# Interplay of Intrinsic versus Forced Decadal Kuroshio Extension Variability: Observations & Predictability

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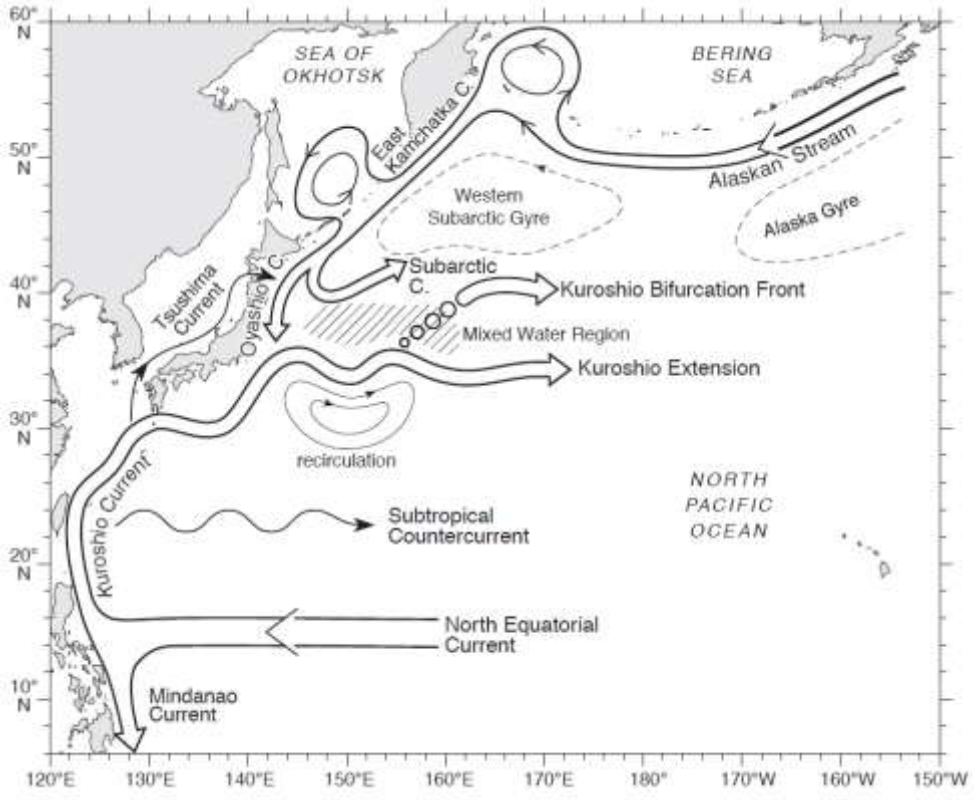
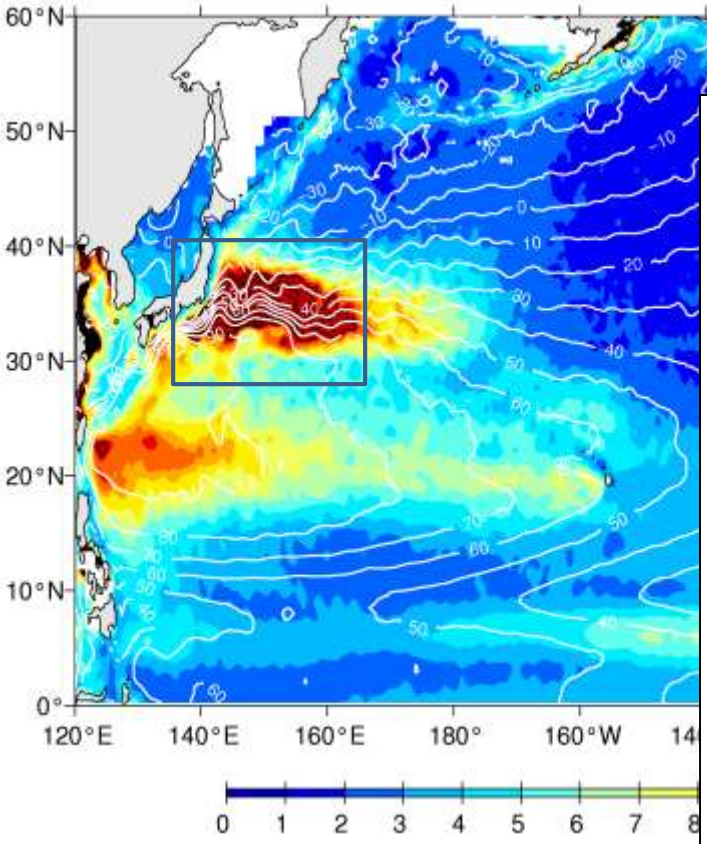
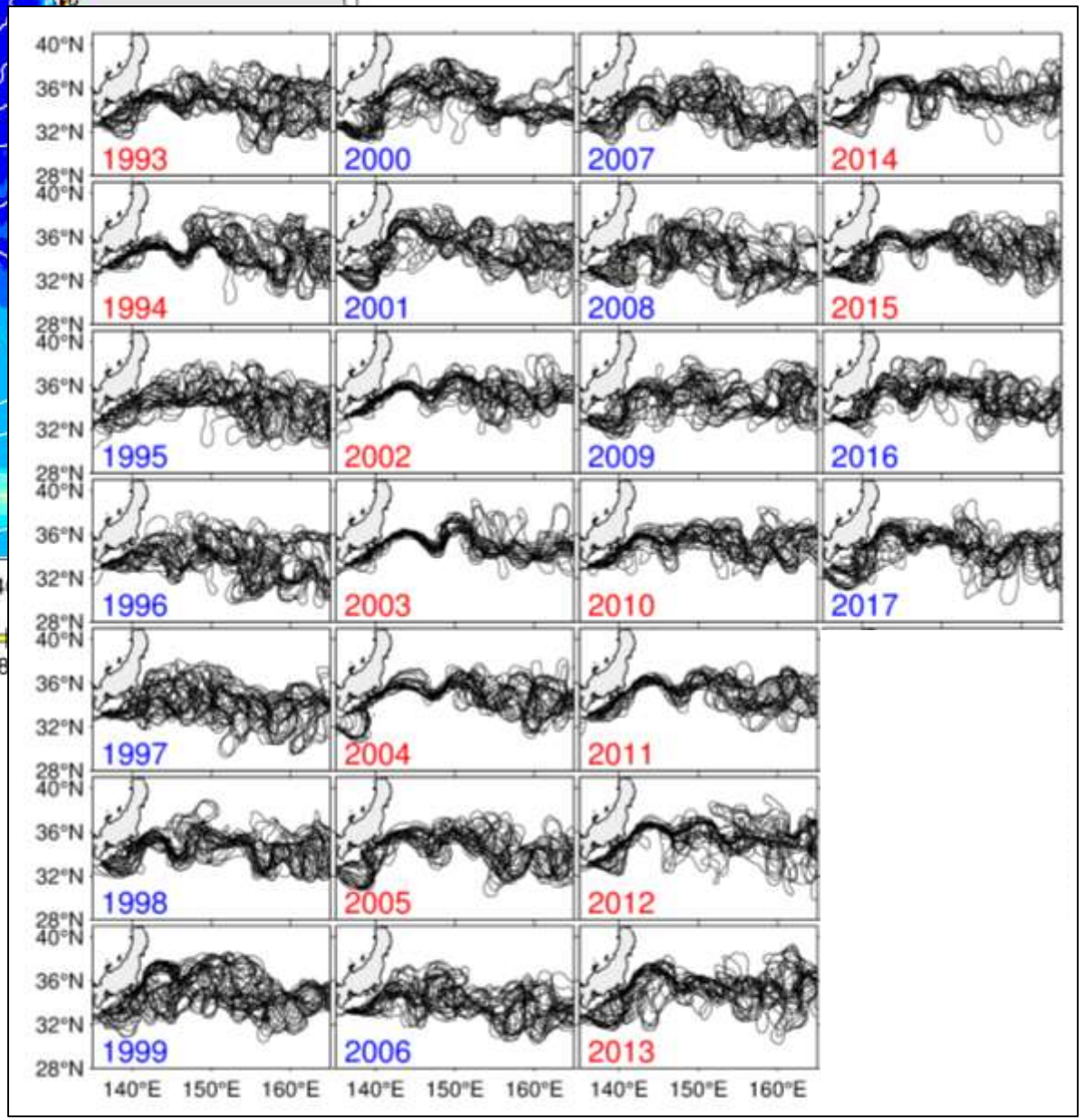



