Use of Satellite Altimeter Data for Decadal Predictions of the Kuroshio Extension Dynamic State

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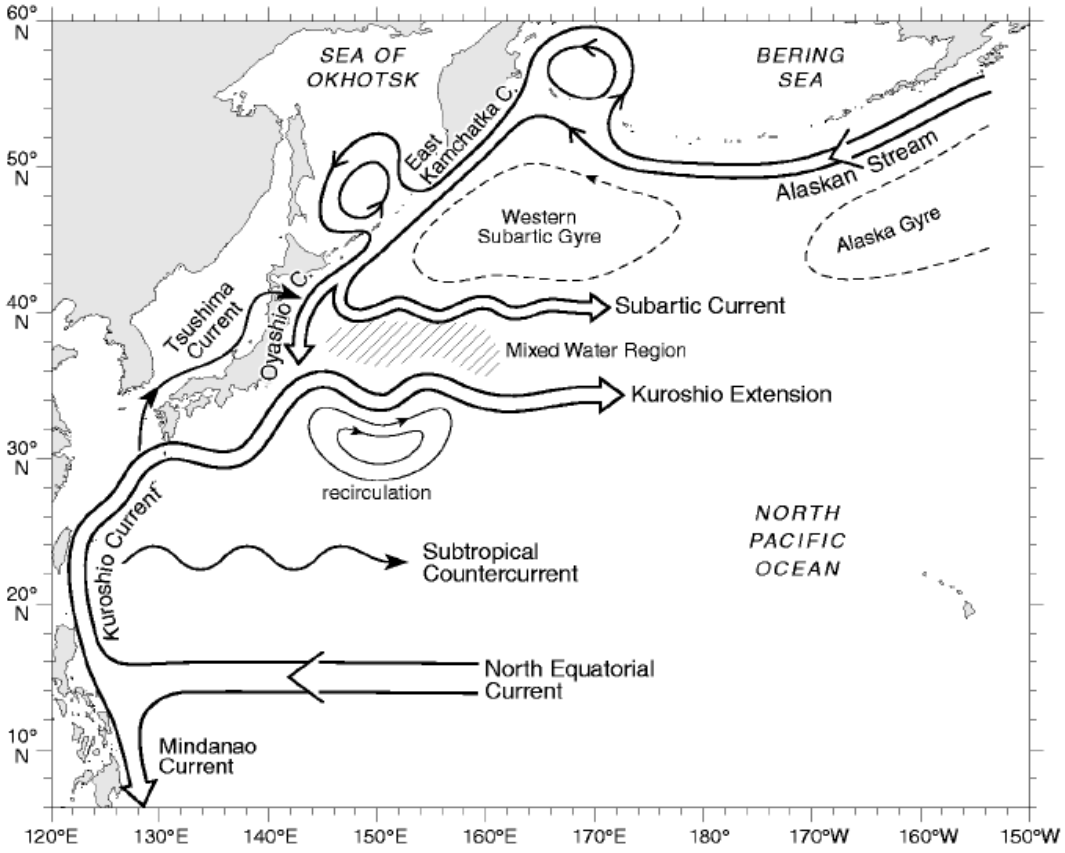
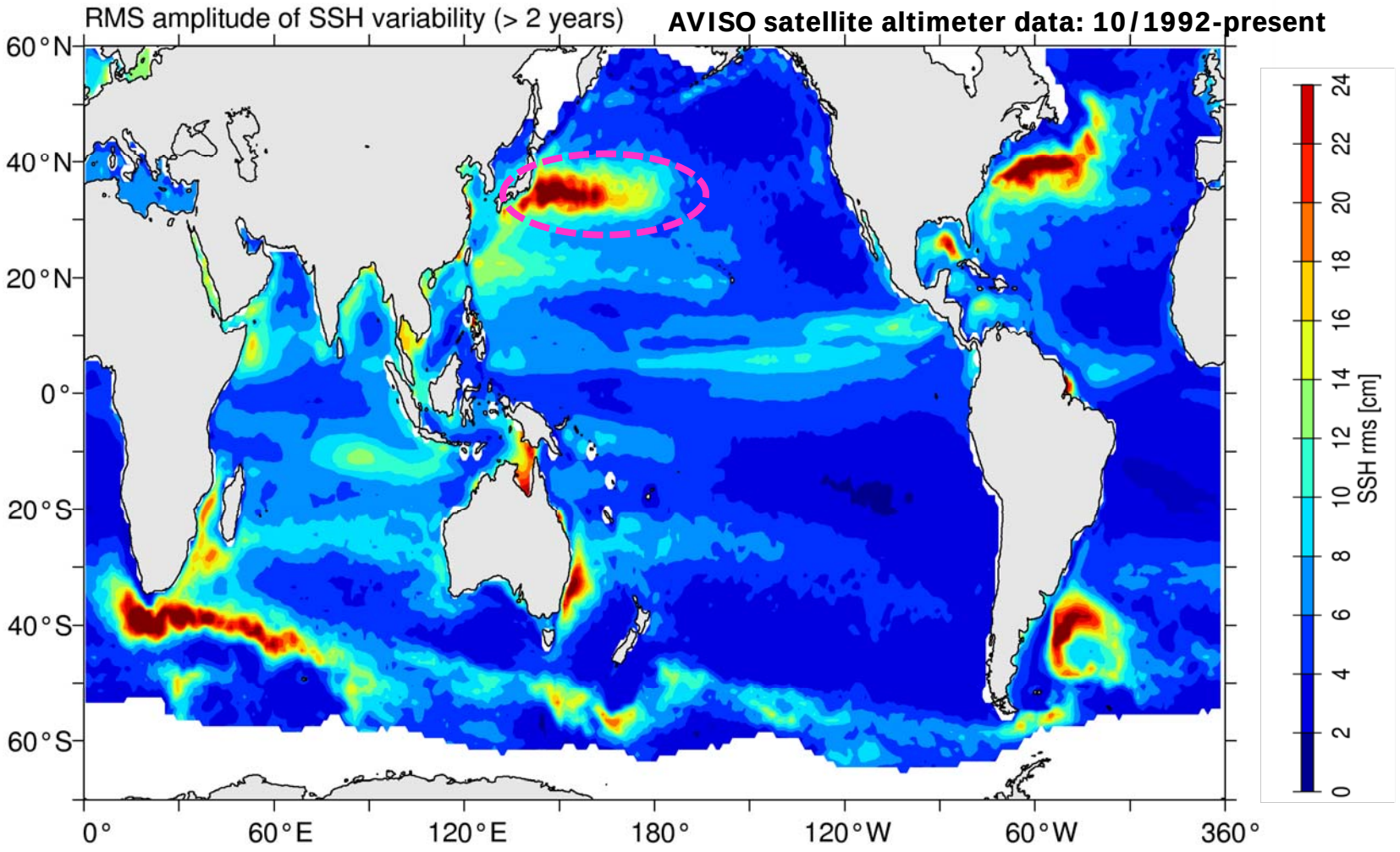


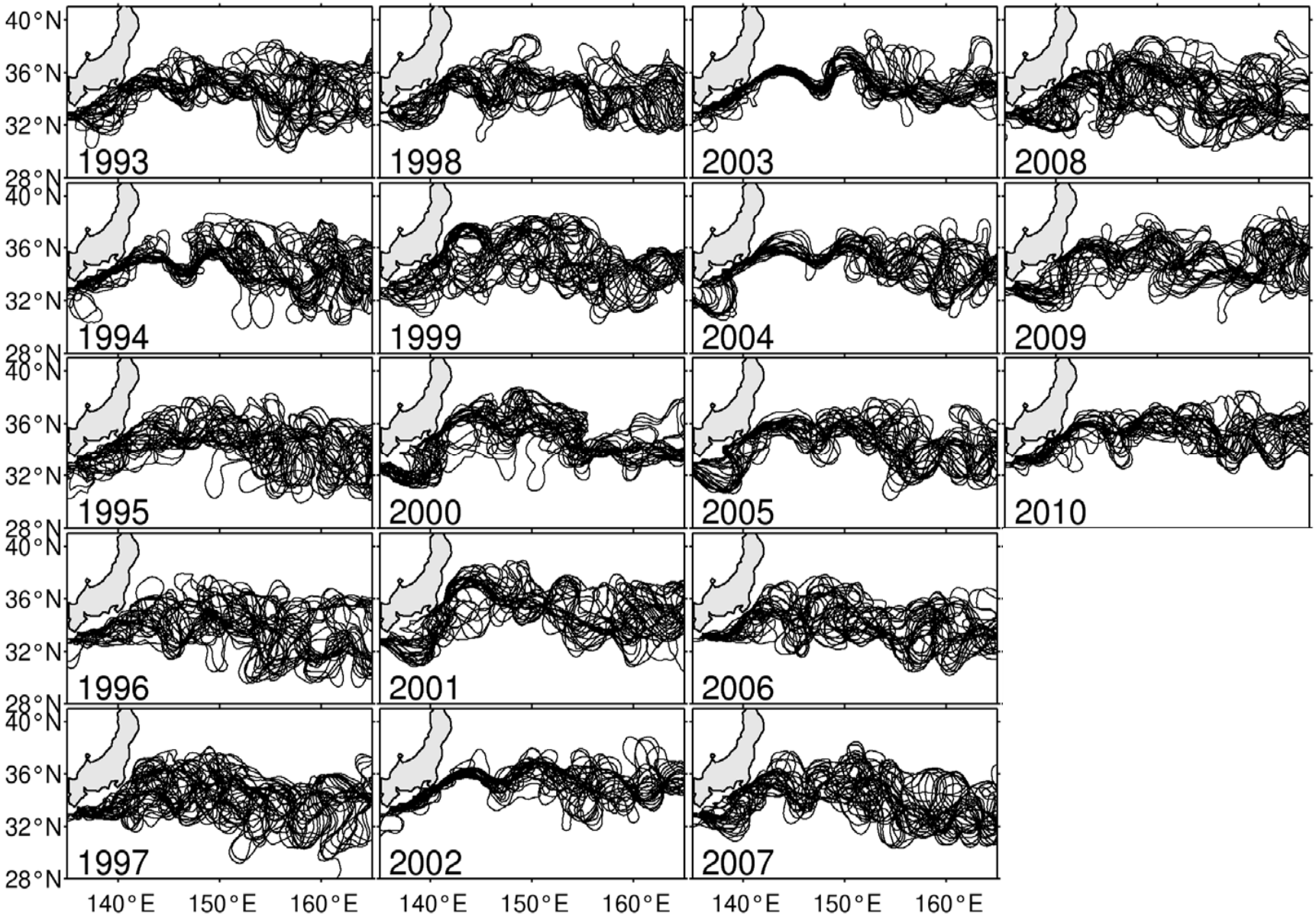
Western North Pacific circulation schematic

Outlines

- Observed changes in the Kuroshio Extension system
- Decadal KE variability as a coupled ocean-atmos. mode
- Impact of forced vs coupled mode on prediction



