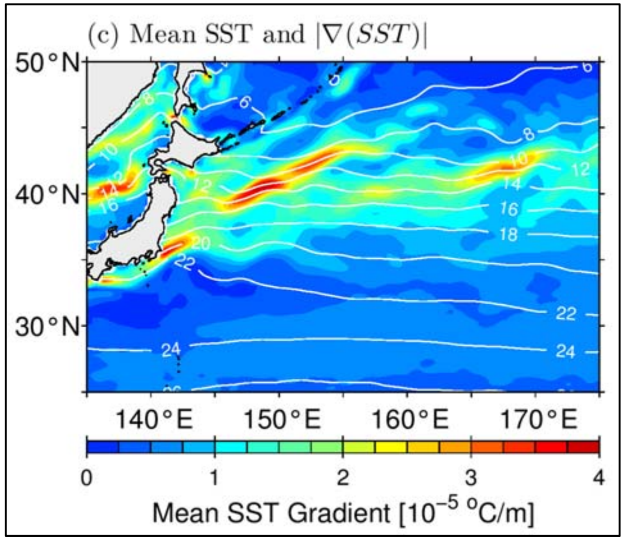
Q2: What processes control the OE variability ?

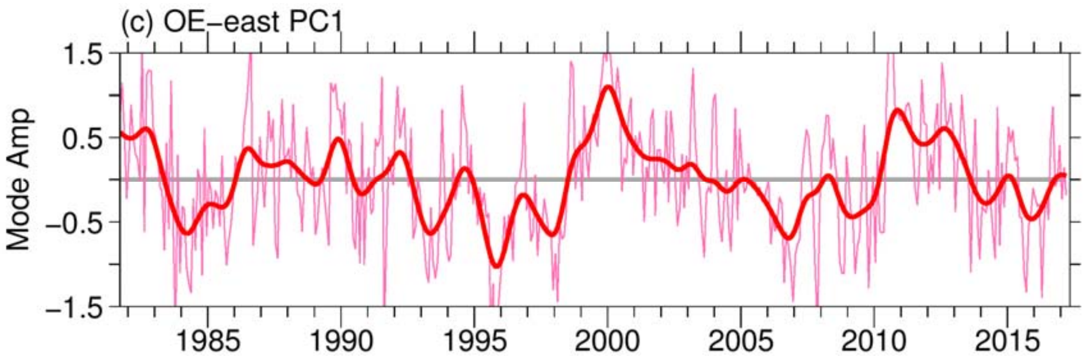
Q3: What sets the decadal timescale dominating the mid-latitude North Pacific climate variability ?



EOF analysis on maximum ∂SST/∂y east of 153°E







- **Following Frankignoul et al. (2011), conducted EOF analysis on max ∂SST/∂y using Reynolds OI-SST dataset**
- **EOF PC-1 exhibits significant low-frequency fluctuations**