Schematic of NW Pacific Ocean Circulation (Qiu 2019, Encyc. Oce. Sci.)

**OSTST Science Team Meeting, Online, 19-23 October 2020**

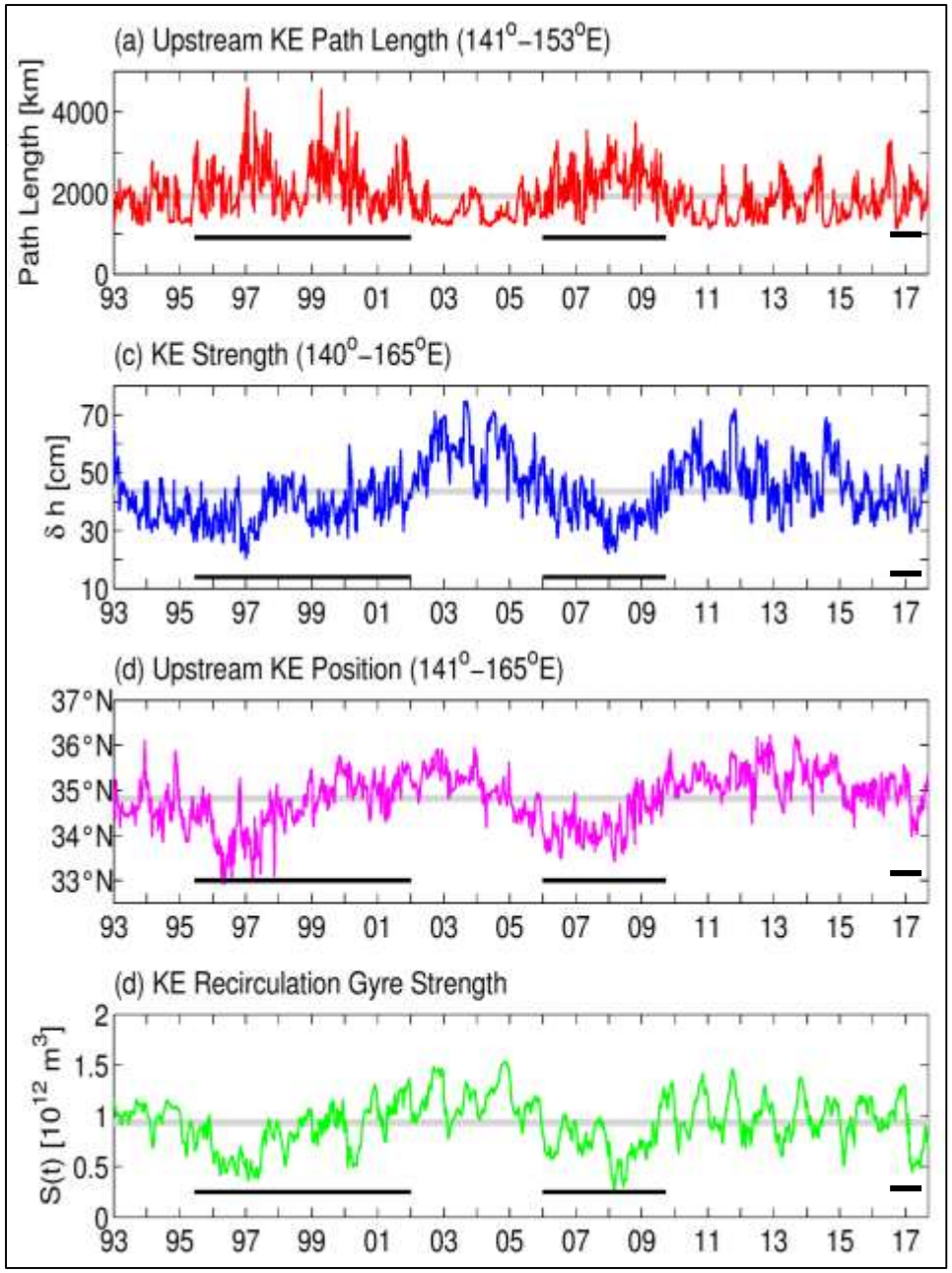
# Annual maps of bi-weekly paths of the Kuroshio/KE jet