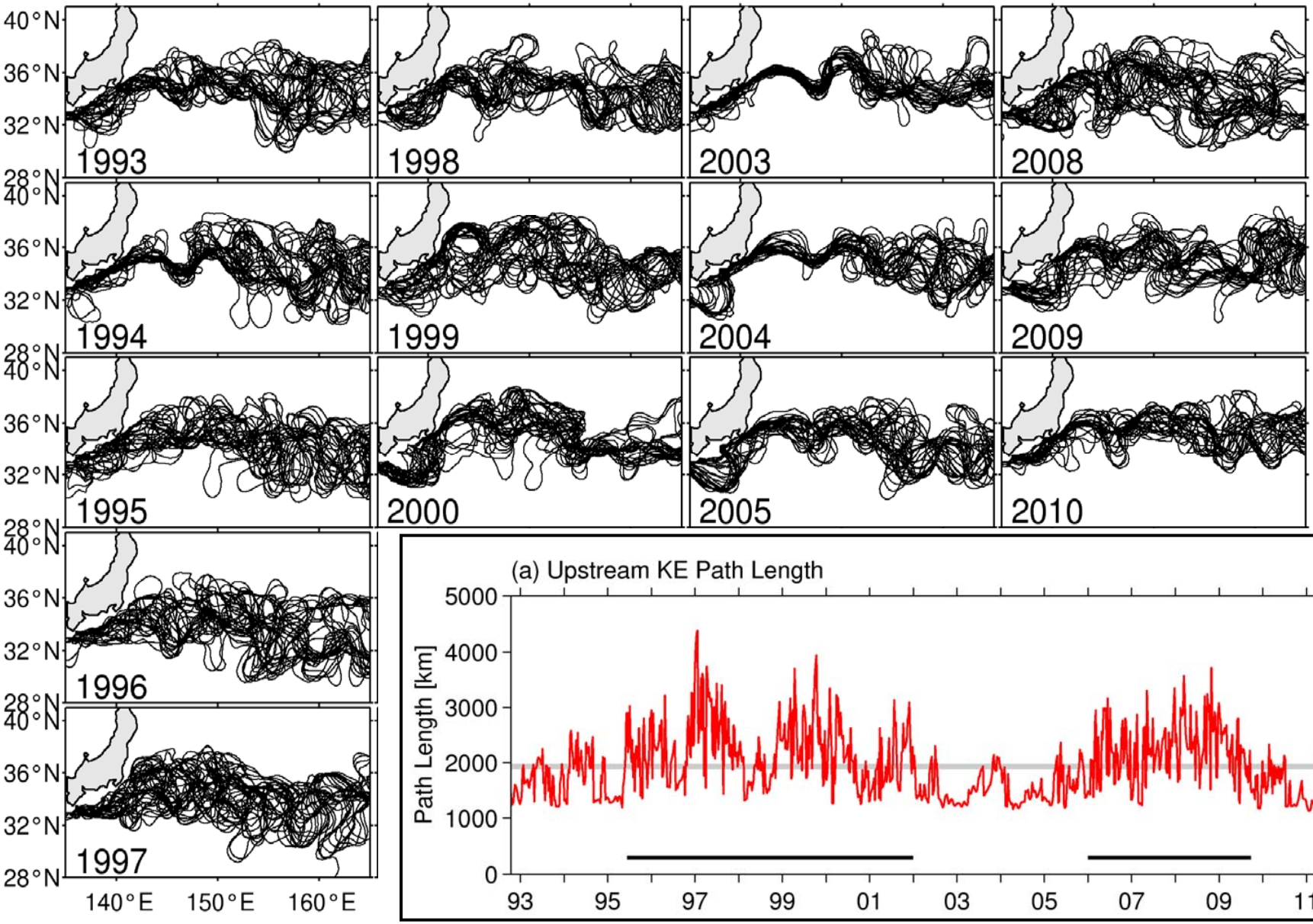
Semi-monthly KE paths from altimeter-derived 1.7m SSH contours



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

Unstable yrs: 1996-2001, 2006-08

Semi-monthly KE paths from altimeter-derived 1.7m SSH contours



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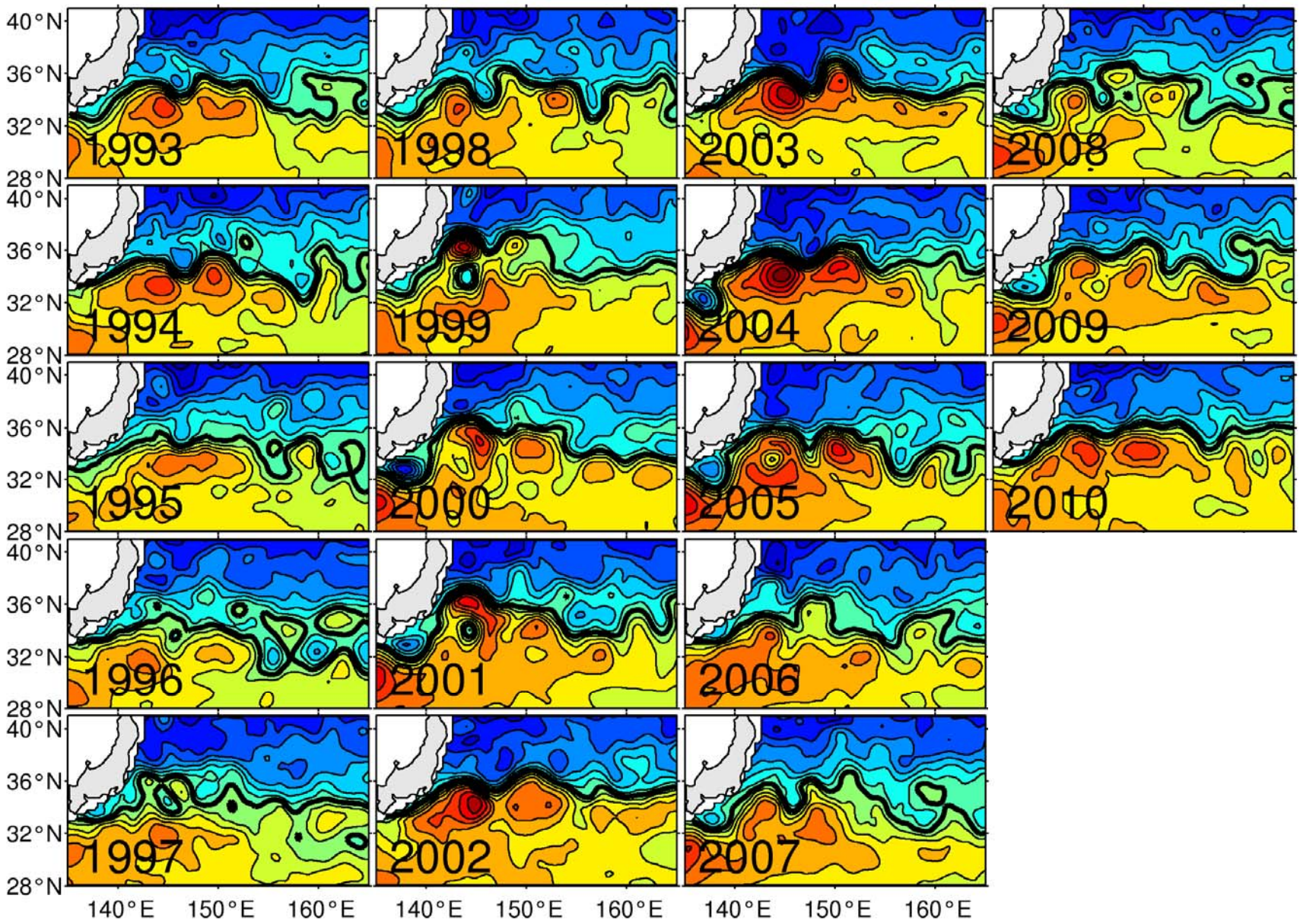
Yearly-averaged SSH field in the region surrounding the KE system



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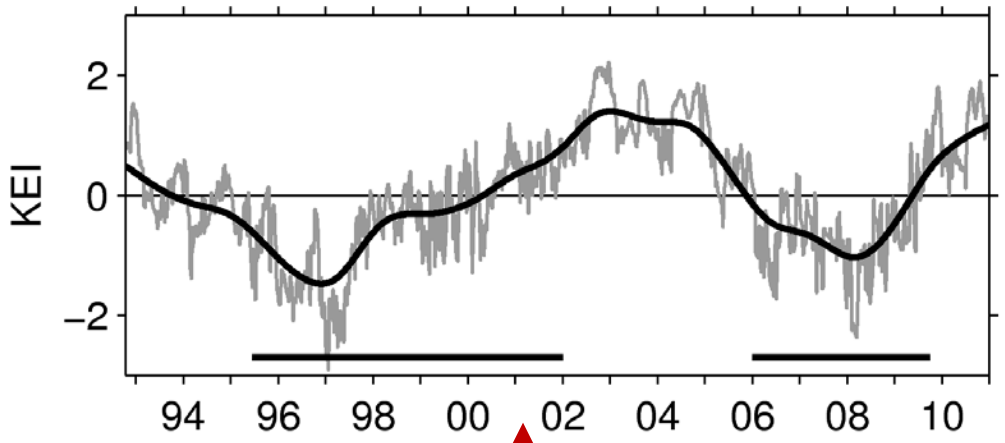
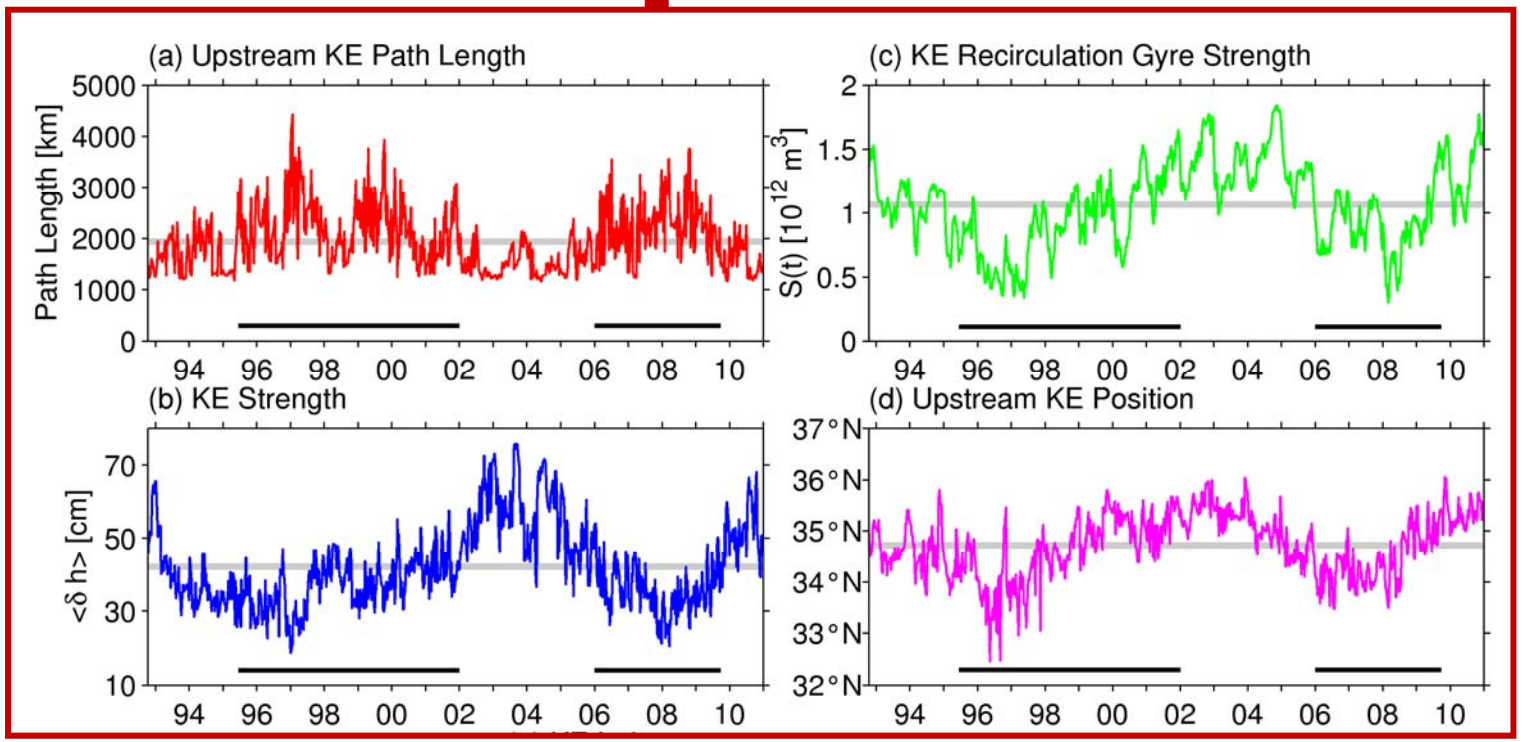
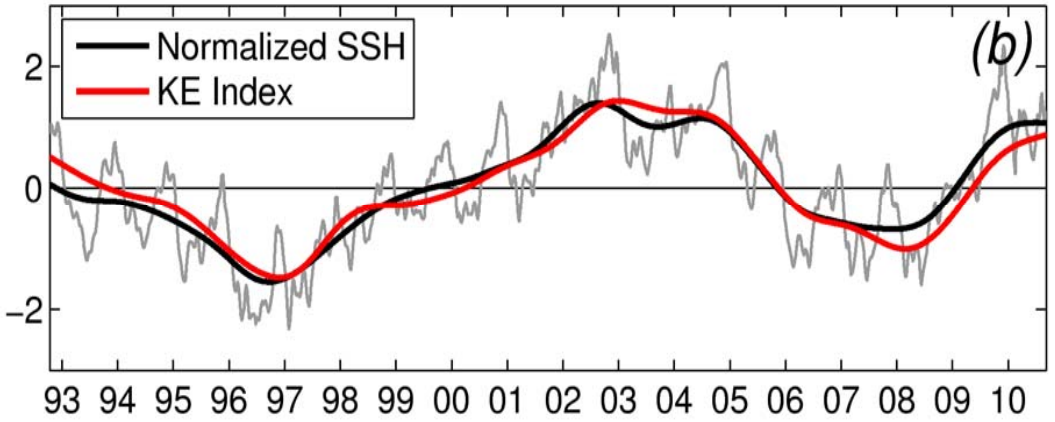
A composite index quantifying the KE dynamic state: the KE index