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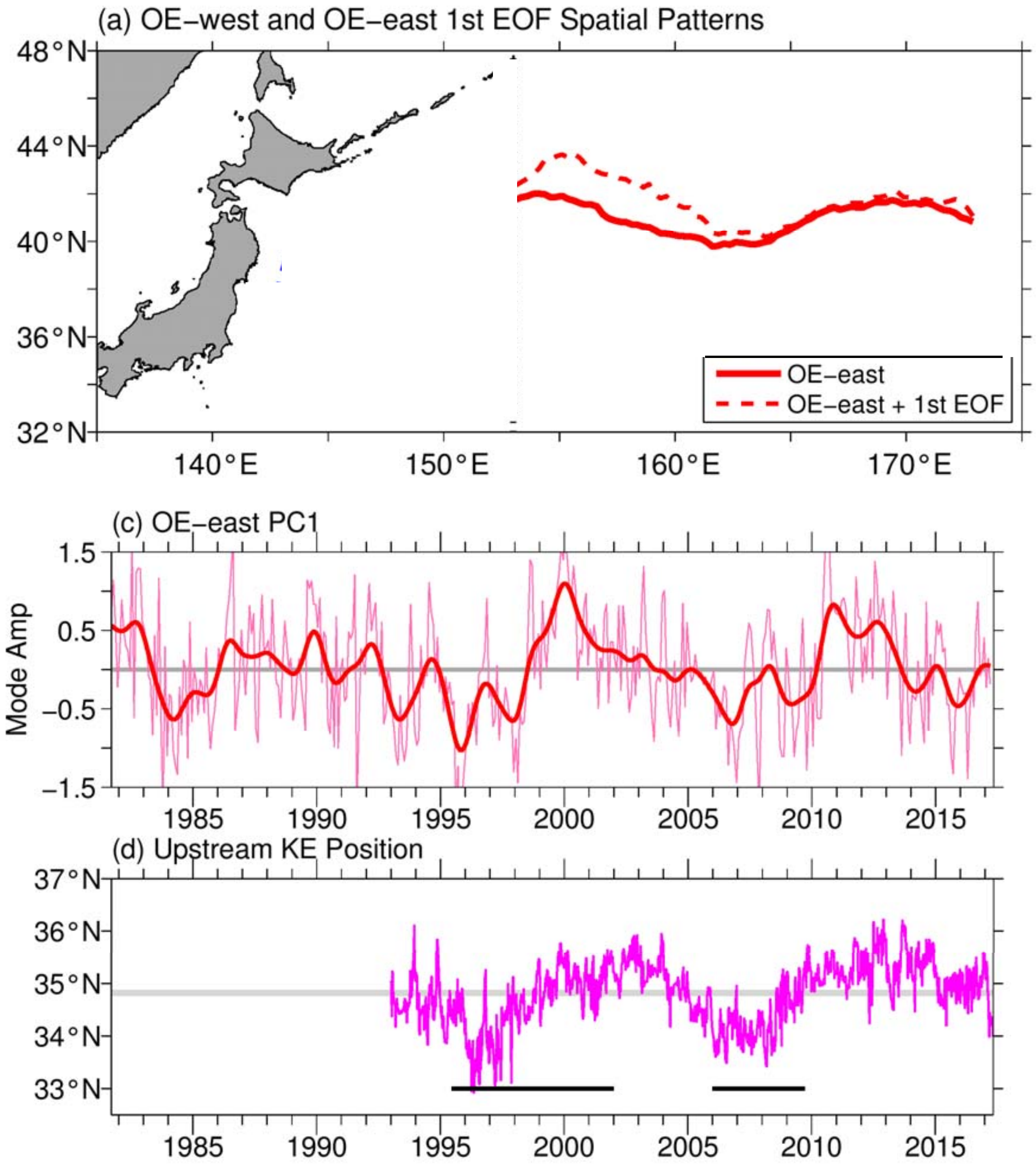
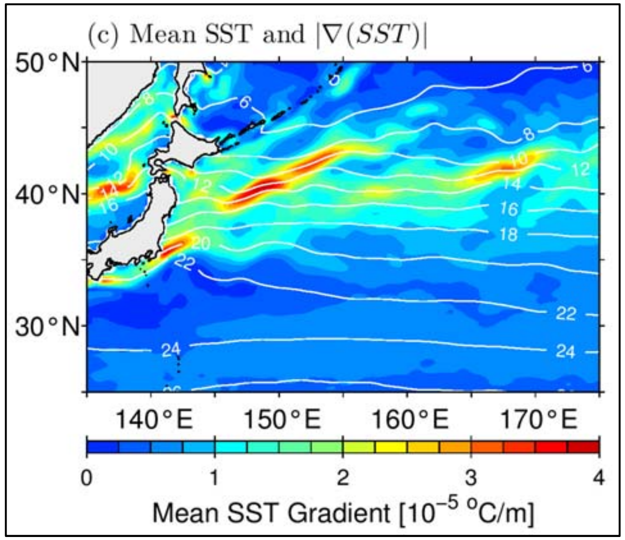
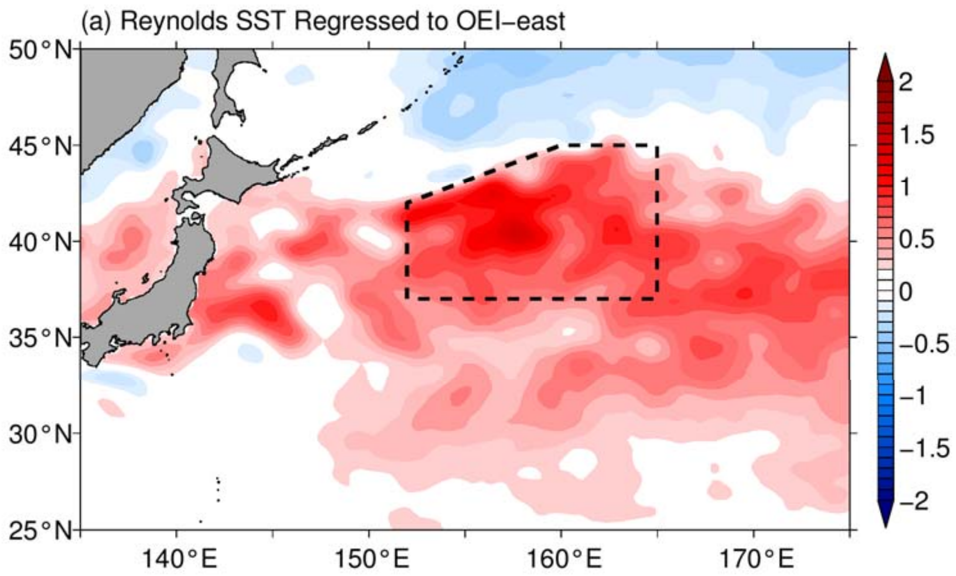
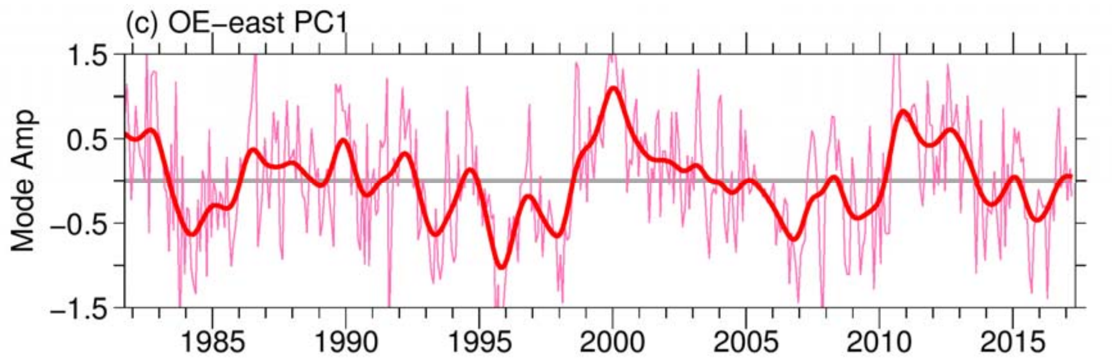




- **Following Frankignoul et al. (2011), conducted EOF analysis on max ∂SST/∂y using Reynolds OI-SST dataset**
- **EOF PC-1 exhibits significant low-frequency fluctuations**
- **PC-1 correlates well with KE's zonal-mean position change**

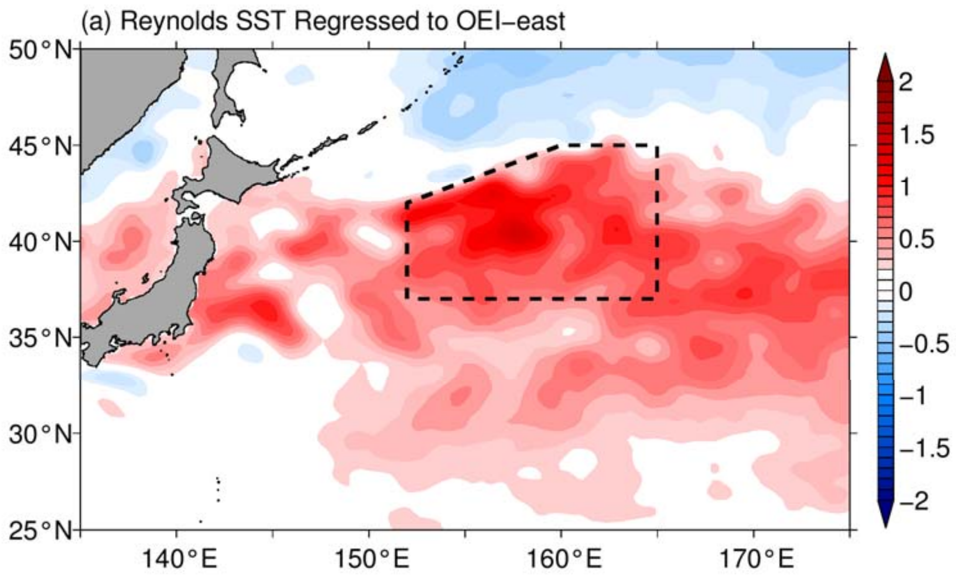
SST anomaly map regressed to OE EOF PC-1