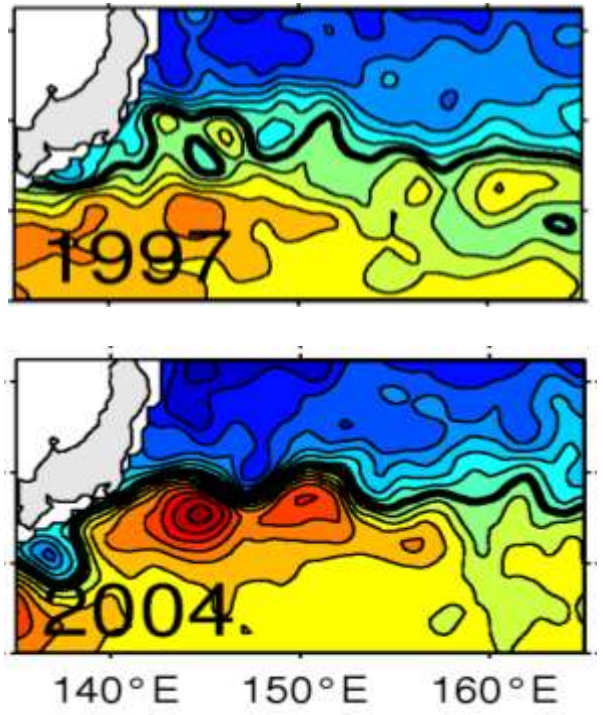




**Alternation between unstable versus stable states**

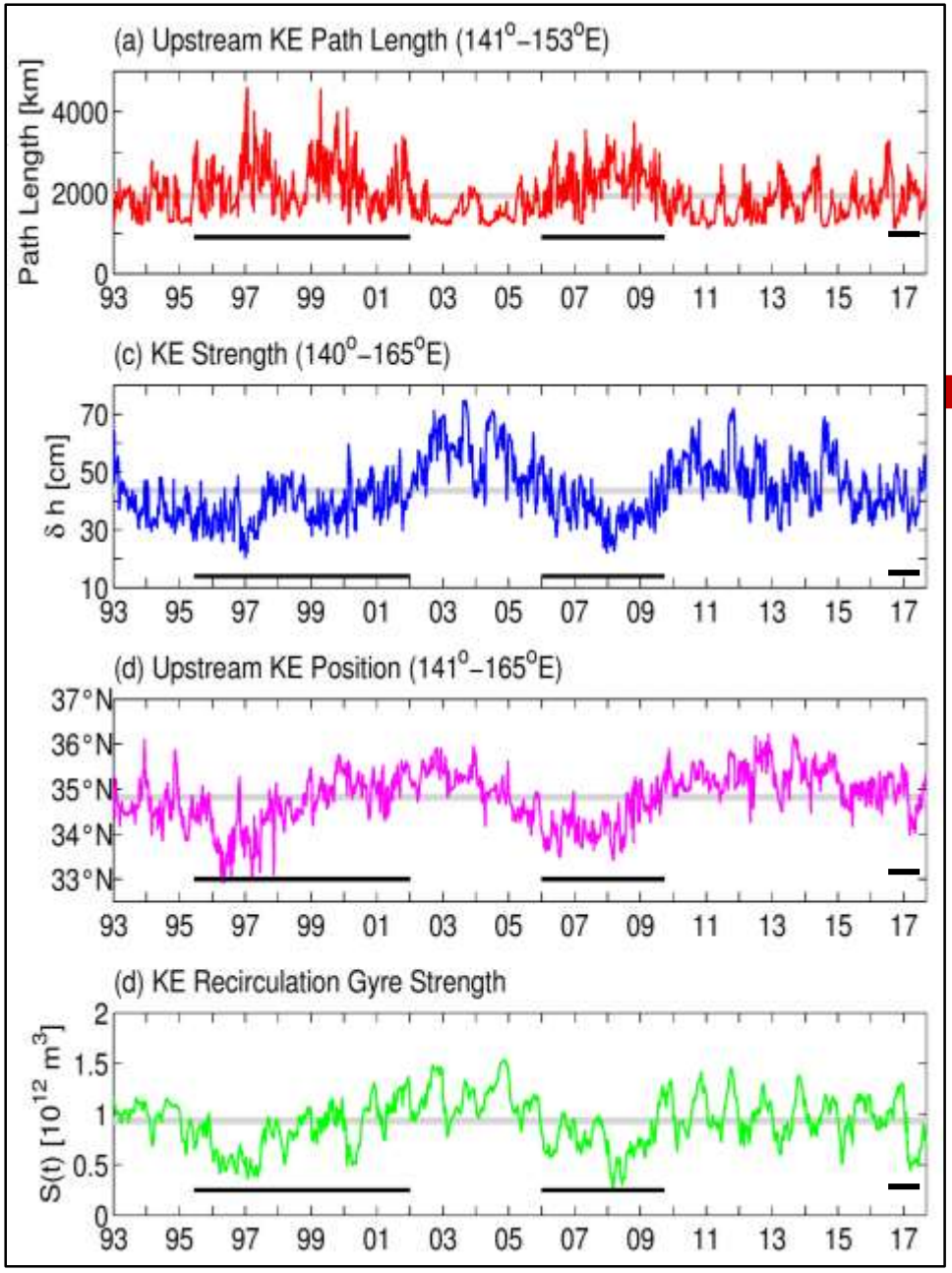
# Dynamically unstable vs. stable states of the KE system