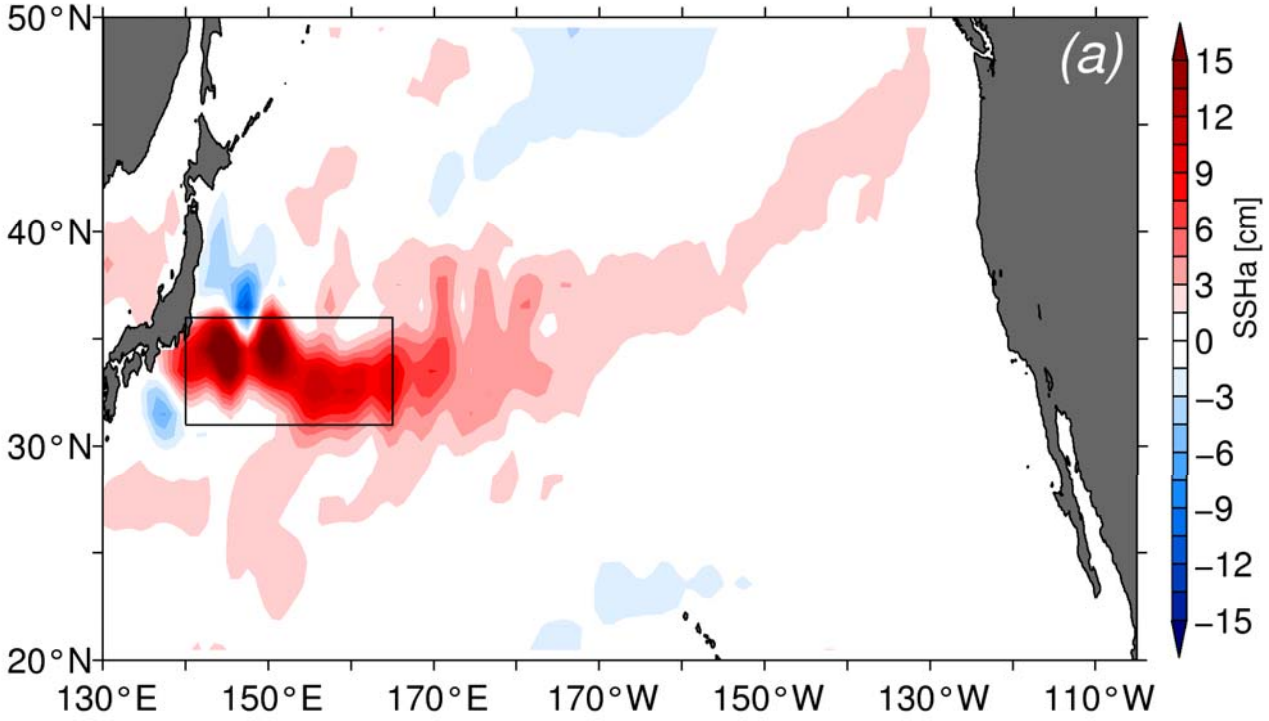


KE index: average of the 4 dynamic properties (normalized)



Regression between the KE index and the AVISO SSH anomaly field



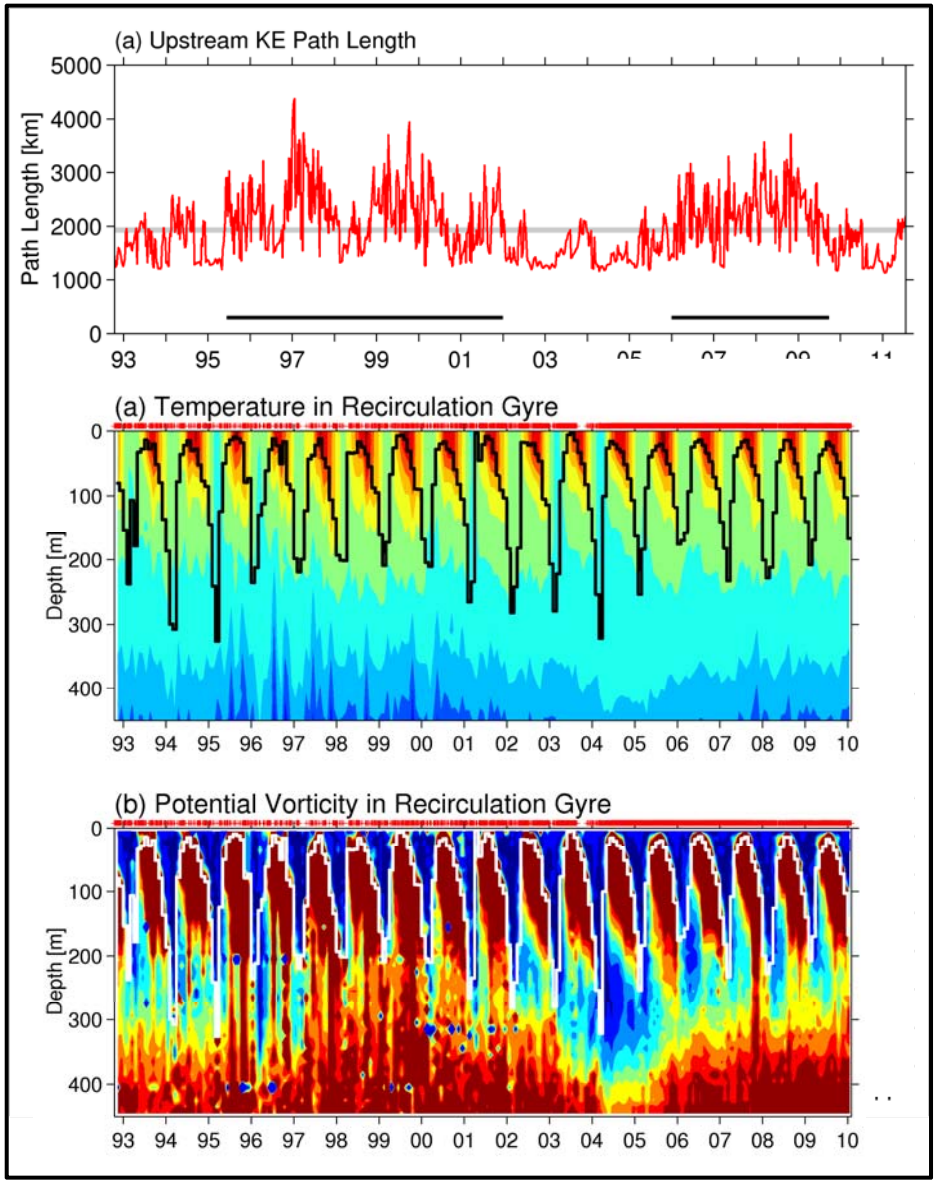


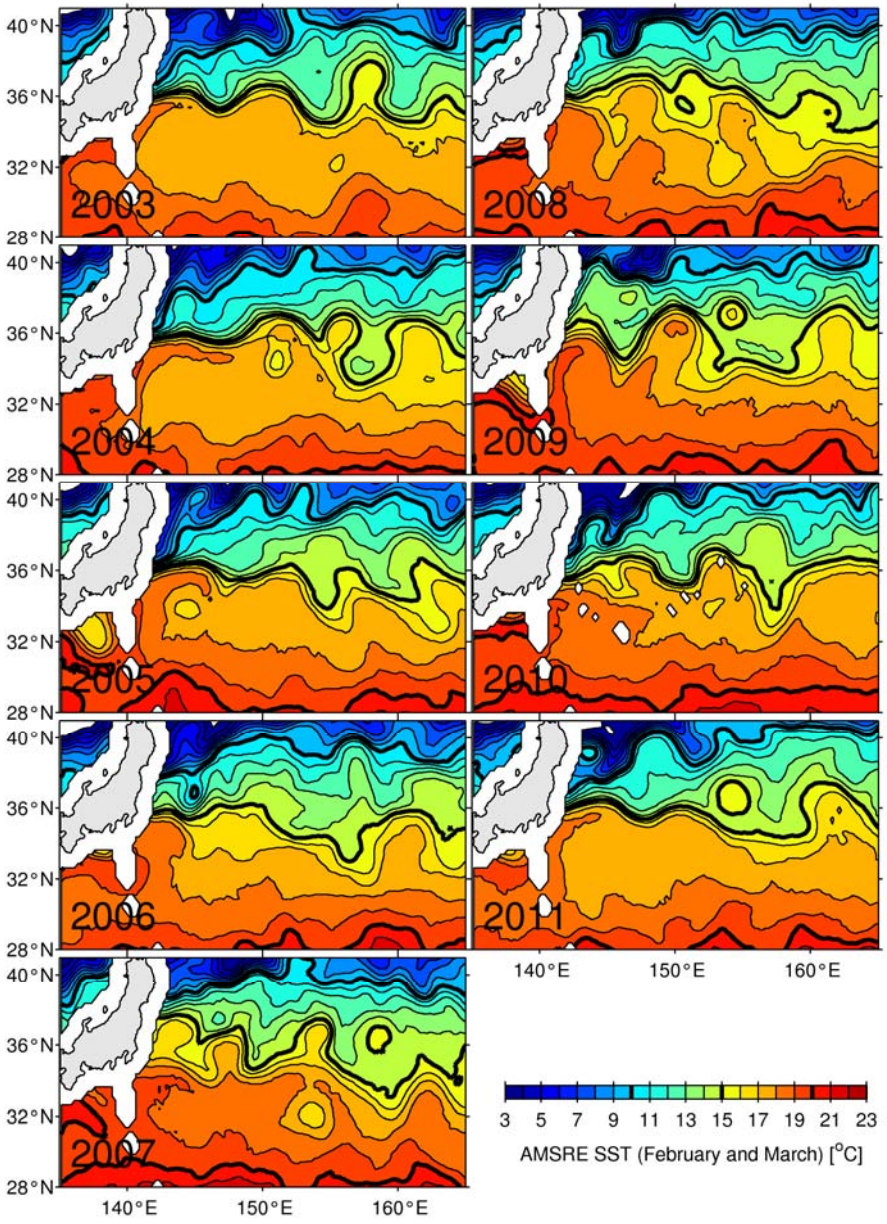
KE index: represented well by SSH anomalies in 31-36°N, 140-165°E

Implications:

Predicting KE index becomes equivalent to predicting SSH anomalies in this key box