- OE variability is sensitive to SST changes in this key box along the OE front

SST anomaly map regressed to OE EOF PC-1



- OE variability is sensitive to SST changes in this **key box** along the OE front

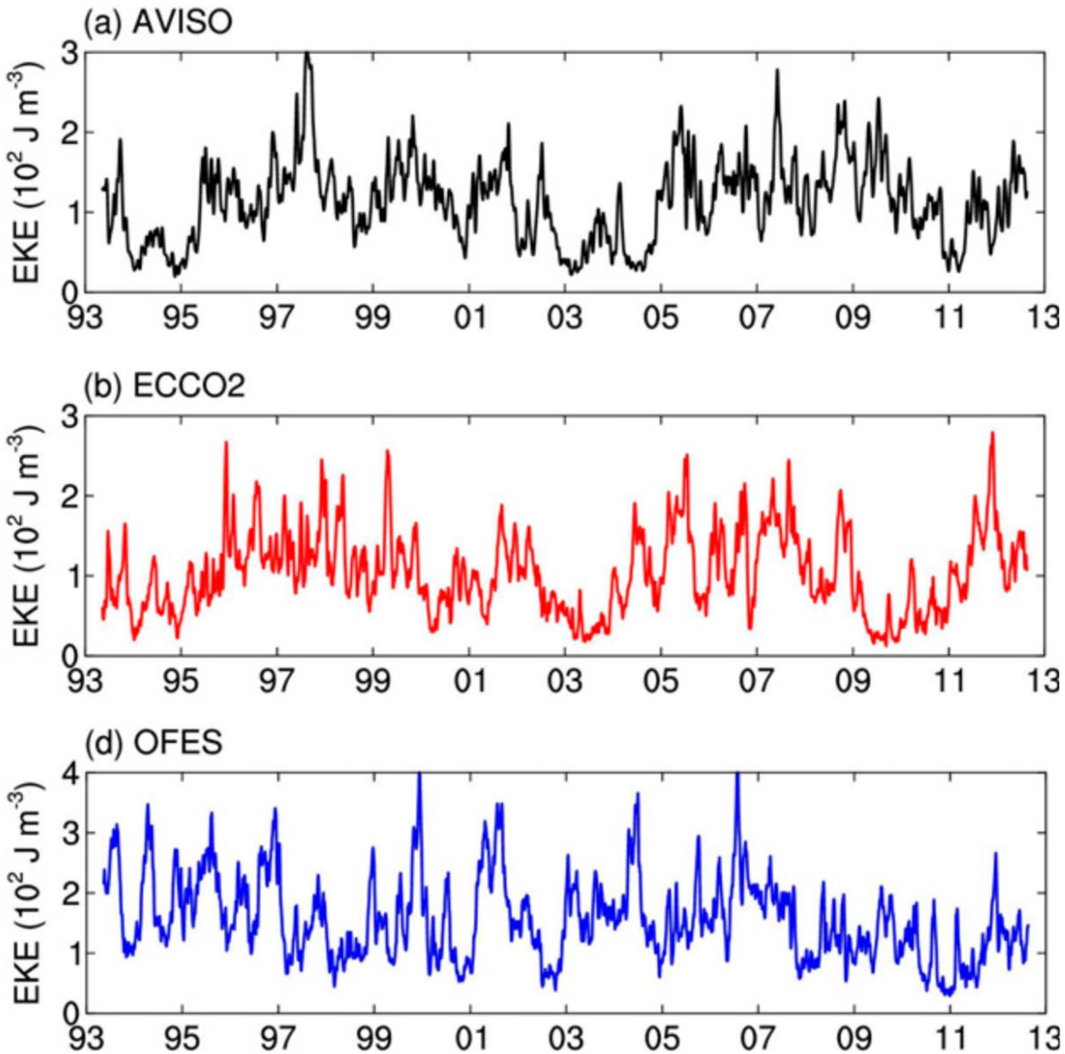
- Conduct upper ocean temperature budget analysis to quantify processes contributing to **low-frequency T_{250m} changes** in these **key boxes**

$$\frac{\partial}{\partial t}\left(\frac{1}{H}\int_{-H}^{0} T dz\right) = -\frac{1}{H}\int_{-H}^{0} \mathbf{u}\cdot\nabla T dz + \frac{Q_{net}}{\rho C_p H} + \left[\frac{K_h}{H}\int_{-H}^{0} \nabla_h^2 T dz - \frac{K_z}{H}\frac{\partial T}{\partial z}\Big|_{z=-H}\right]$$

rate of T_{250m} change — advective flux convergence — net surface heat exchange — diffusive flux convergence

- Integrate above equation in time & examine correlation between T_{250m} changes and advection vs. heat flux forcing based on **ECCO2 output**