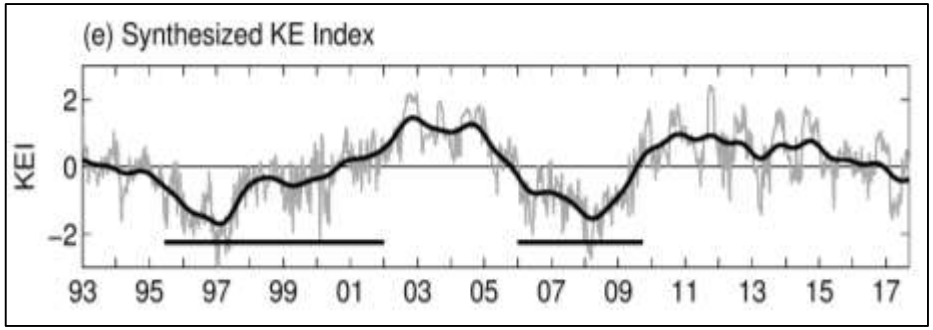



**Typical yearly SSH patterns in unstable vs. stable dynamic states**



# Form a comprehensive index representing the KE variability

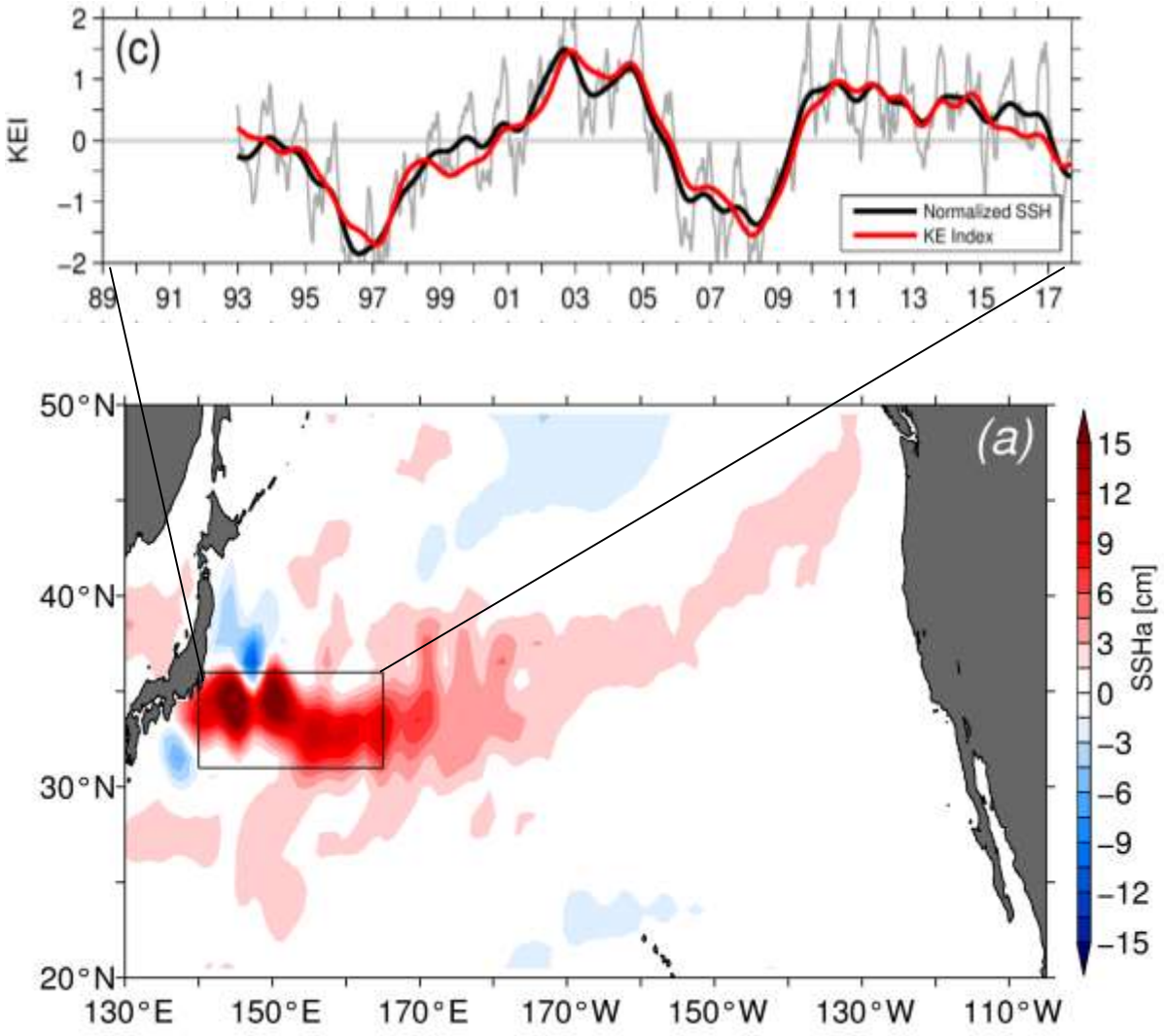



**KE index : average of these 4 dynamic quantities (normalized)**

Qiu et al. (2014, JC)

# Regression between the KE index and basin-wide SSH anomaly field




**KE index: represented well by SSH anomalies in the southern RG box (31-36°N, 140-165°E)**

KE index from dynamic properties

box-averaged SSH time series

**Implications**

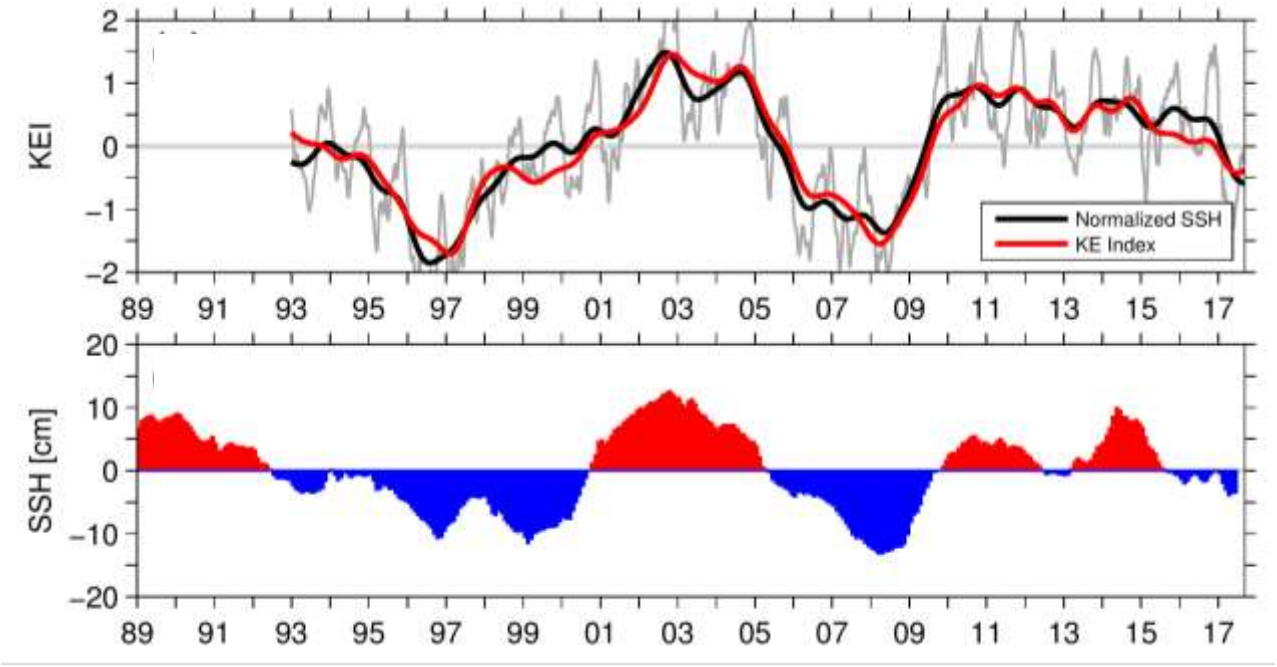
- Examining KE index becomes equivalent to examining SSH anomalies in this key box