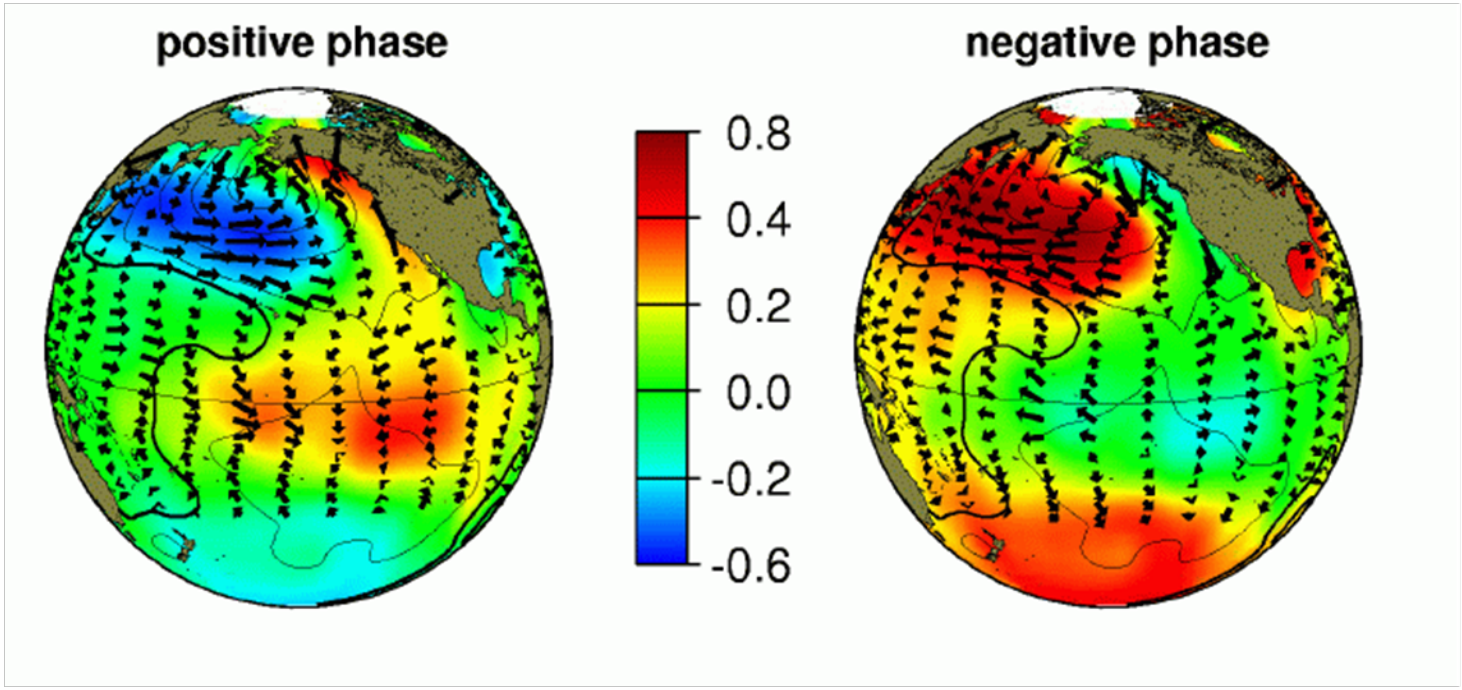
KE dynamic state affects regional SST, MLD and mode water formation



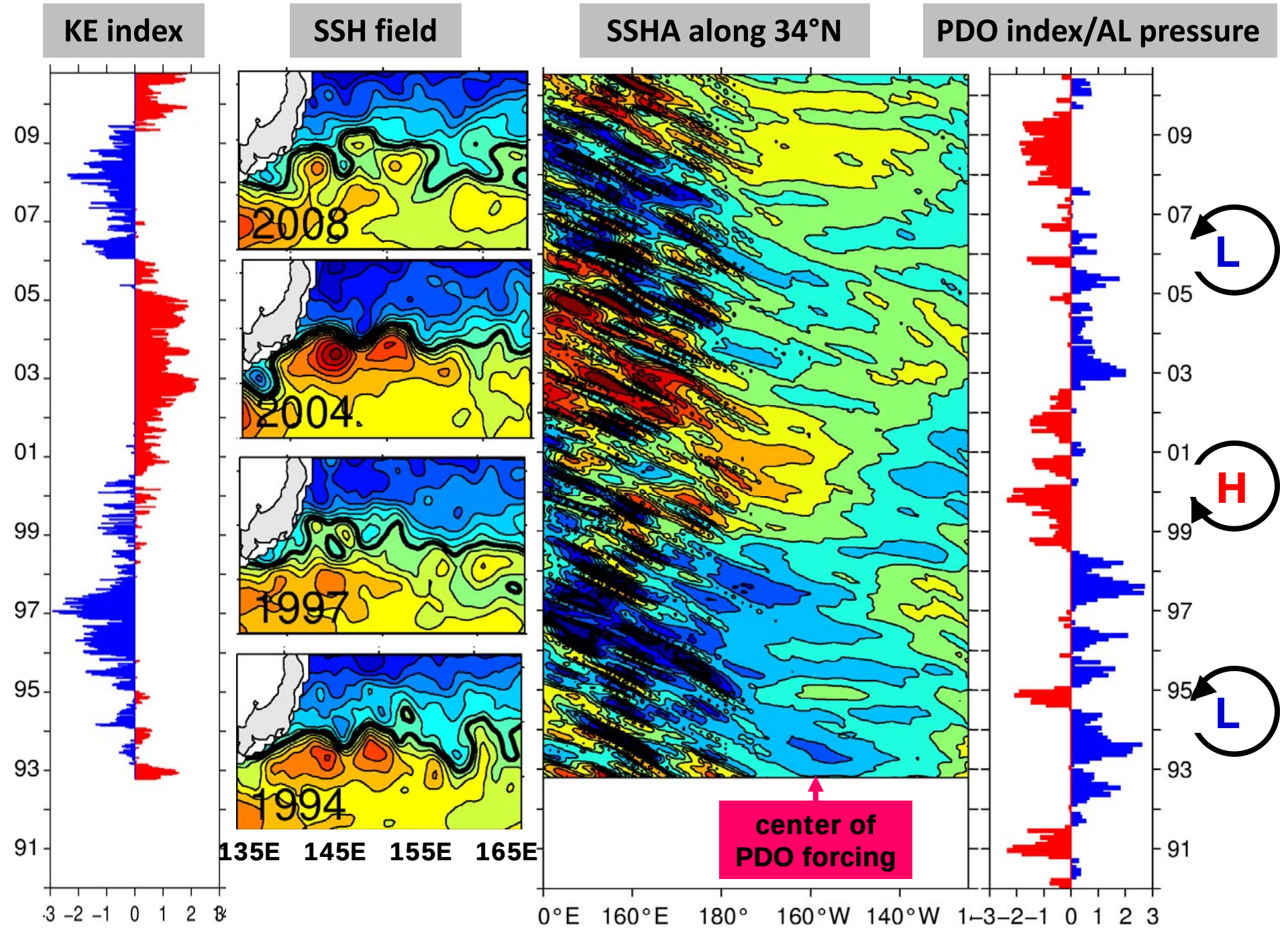


The basis for long-term KE index prediction rests on 2 processes:

1. **Oceanic adjustment in mid-latitude N Pacific is via slow, baroclinic Rossby waves + PDO wind forcing is located in the eastern basin**



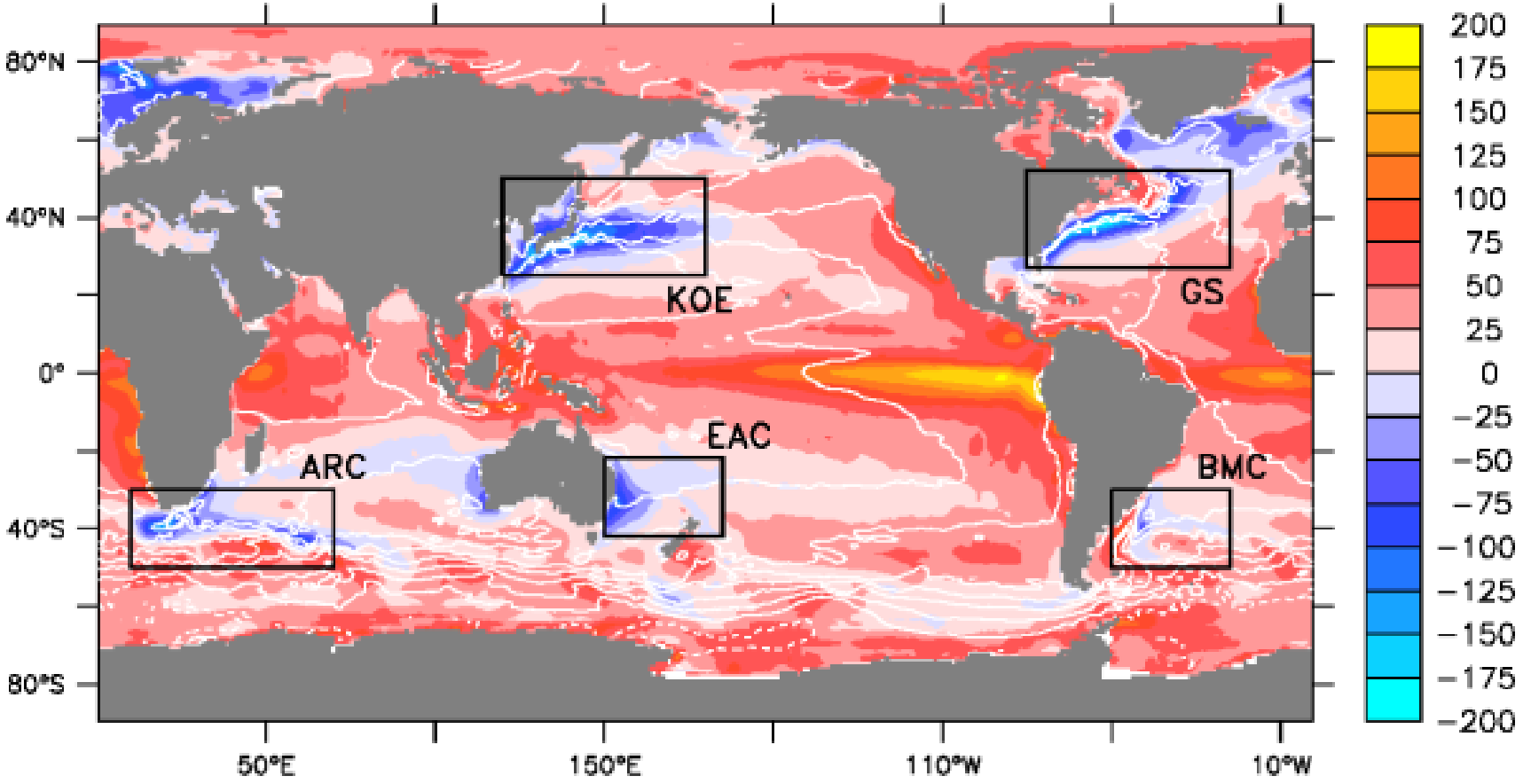
Mantua et al. (2007, BAMS)


KE index
SSH field
SSHA along 34°N
PDO index/AL pressure
2008
2004
1997
1994
135E
145E
155E
165E
0°E
160°E
180°
160°W
140°W
center of
PDO forcing
L
H
L
09
07
05
03
01
99
97
95
93
91
-3
-2
-1
0
1
2
3

The basis for long-term KE index prediction rests on 2 processes:

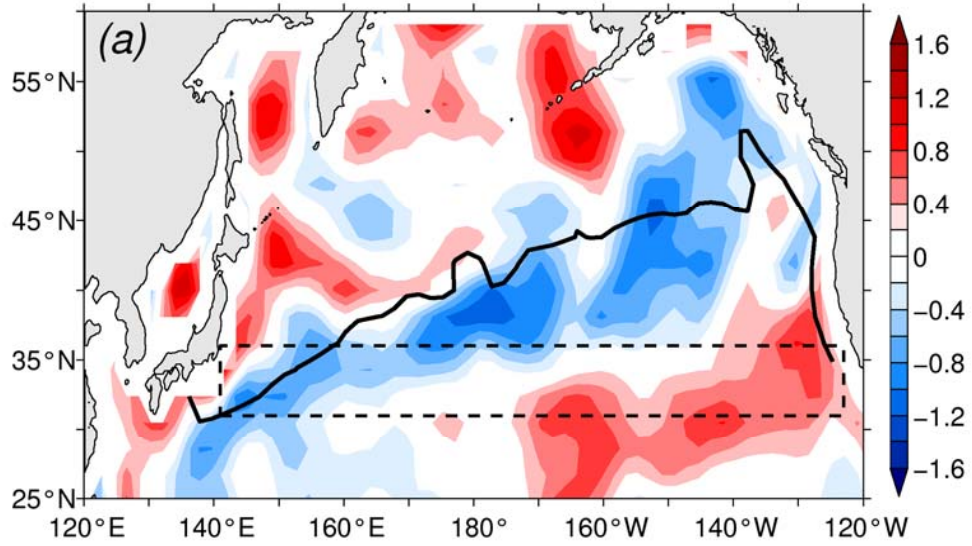
2. The KE jet exists in the region of intense air-sea interaction; its decadal variability affects the basin-scale wind stress curl field