ECCO2 is capable of simulating the correct decadal EKE modulations



observation

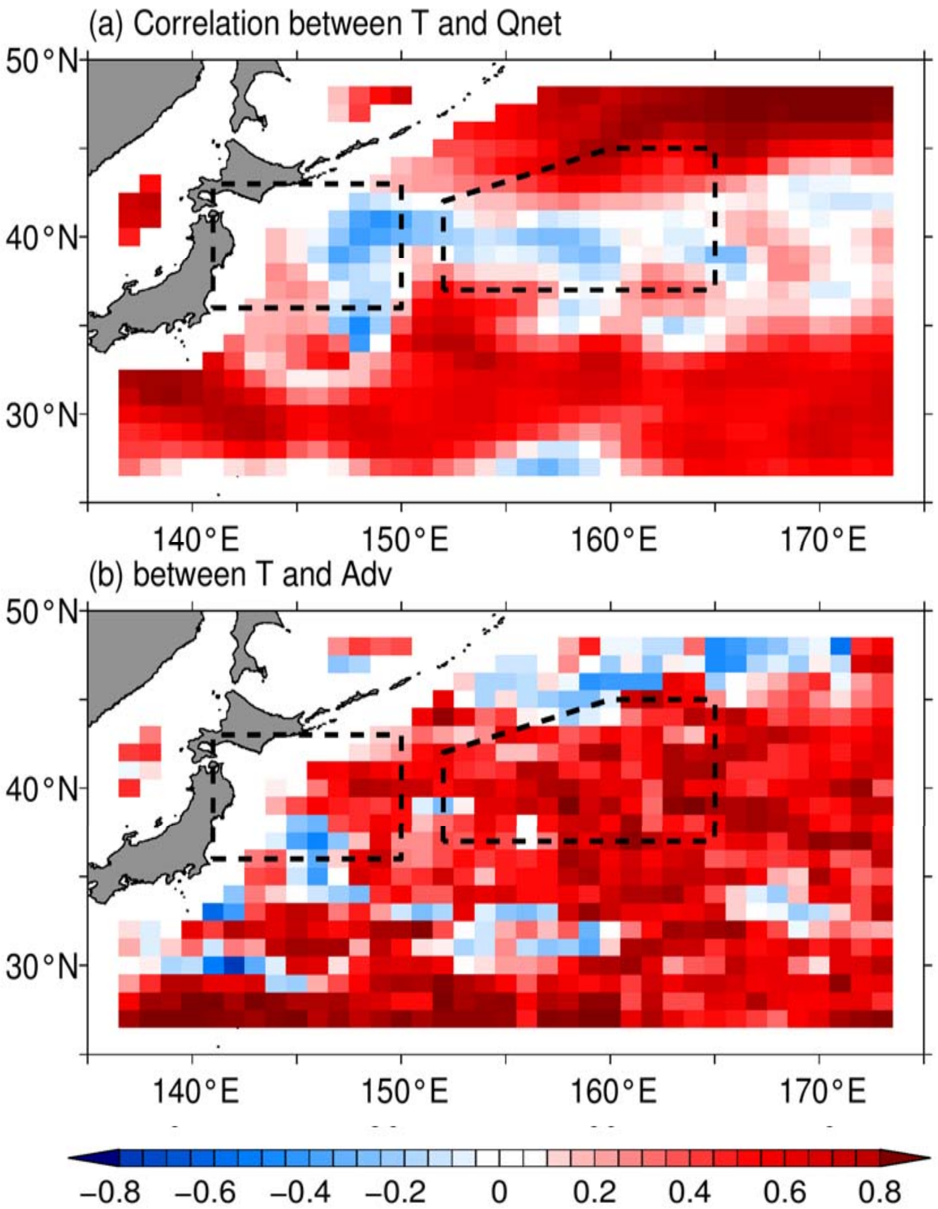
data-constrained ECCO2 simulation

unconstrained OFES simulation

FIG. A1. Area-mean surface EKE time series (averaged over the rectangle box in Fig. 4b) constructed from (a) the satellite observation (AVISO), (b) the ECCO2 state estimate, (d) the OFES hindcast.

Yang et al. (2017, JPO)

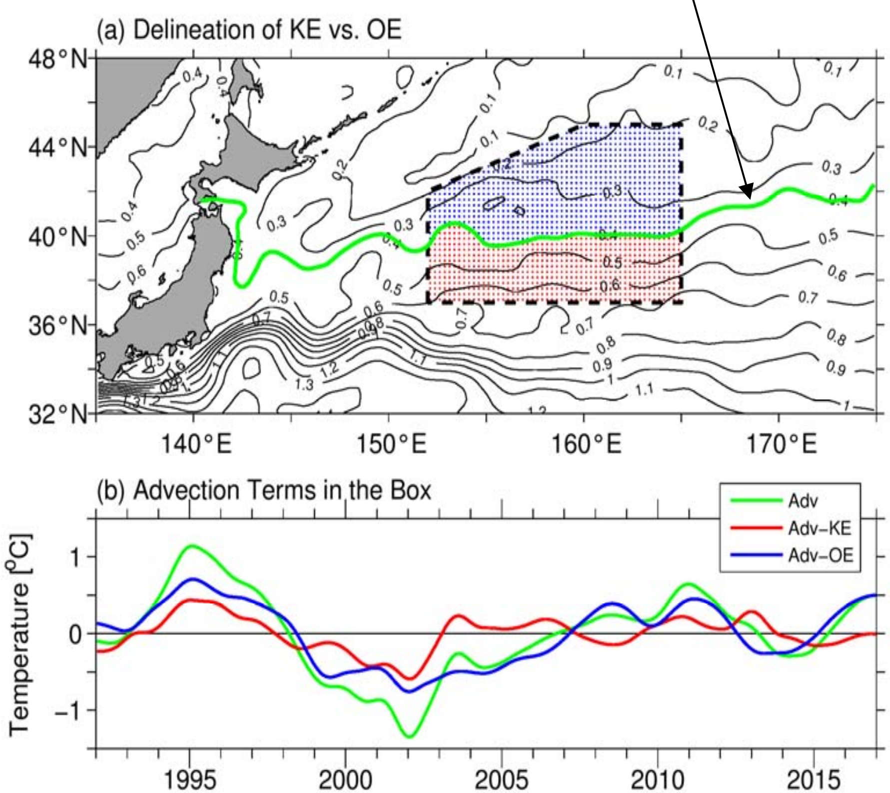
Regional upper ocean temperature budget analysis



- Rather than forcing T_{250m} changes, surface net heat flux responds to SST changes in OE front regions
- Advective temperature flux convergence plays an important role in determining low-frequency T_{250m}

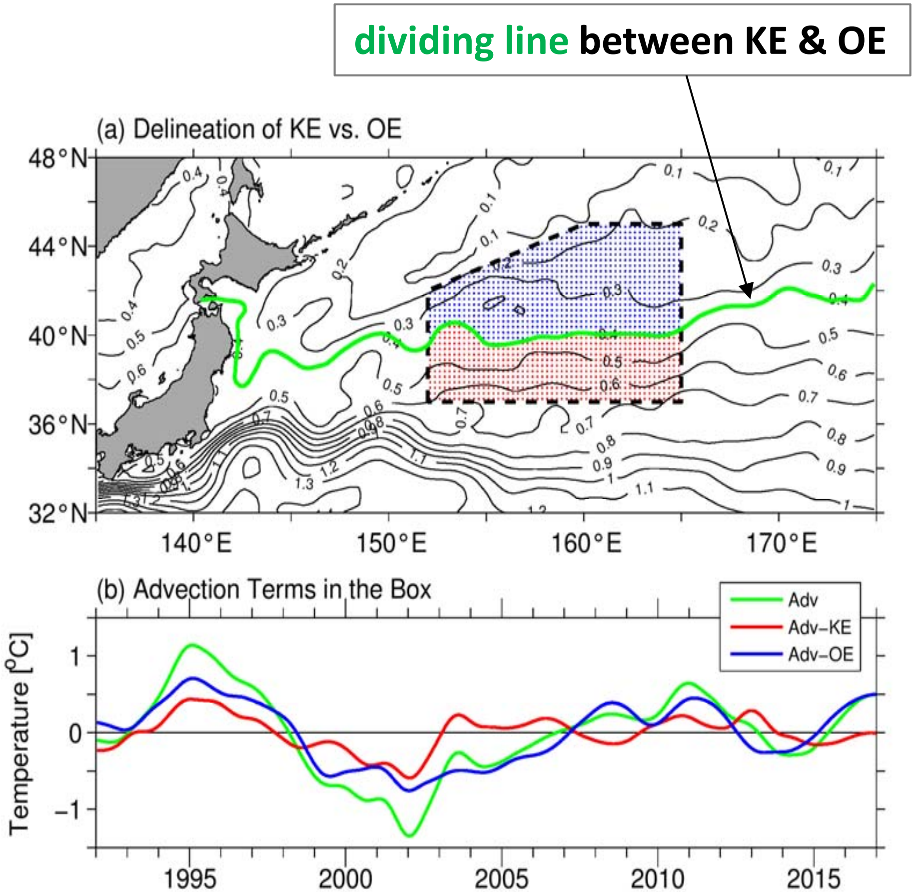
A closer look at the advective fluxes: KE vs. OE contributions