# Quantifying the KE index using a wind-forced linear vorticity model

- **The proxy KE index is governed by wind forcing along the 31°-36°N band across the North Pacific basin:**

$$\frac{\partial h}{\partial t} - c_R \frac{\partial h}{\partial x} = -\frac{1}{\rho} \nabla \times \left( \frac{\boldsymbol{\tau}_{wind}}{f} \right)$$

- **Hindcast of KE index using ECMWF interim Ekman pumping data along Rossby wave characteristics:**



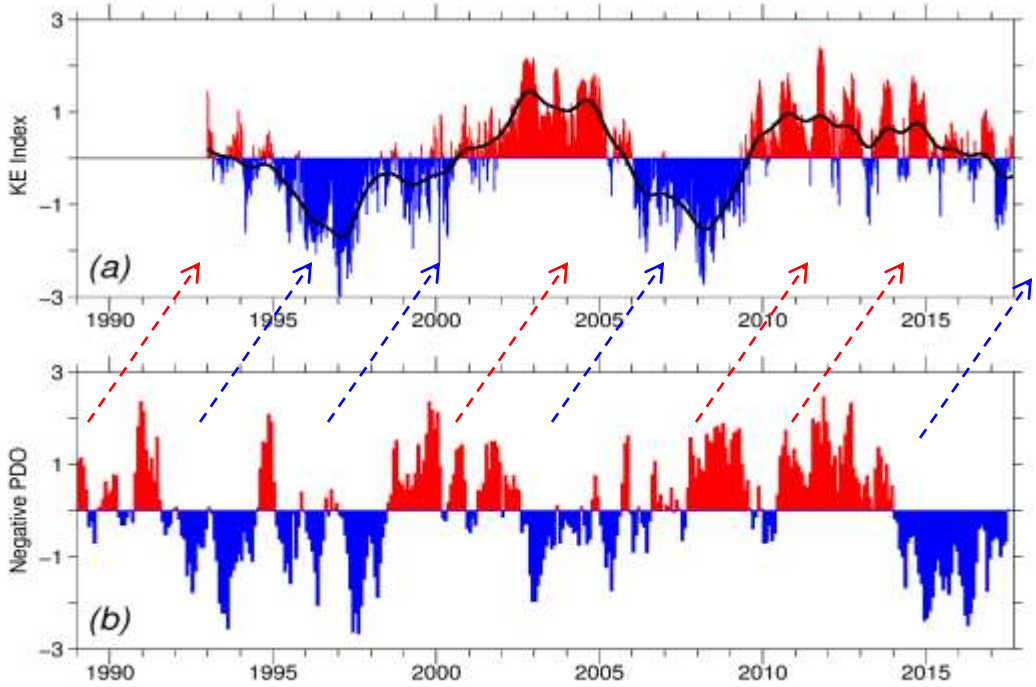

**original time series:**

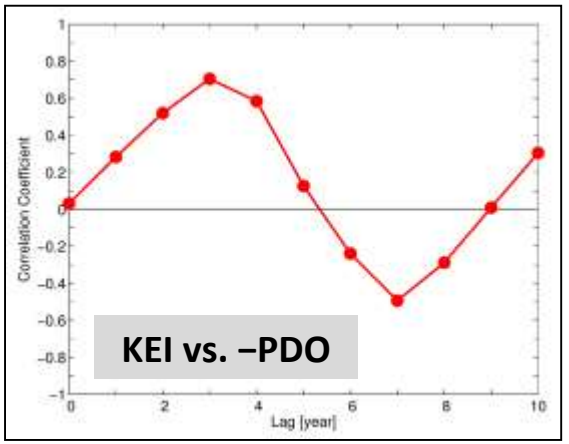
**r = 0.65**

**low-pass filtered TS:**

**r = 0.87**

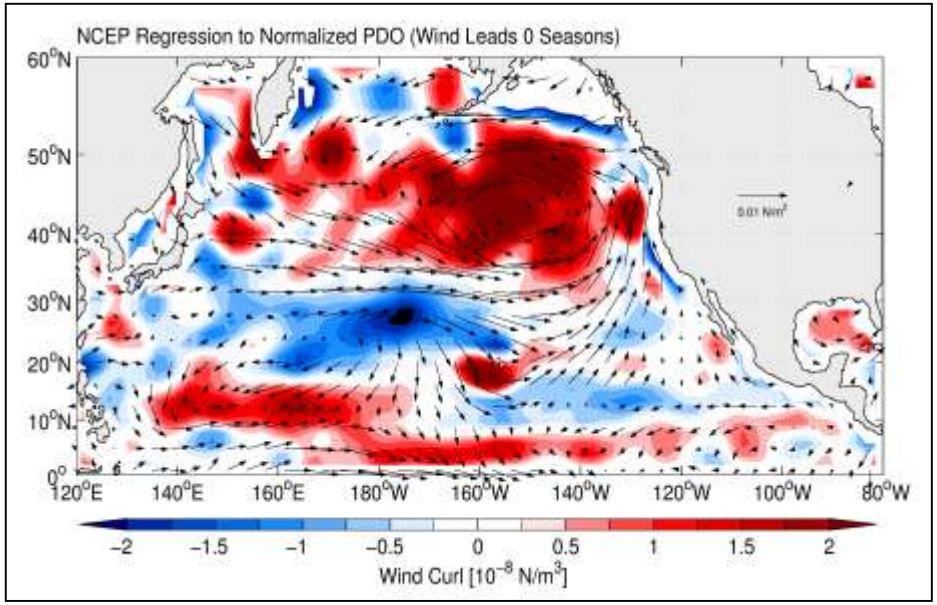
# Decadal KE variability lags the negative PDO index by ~ 3 years ( r = 0.74 )