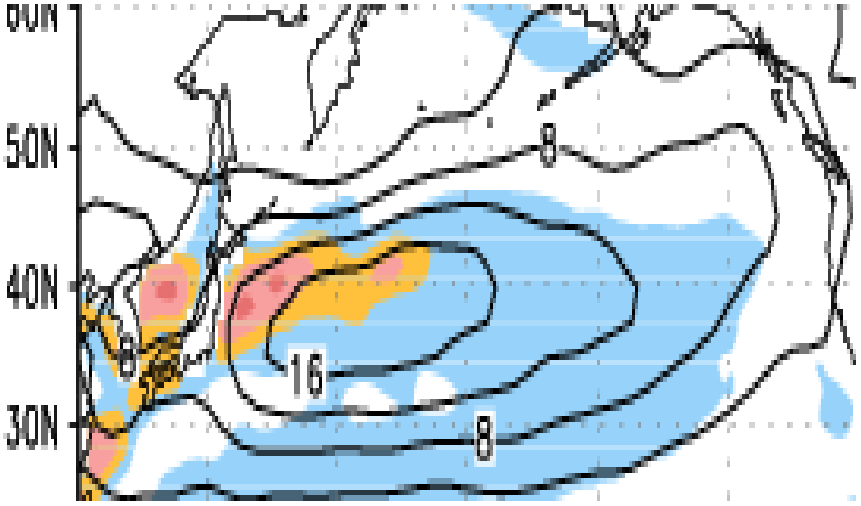
Mean net surface heat flux (W/m^2; Cronin et al. 2010)

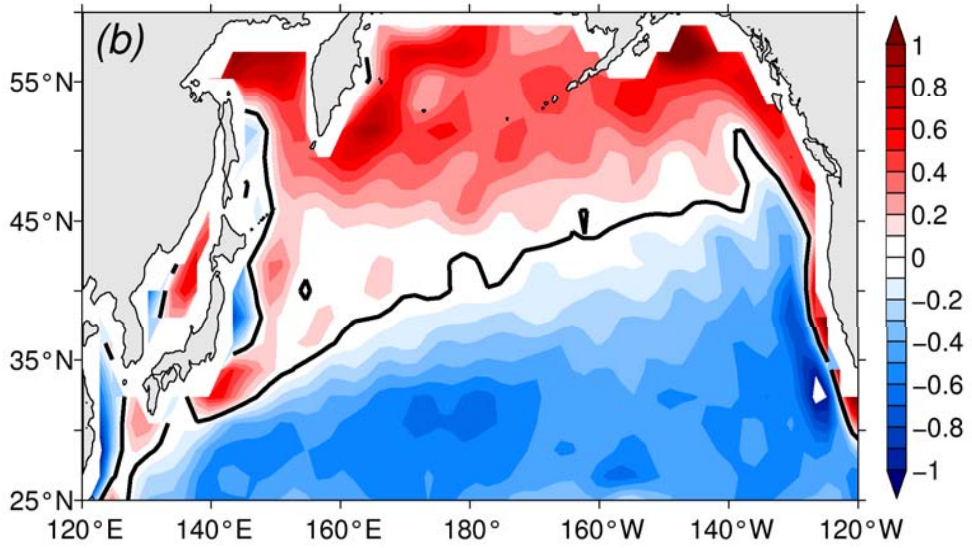


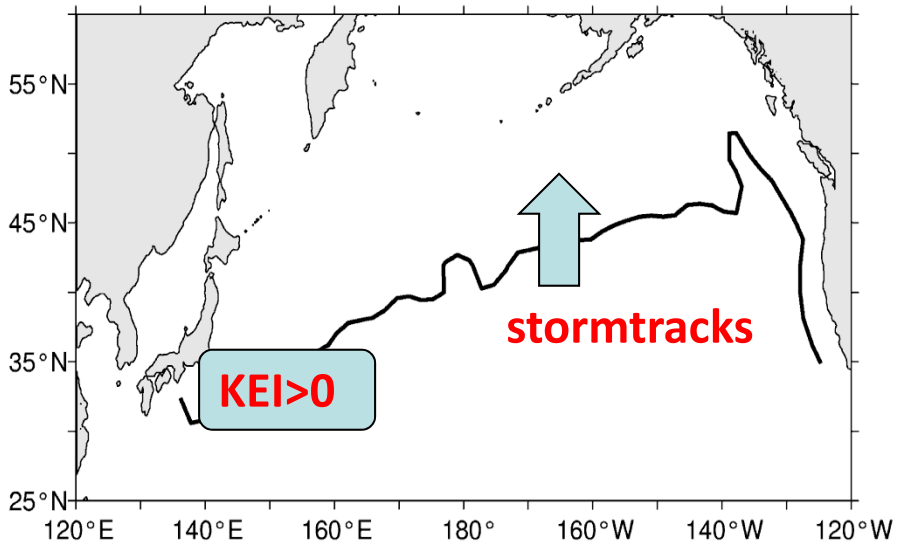
KE index-regressed curl field

mean wintertime stormtracks
850mb v'T' (Nakamura et al. 2004)