dividing line between KE & OE

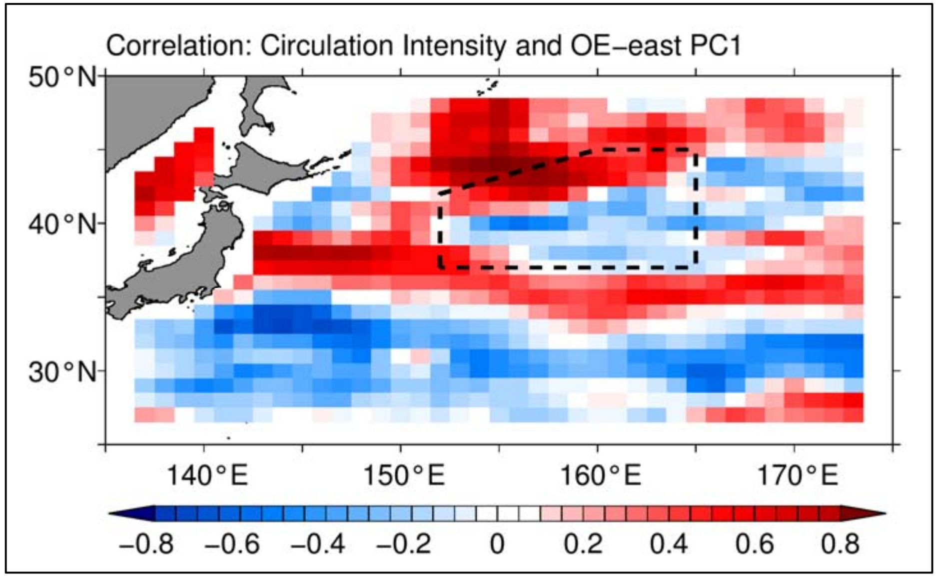


- In OE-east box, advective flux is controlled by admixture of OE & KE contributions

A closer look at the advective fluxes: KE vs. OE contributions



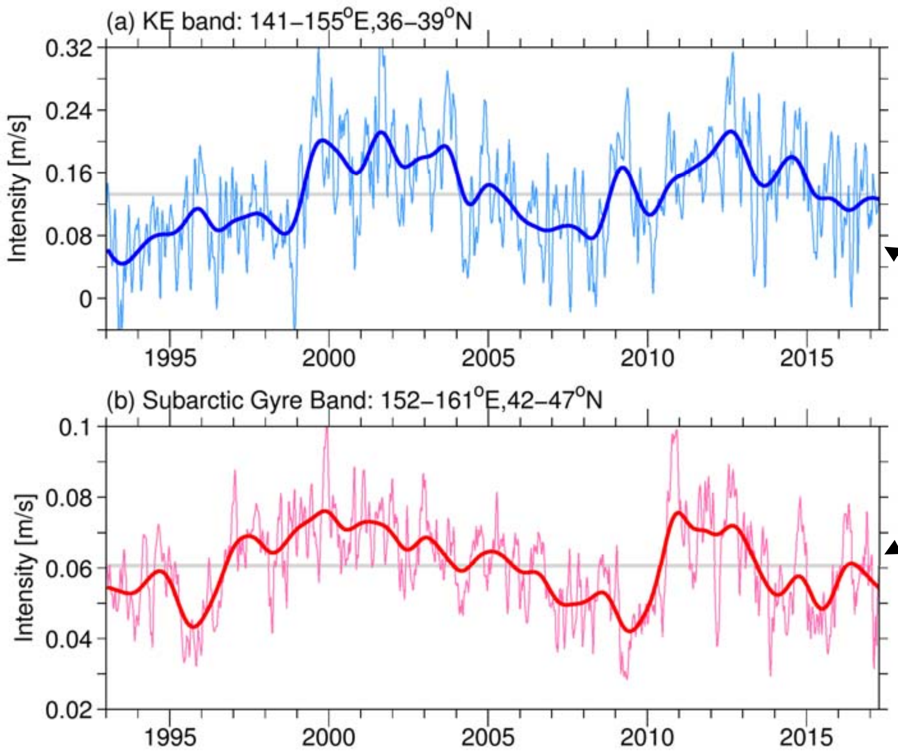
- In OE-east box, advective flux is controlled by admixture of OE & KE contributions
- This is confirmed by examining correlation between OE PC1 & AVISO-derived circulation changes

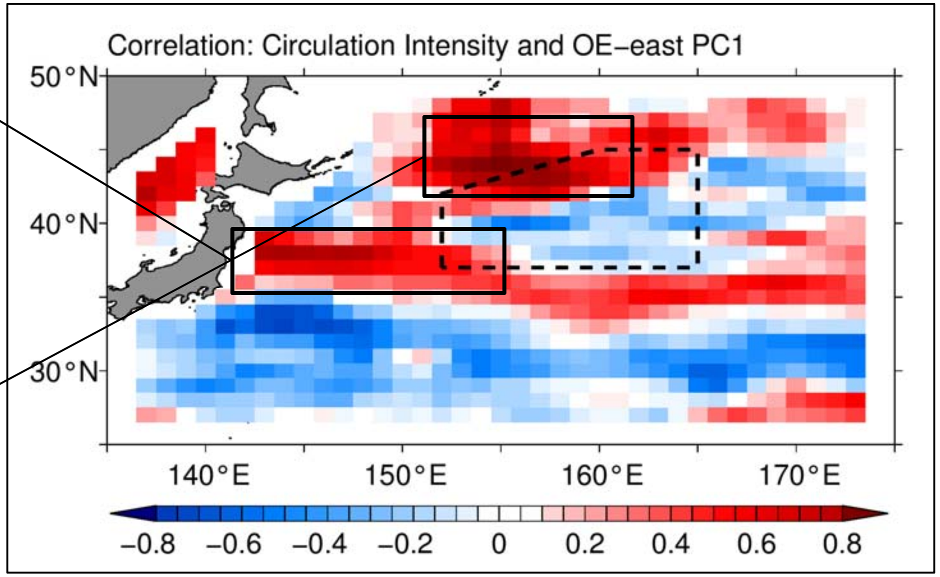


$$V'(t) = \frac{1}{A}\iint_A \mathbf{u}'_g(t)\cdot\frac{\overline{\mathbf{u}}_g}{|\overline{\mathbf{u}}_g|}\,dx\,dy,$$