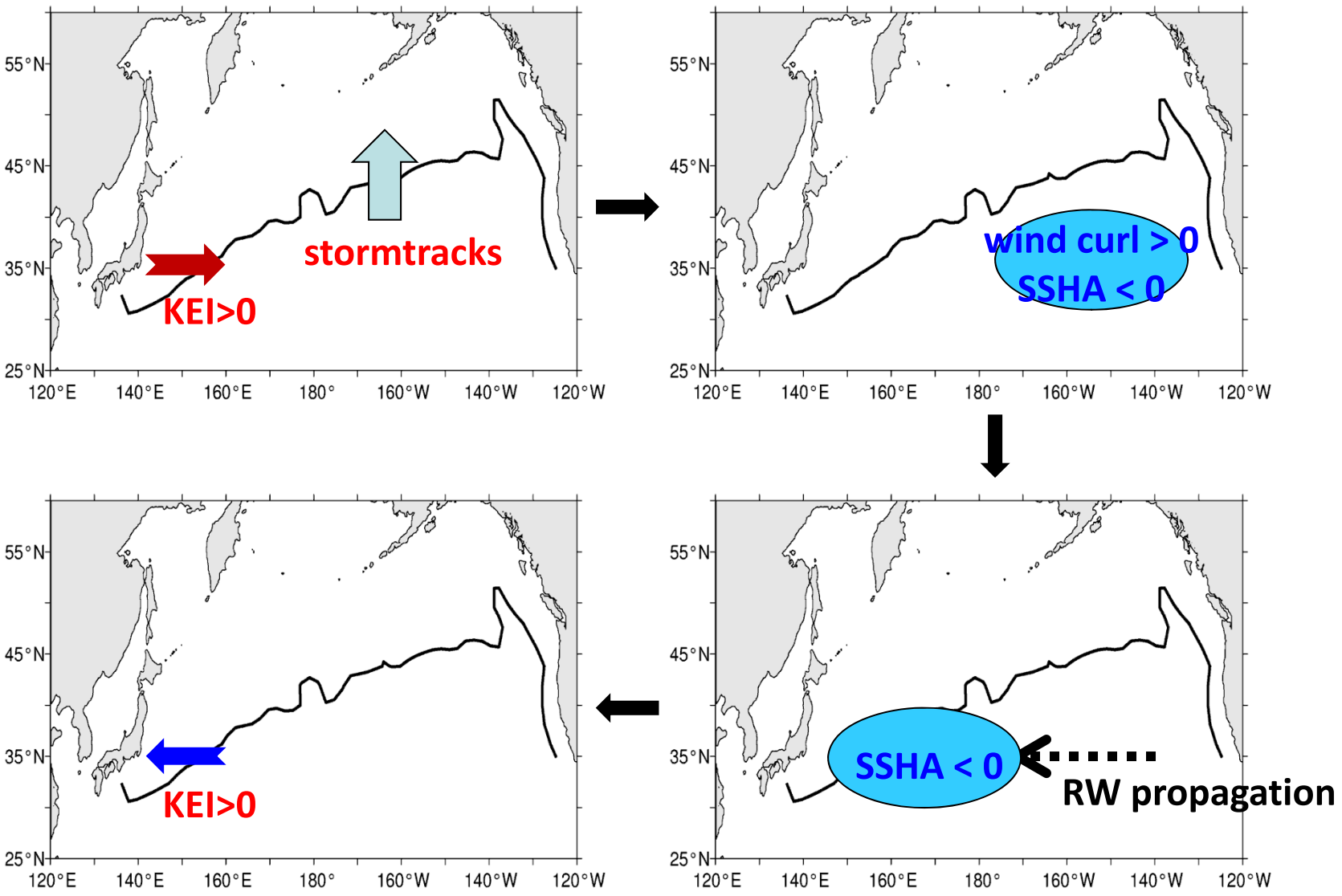






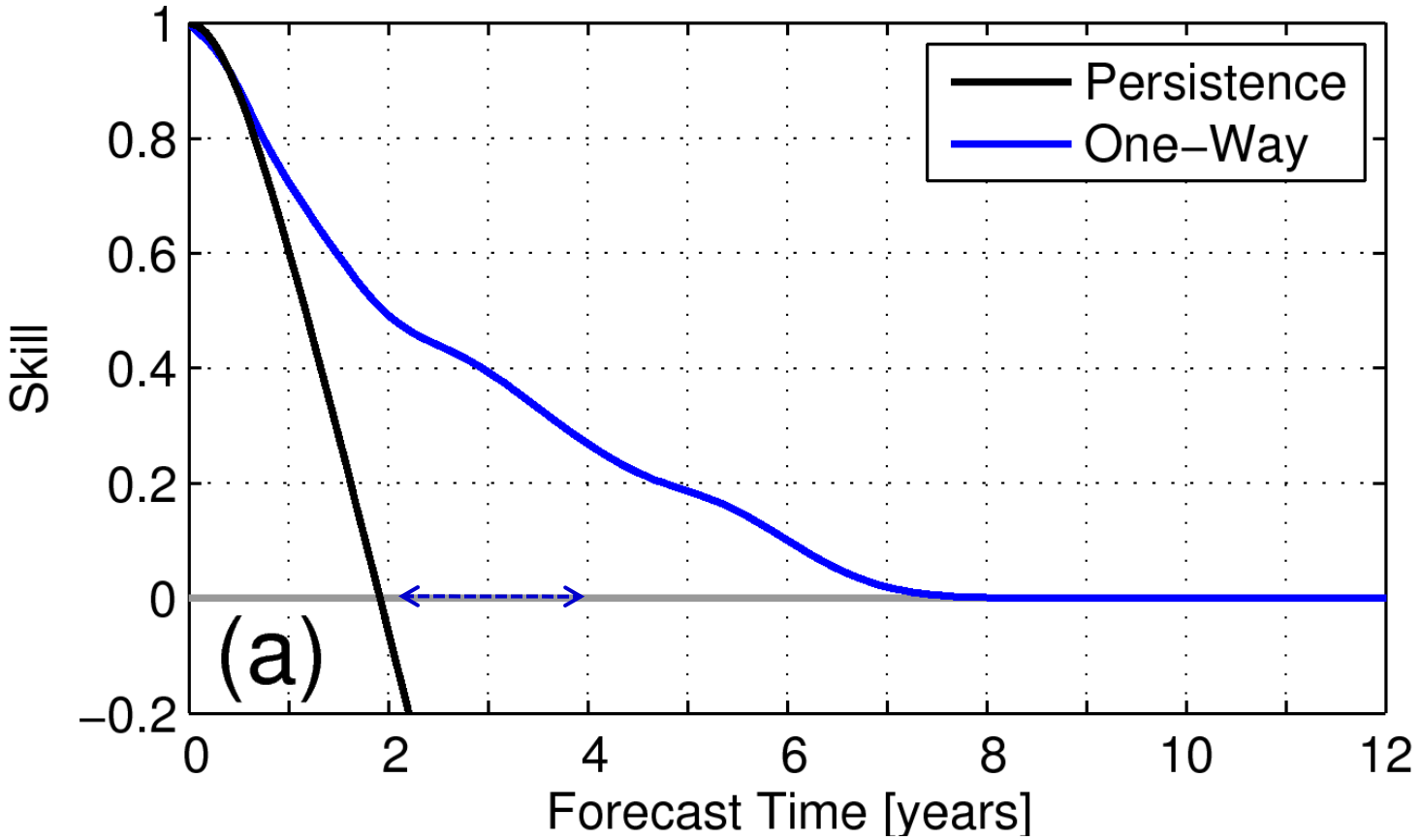
mean wind stress curl field

Schematic for a delayed negative feedback decadal oscillation



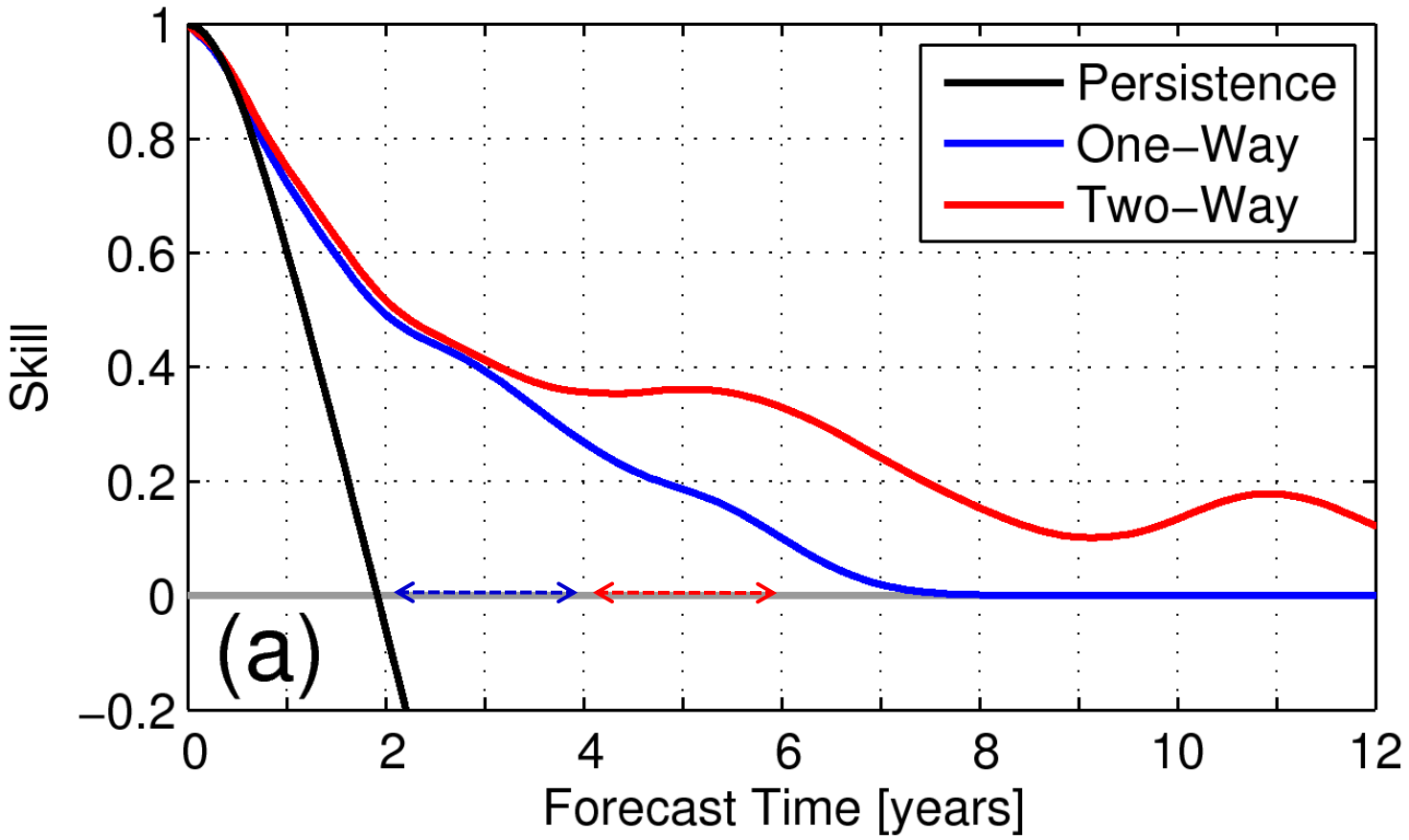
half of the oscillation cycle: ~5 yrs in the N Pacific basin

Mean square skill of the predicted KE index



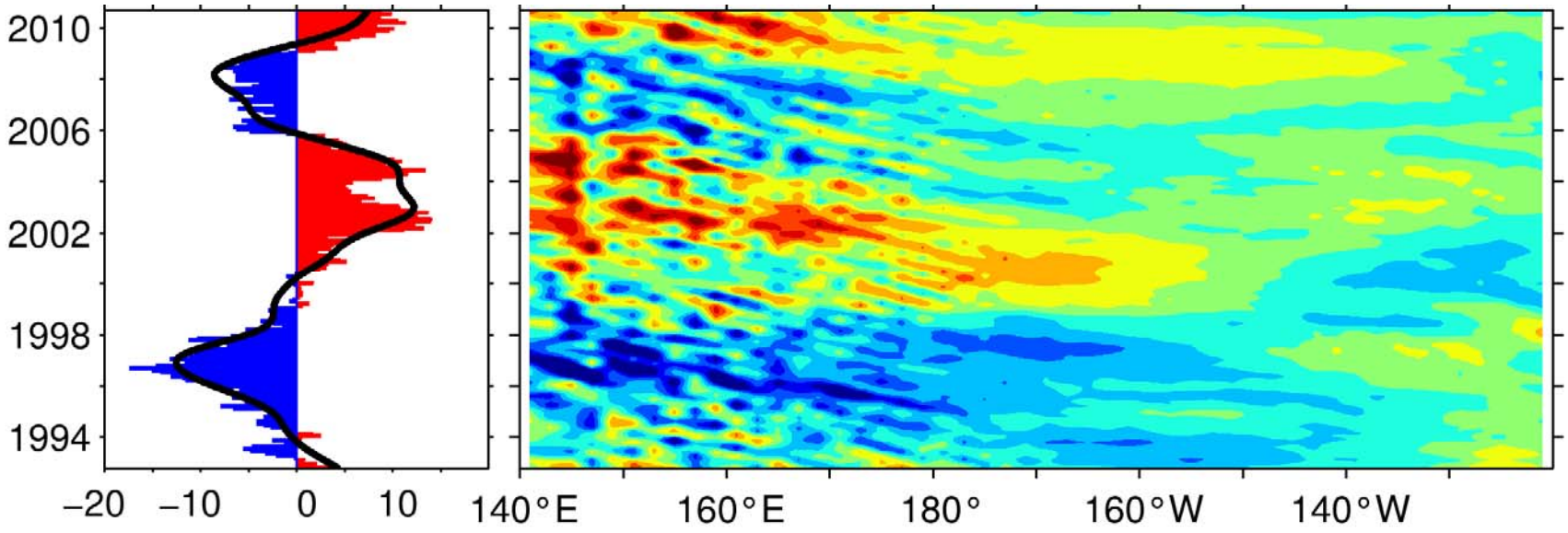
- **Compared to persistence, wave-carried SSHAs increase predictive skill**

Mean square skill of the predicted KE index

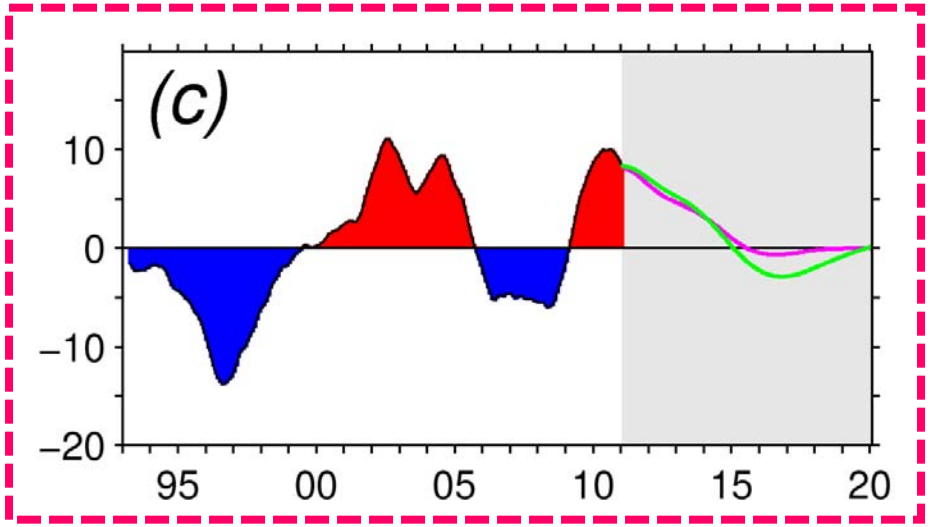


- **Compared to persistence, wave-carried SSHAs increase predictive skill**
- **Additional skill is gained by considering the wind forcing due to the KE feedback**

AVISO KE index and x-t plot of SSHAs along 31°-36°N



2011-2020 KE index forecast based on 2010 AVISO SSH data

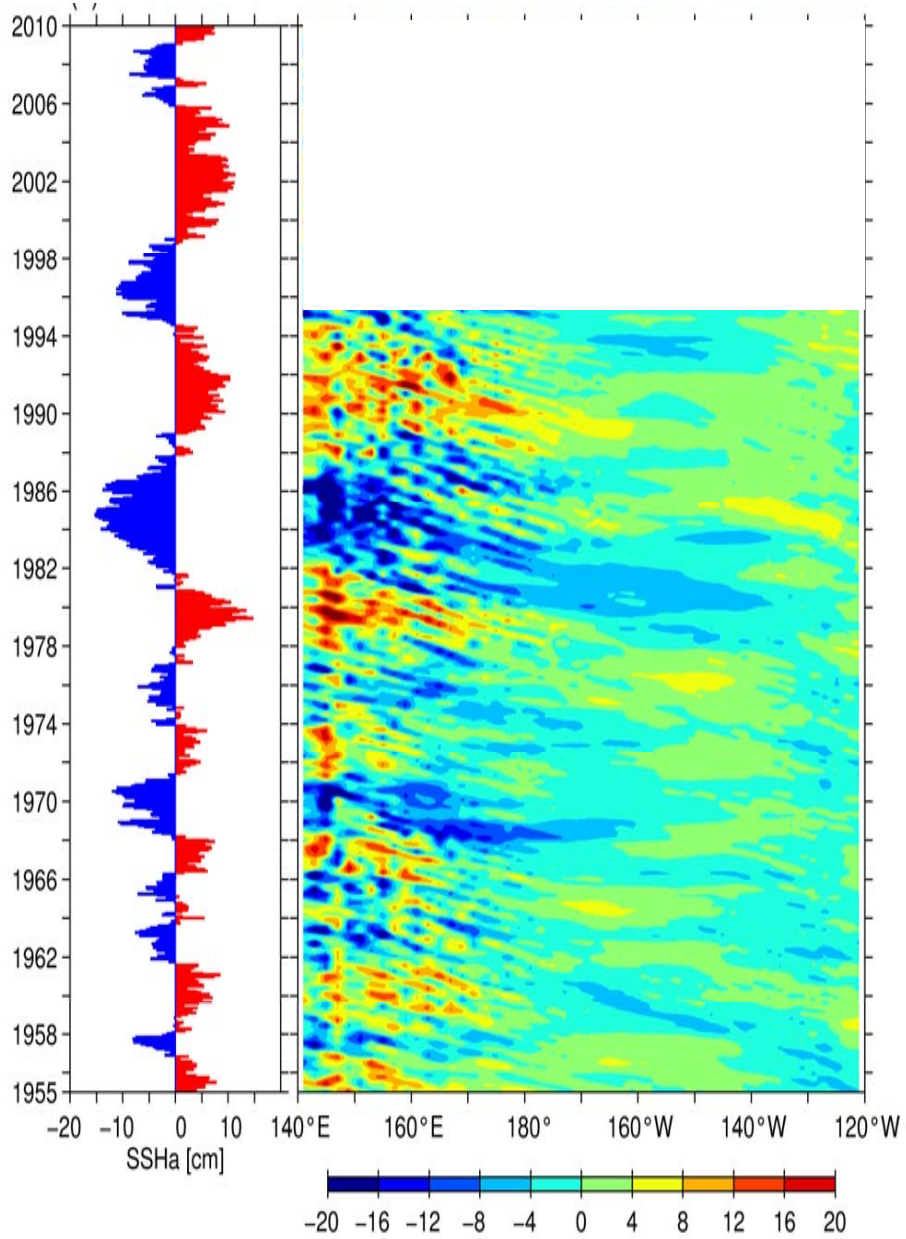


Summary

- KE dynamic state (i.e. EKE level, path, and jet/RG strengths) is dominated by decadal variations after the 1976-77 climate shift.
- SSH anomaly signals in 31-36°N, 140-165°E provide a good proxy for the decadally-varying KE index.
- A positive KE index induces overlying-high and downstream-low pressure anomalies. This feedback favors a coupled mode with a ~10 yr timescale.

  → Oscillatory nature of this mode enhances predictability
- Rossby wave dynamics contributes to the KE index predictability with 2~3 yr lead times.
- Inclusion of the KE-feedback wind forcing increases the predictive skill in the lead times of 4~5 yrs.

OFES KE index and x-t SSHAs



1. Prediction with Rossby wave dynamics

$$h_1(x, t) = h_{obs}\,[\, x + c_R(t - t_0),\ t_0 \,]$$

where

$h_{obs}(x, t_0)$: **initial SSHAs**

c_R : **Rossby wave speed**

2. Prediction with Rossby wave dynamics + KE feedback to wind forcing

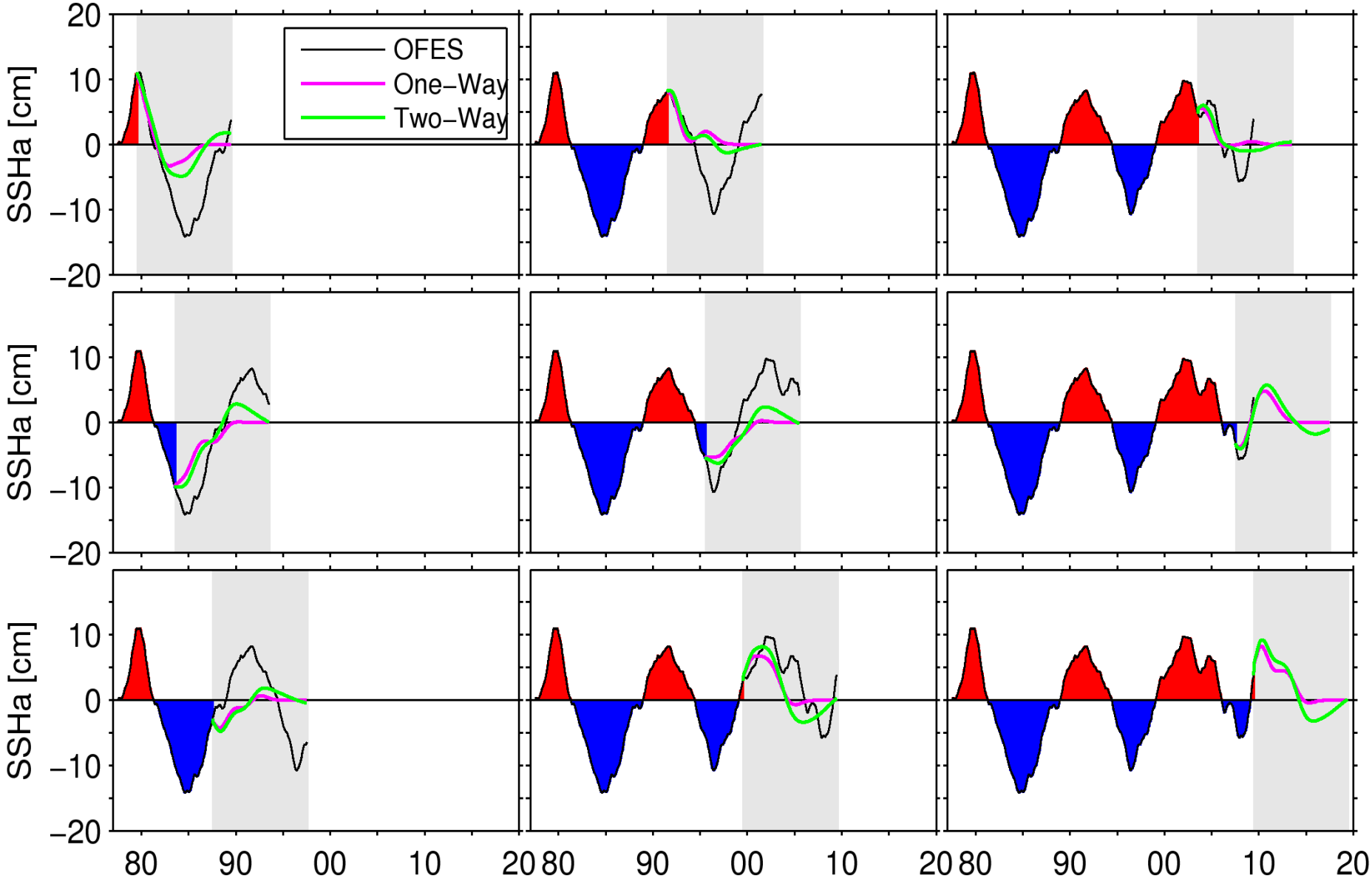
$$h_2(x, t) = h_1(x, t) + \int_{t_0}^{t} b[\, x + c_R(t' - t_0)\,]\, K(t')\, dt'$$

where

$b(x)$: **feedback coefficient**

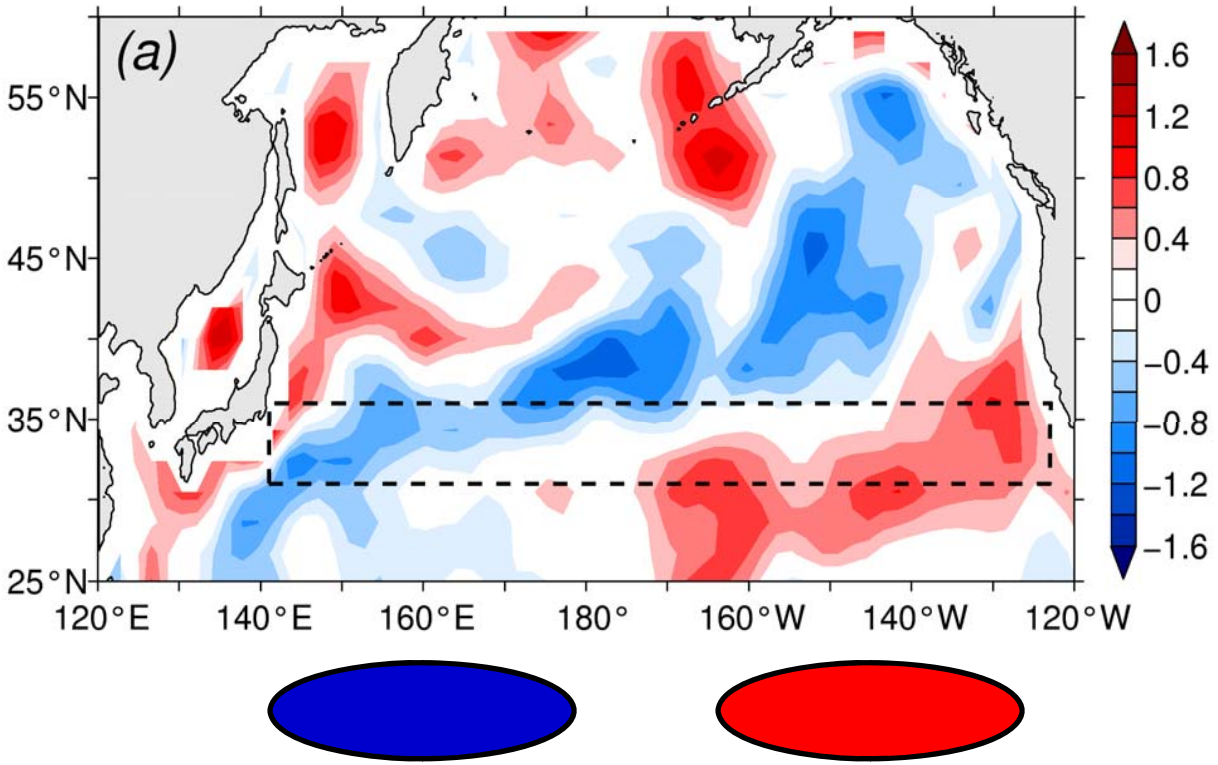
$K(t)$: **forecast KE index**

Examples of decadal KE index predictions and verifications

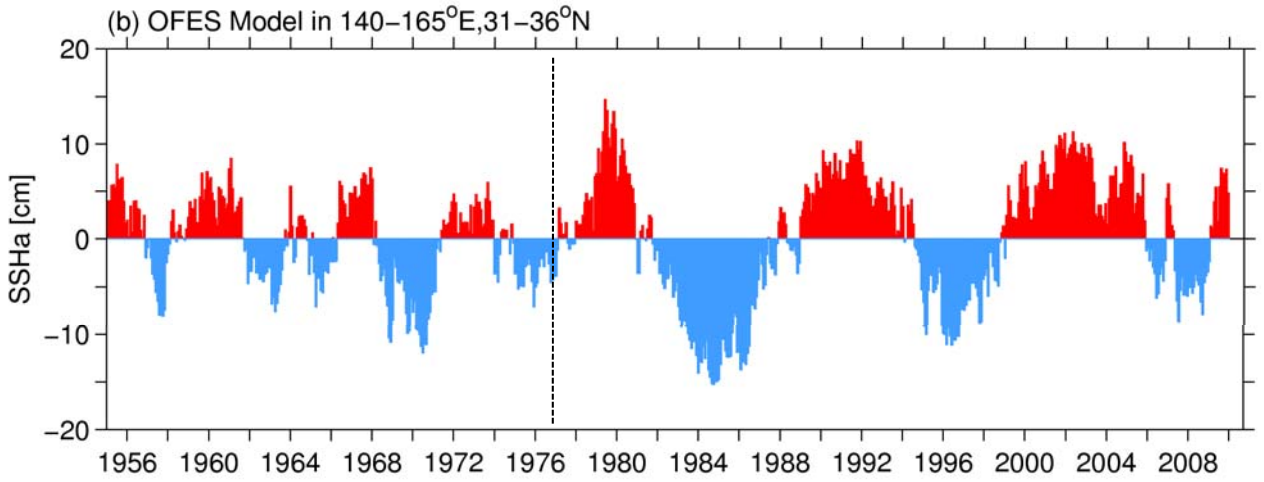


Lagged regression between the OFES KE index and NP curl-tau field

- NCEP reanalysis data (1977-2010)
- ENSO signals (Nino 3.4) regressed out
- b(x,y) with m = 2 months



Our goal is to explore the predictability of the proxy KE index after the 1976-77 climate shift