A closer look at the circulation changes contributing to OE

- In **OE-east** box, advective flux is controlled by admixture of **OE & KE contributions**
- **KE contribution** is related to the KE's decadal position change
- **OE contribution** is also decadal, nearly in phase with the KE signal





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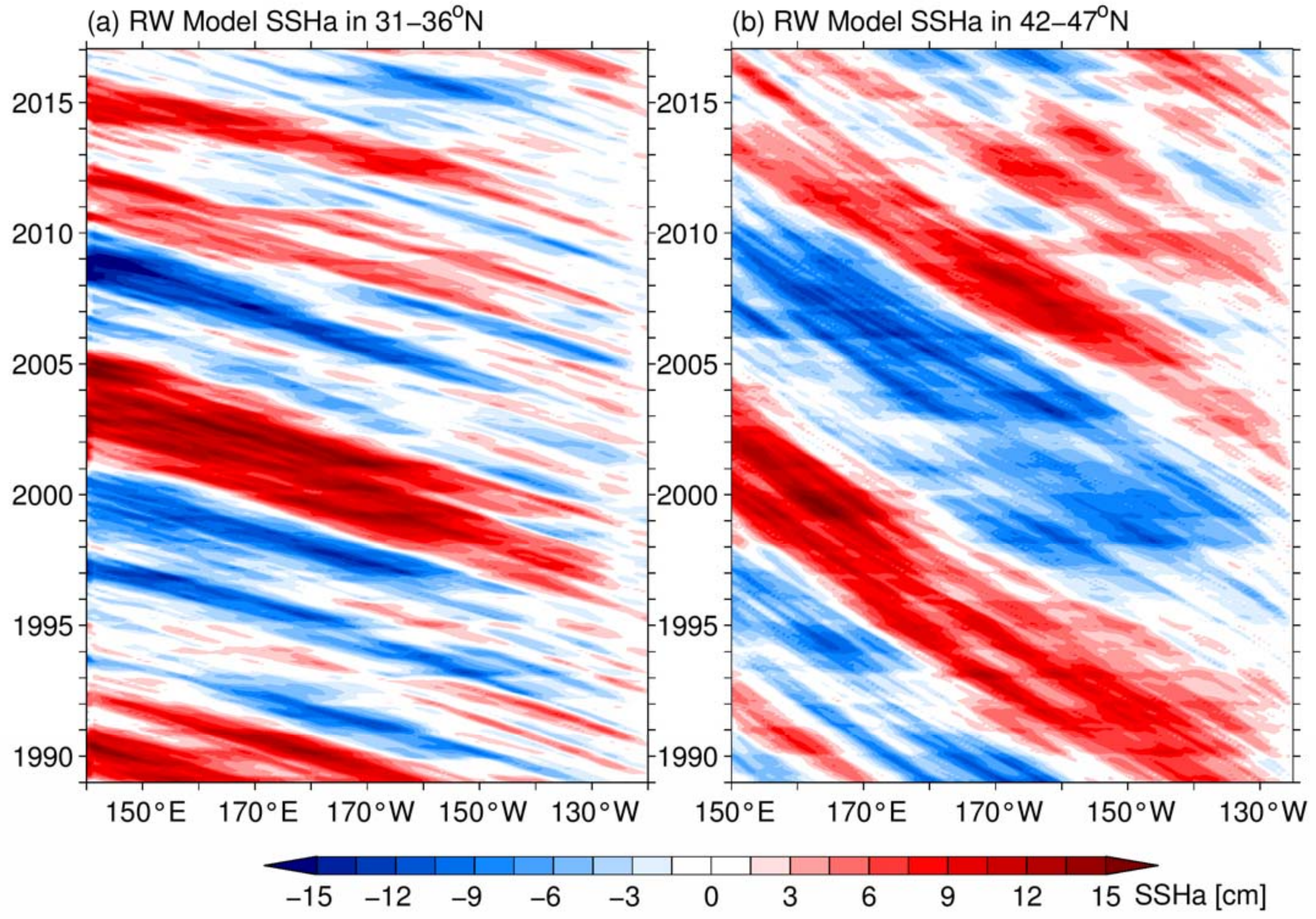
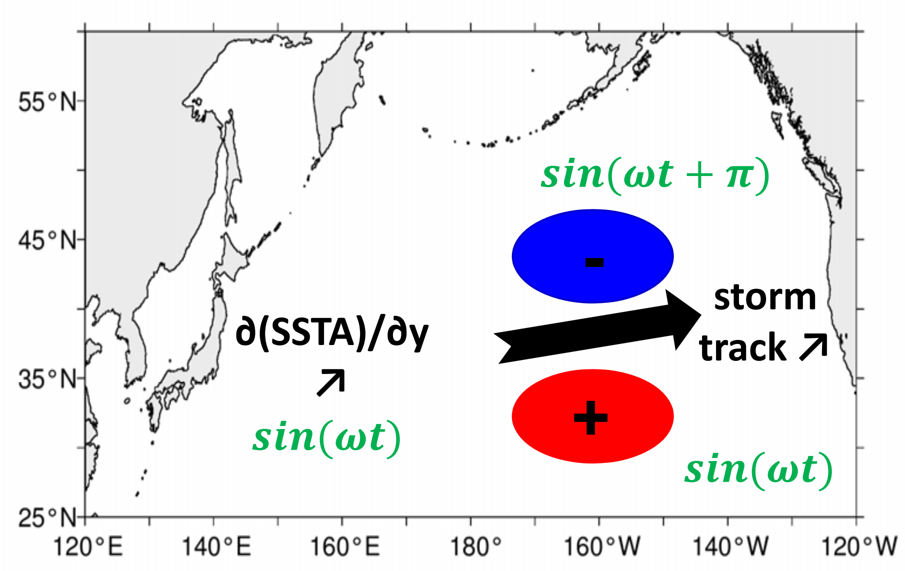
Why should the KE position & OE intensity changes be in-phase?



- **Westward propagating speed for wind-induced SSH anomalies is different at latitudes important for the KE & OE**
- **It take ~4 (~9) yrs for wind-forced SSH anomalies to reach KE (OE) from the eastern basin**

What sets the dominant decadal timescale in the N Pacific basin?



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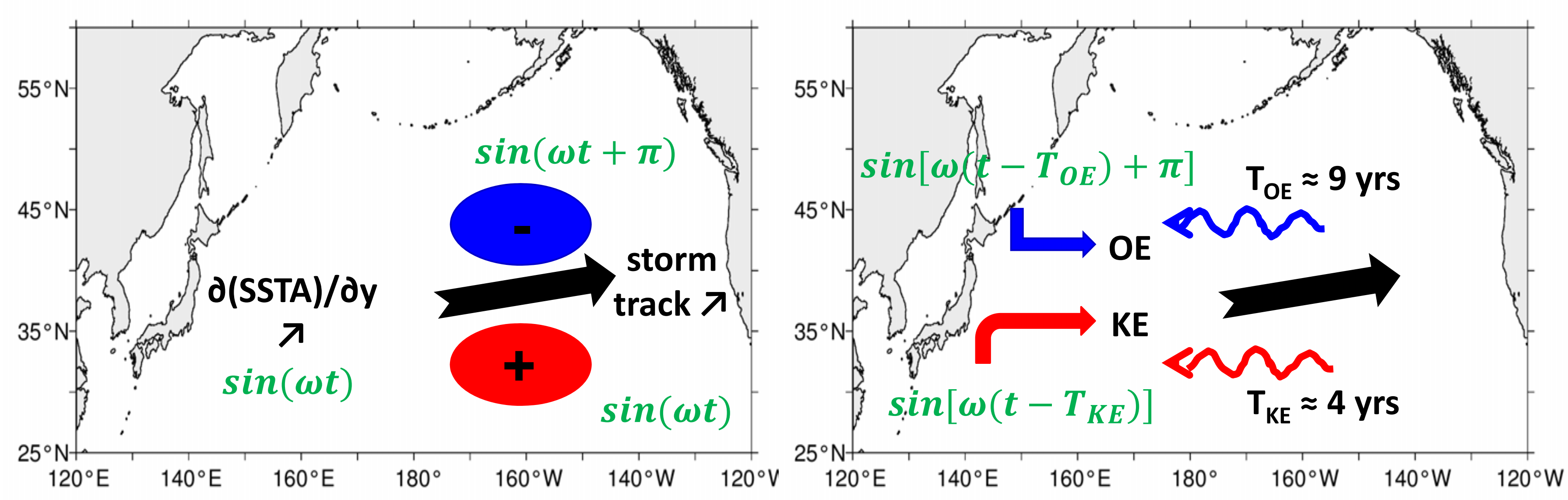

- To induce coherent SST front variability, contributions from KE & OE must be in-phase:

$$\omega(t - T_{OE}) + \pi \; = \; \omega(t - T_{KE})$$

- Optimal period:

$$T_o = \frac{2\pi}{\omega} = 2(T_{OE} - T_{KE}) \approx 10 \text{ yrs}$$

Summary

- **KE dynamic state (i.e. EKE level, path latitude, and jet/RG strengths) is dominated by decadal variations.**
- **Transitions of the decadal KE variations are determined by basin-wide wind forcing; nonlinear rectification controls the amplitude of the KE response.**
- **OE variability is dictated by KE's meridional shift & wind-forced SSH changes inside subarctic gyre. In-phased KE & subarctic gyre changes produce coherent ∂SST/∂y modulations along OE & impact on overlying storm-tracks.**
- **The in-phased KE-OE changes & geometry of the wind forcing favor a coupled oscillation with a ~10-year timescale in the North Pacific basin.**