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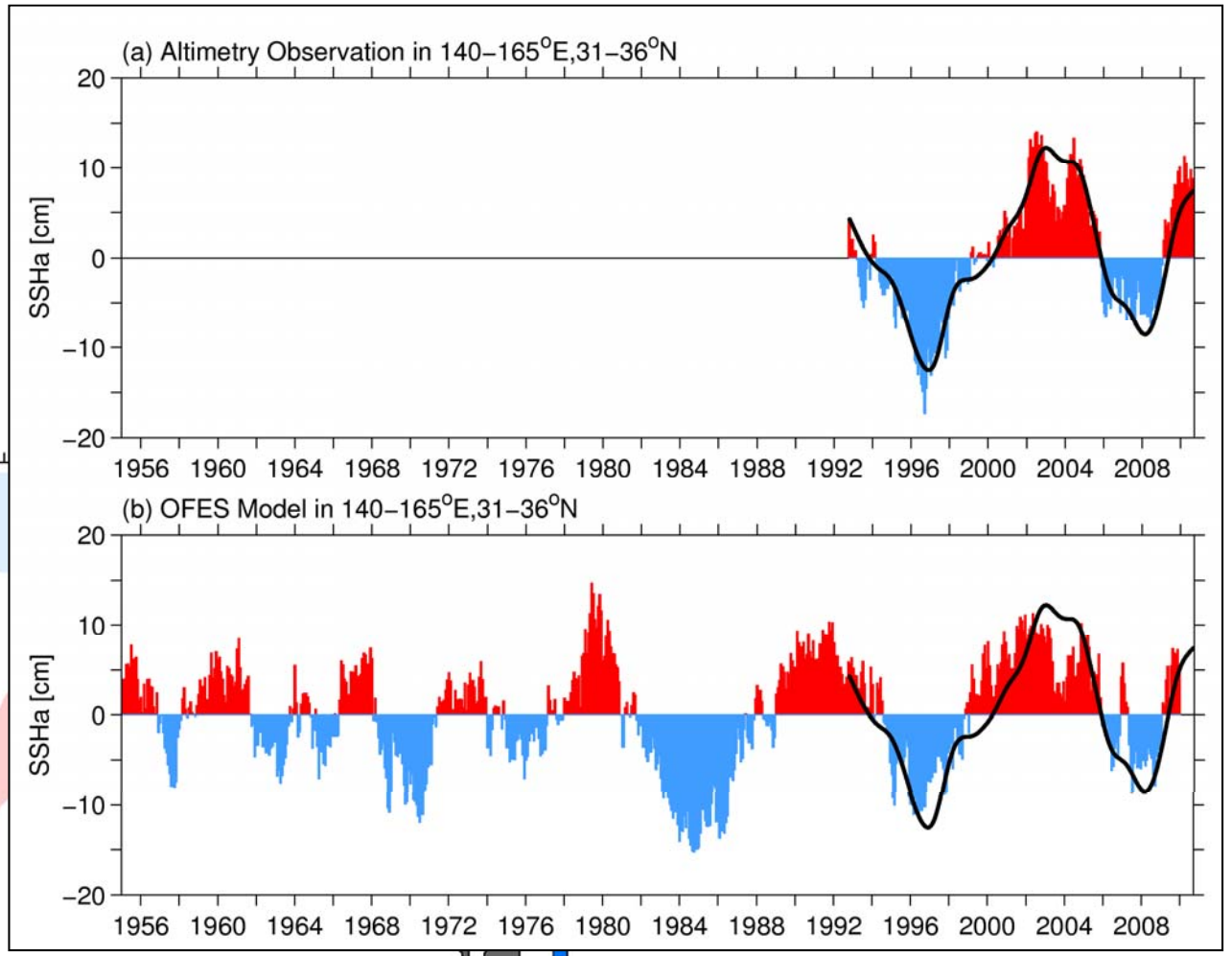
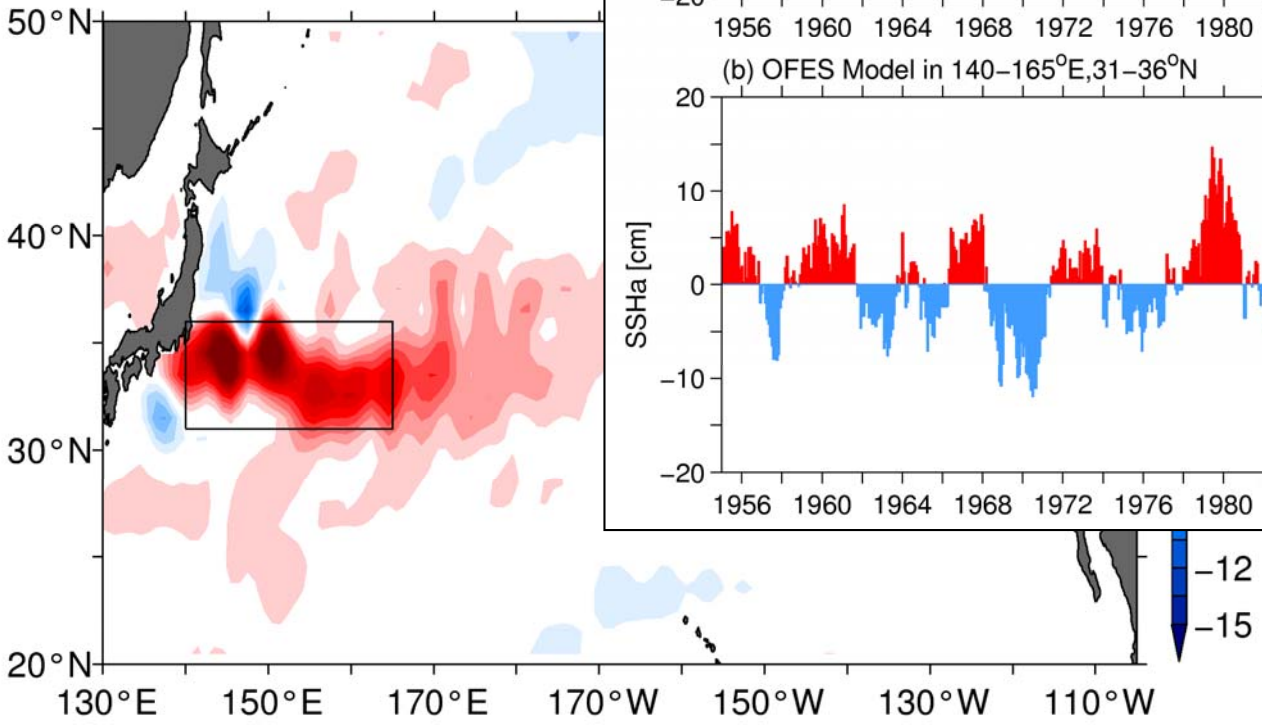
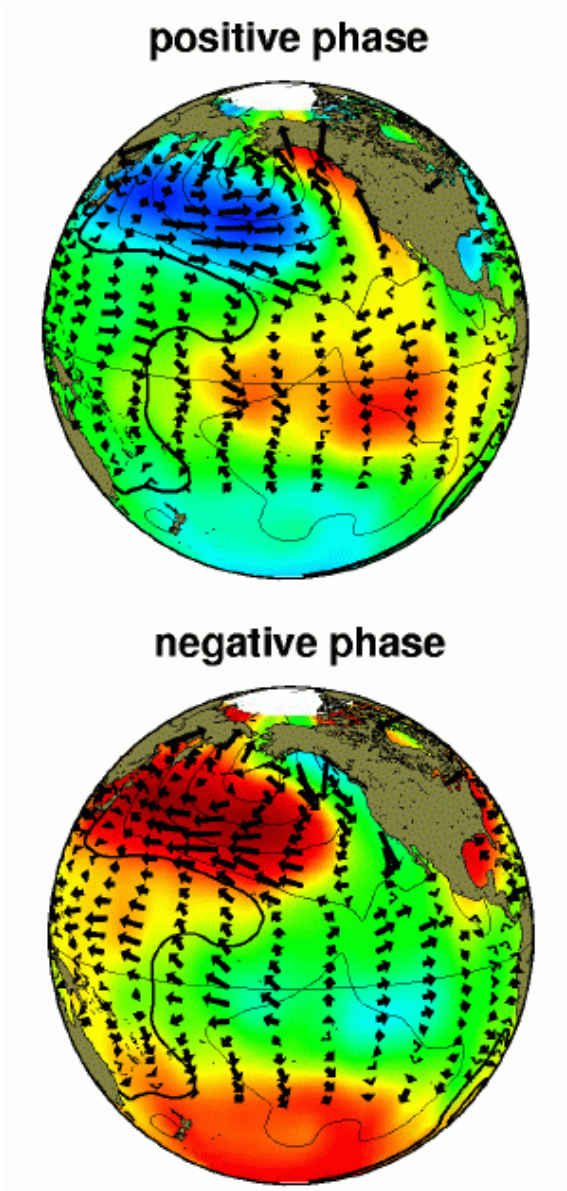
Lengthening the (proxy) KE index using the OFES hindcast results

OFES hindcast run simulates well the observed decadal KE variability (see Taguchi et al. 2007; Nonaka et al. 2008)



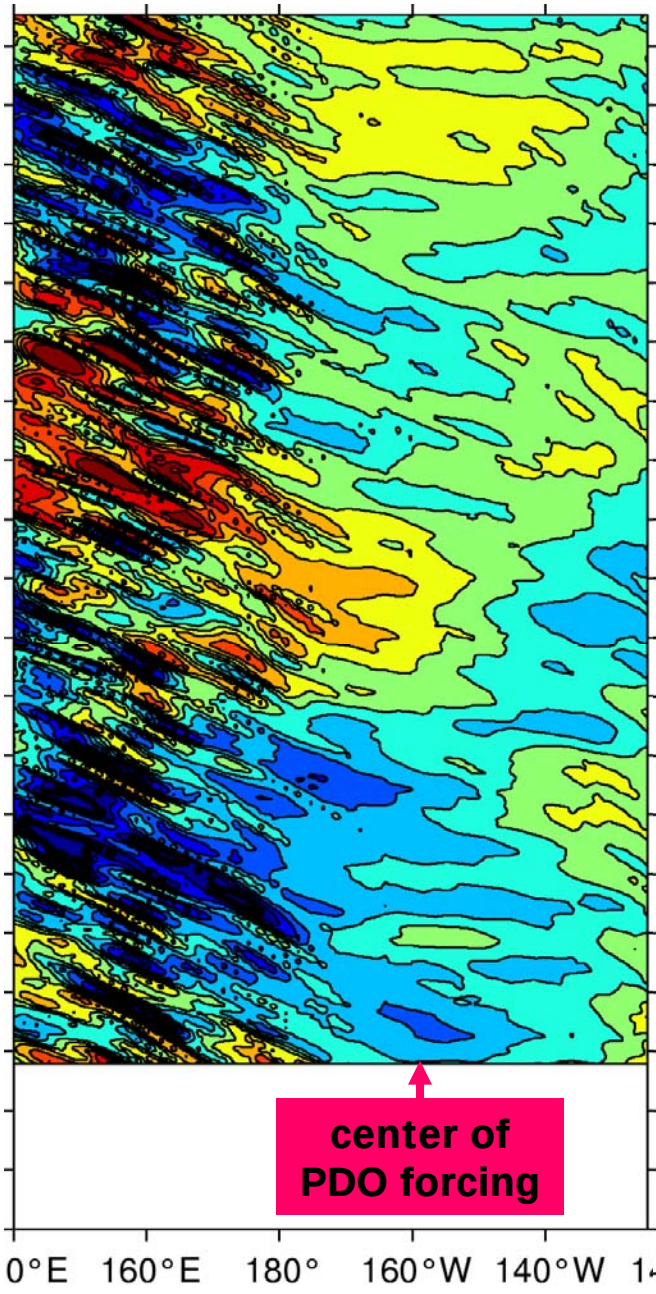


Composite PDO patterns



Mantua et al. (2007, BAMS)

SSHA along 34°N



PDO index/AL pressure