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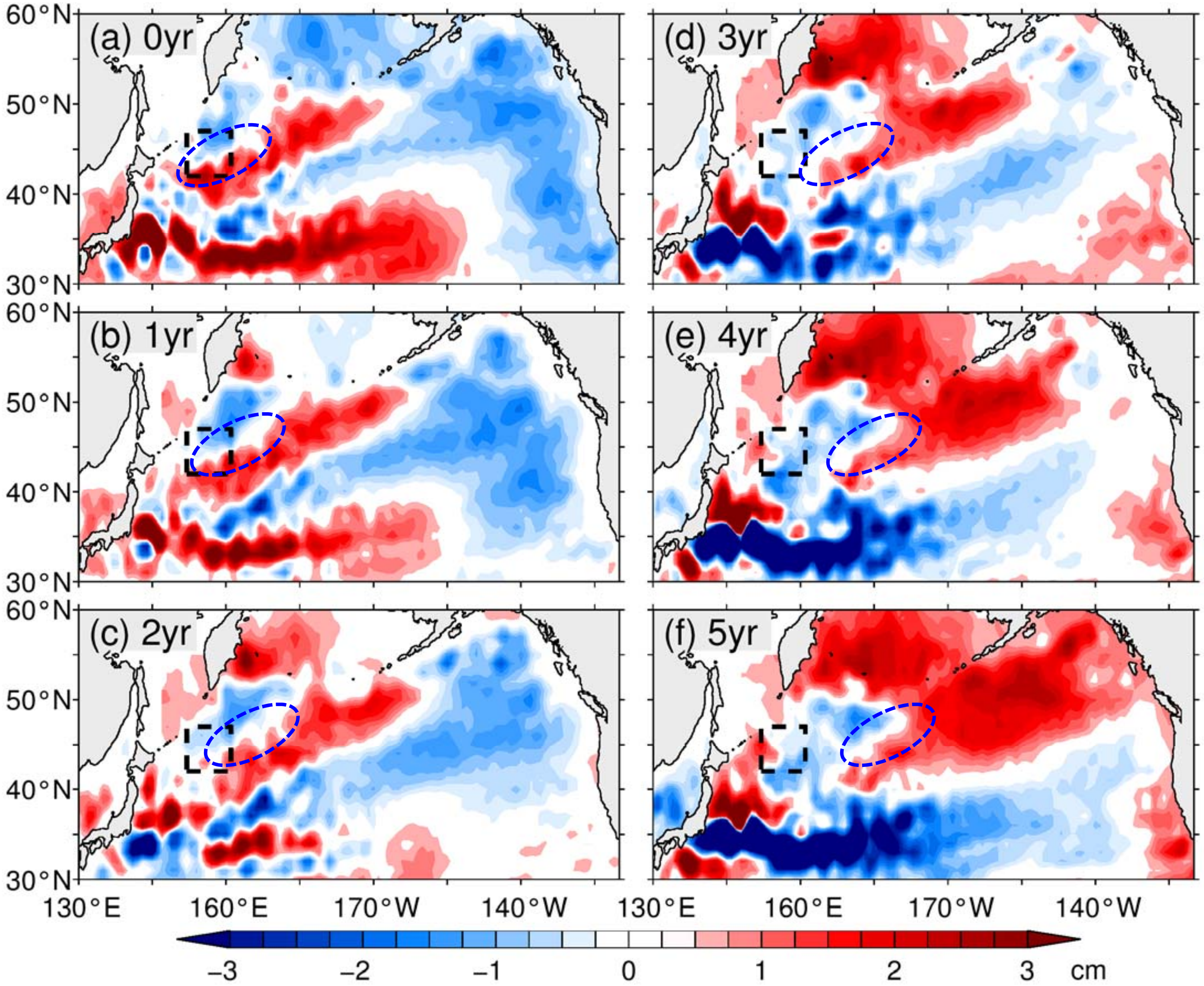
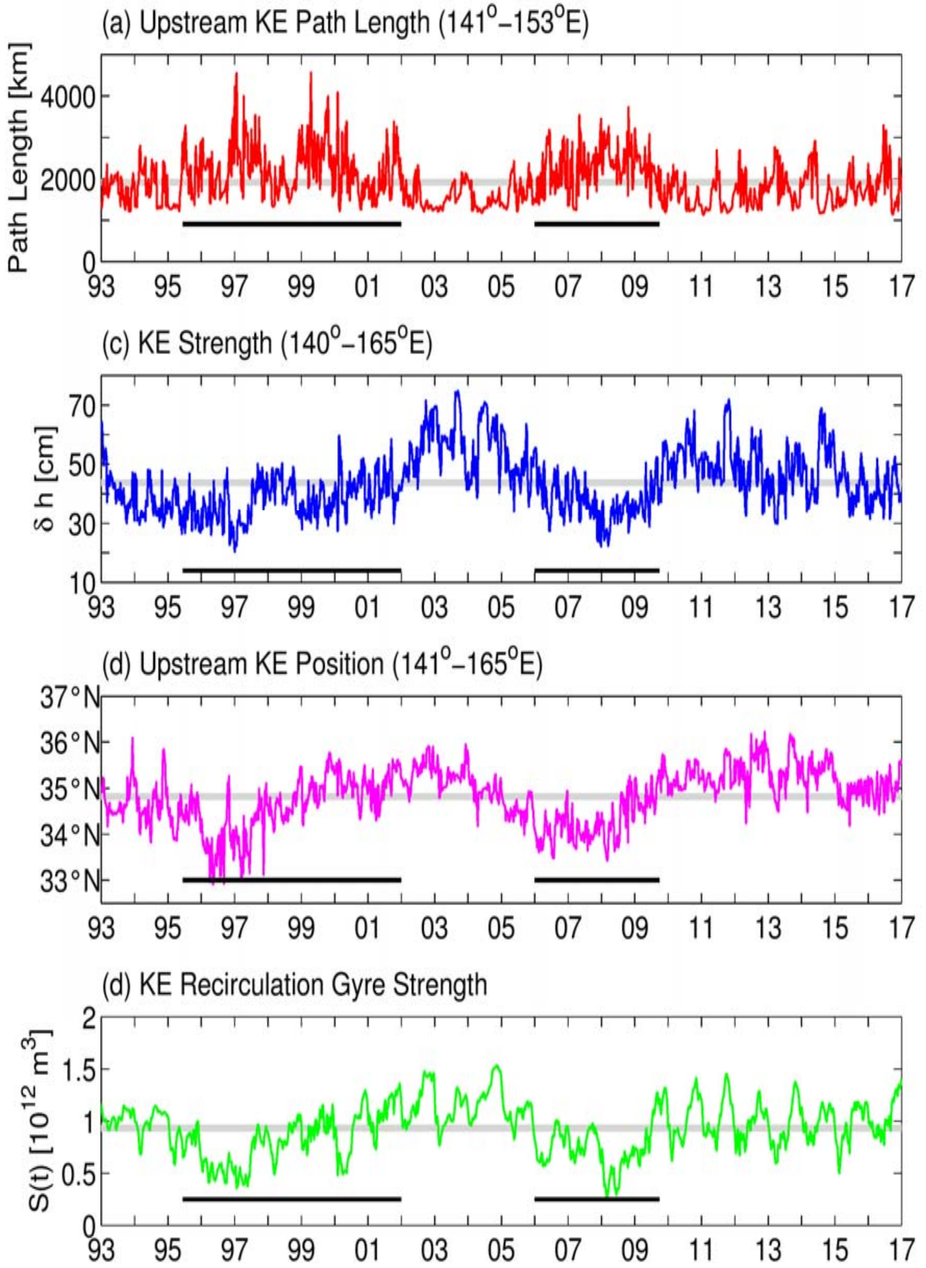
Qiu, B., S. Chen & N. Schneider, 2017: Dynamical links between the decadal variability of the Oyashio and Kuroshio Extensions. *J. Climate*, in press.

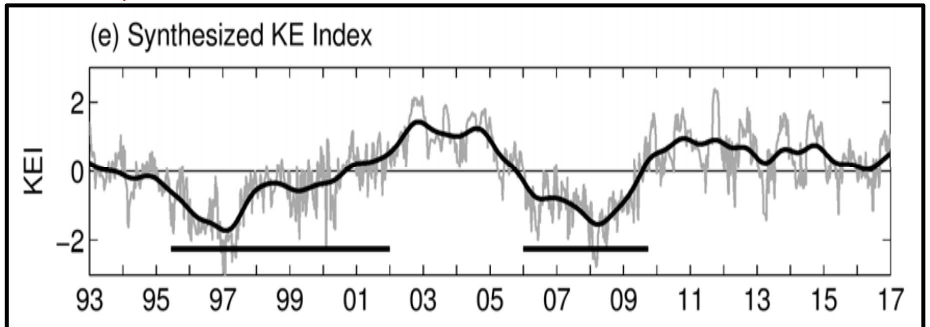
What drives the subarctic gyre changes that are relevant for OE front?



- **SSH anomalies regressed to the subarctic gyre circulation change in dashed box with different lead times; wind-forced baroclinic responses dominate!**

Forming of a comprehensive index representing the KE variability





KE index : average of the 4 dynamical quantities (normalized)

Qiu et al. (2014, JClim)