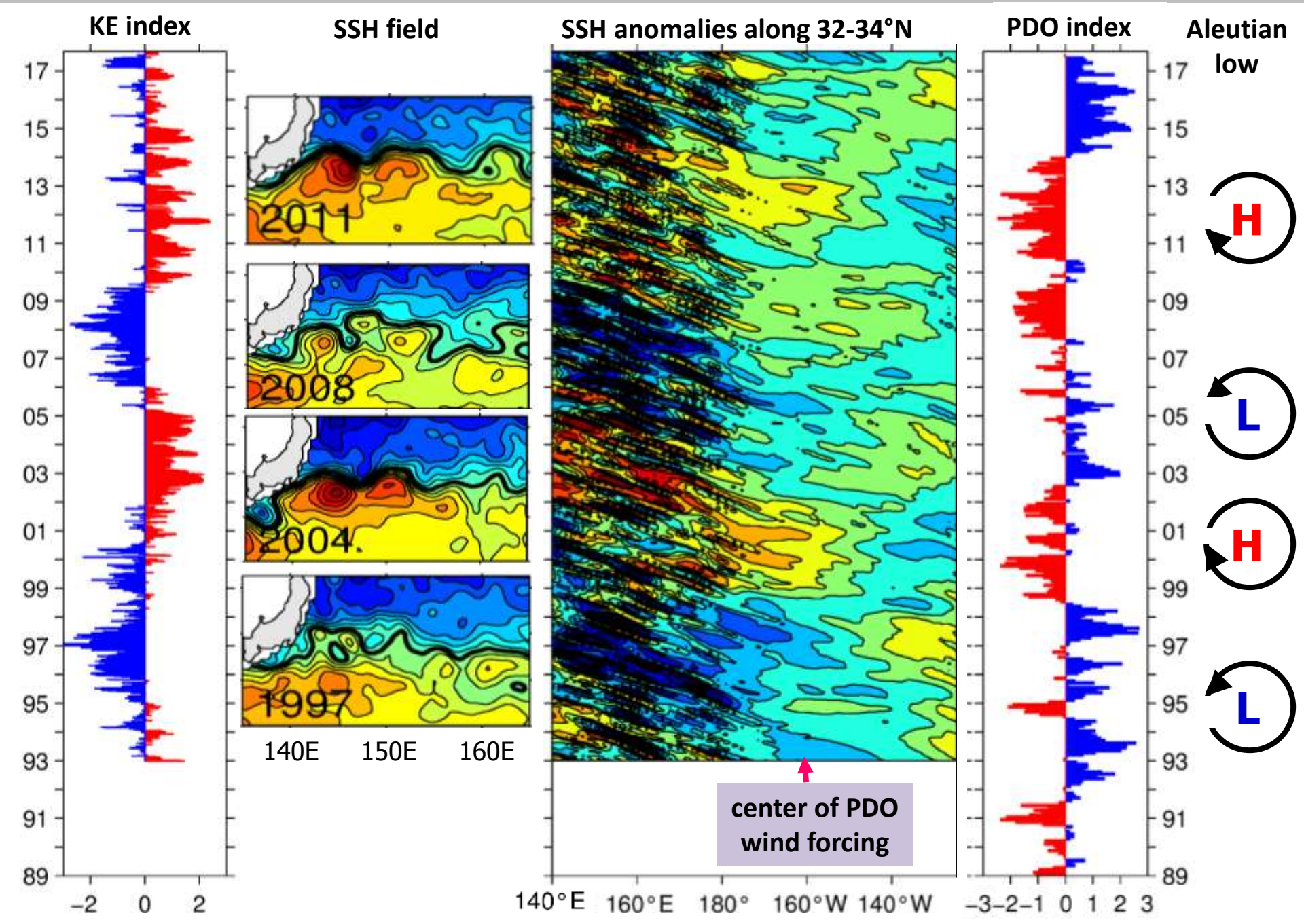




**PDO-regressed wind stress vector & curl (color)**

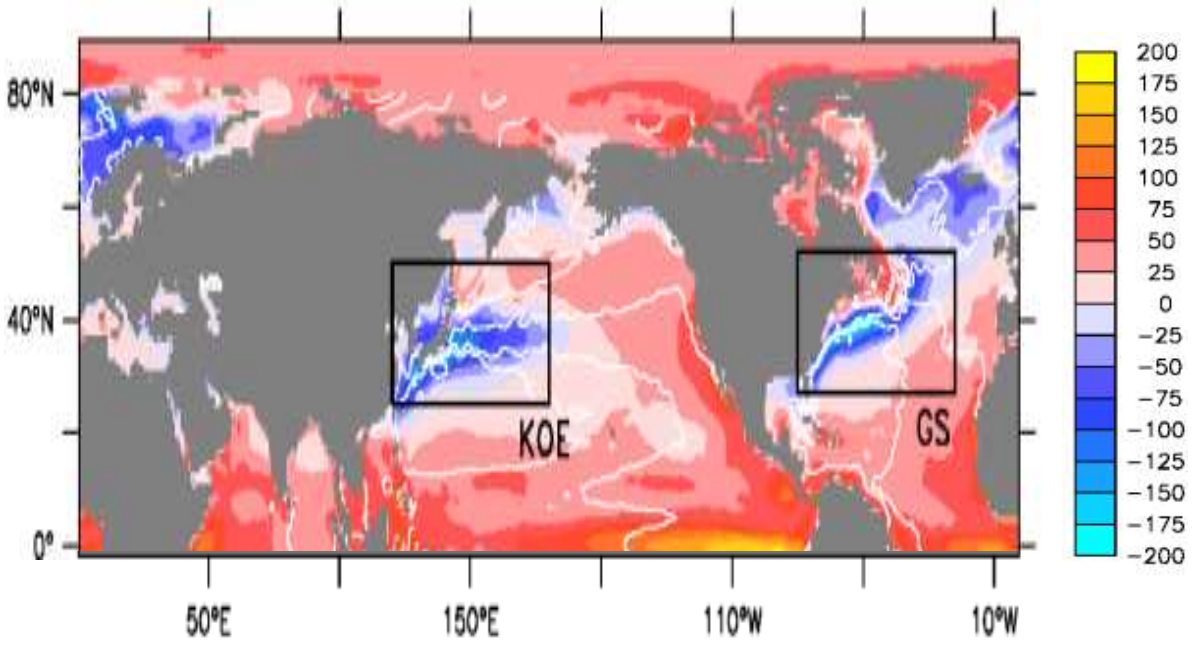
- **Center of PDO wind forcing is in eastern half of N Pacific basin**



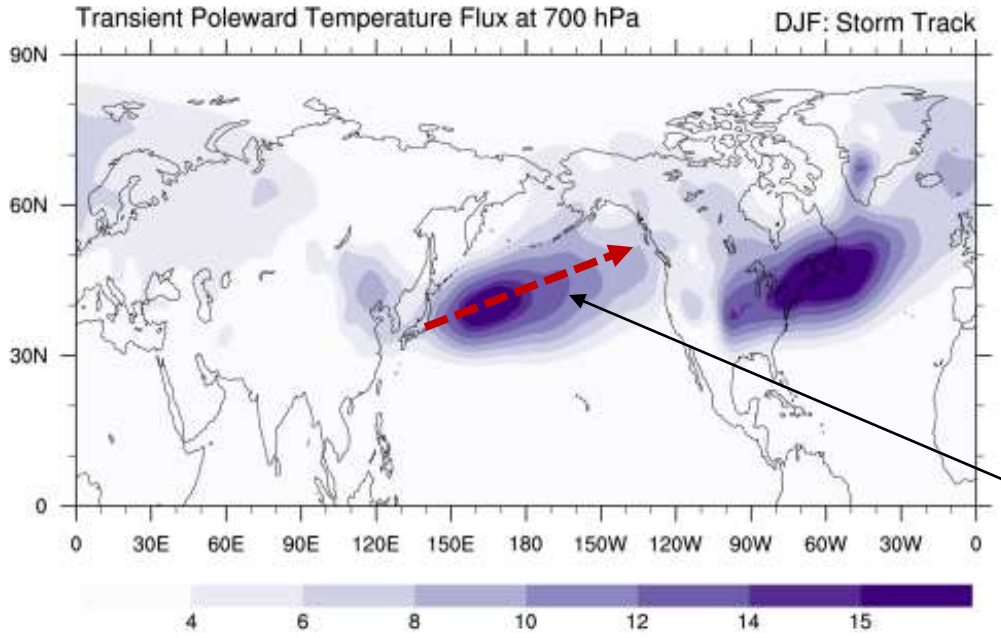
# Connections between PDO forcing, cross-basin SSH adjustment & KE index



# Kuroshio/KE supply heat to overlying atmosphere & anchor stormtracks




**Time-mean net surface heat flux from air to ocean ($W/m^2$ ; Cronin et al. 2009)**

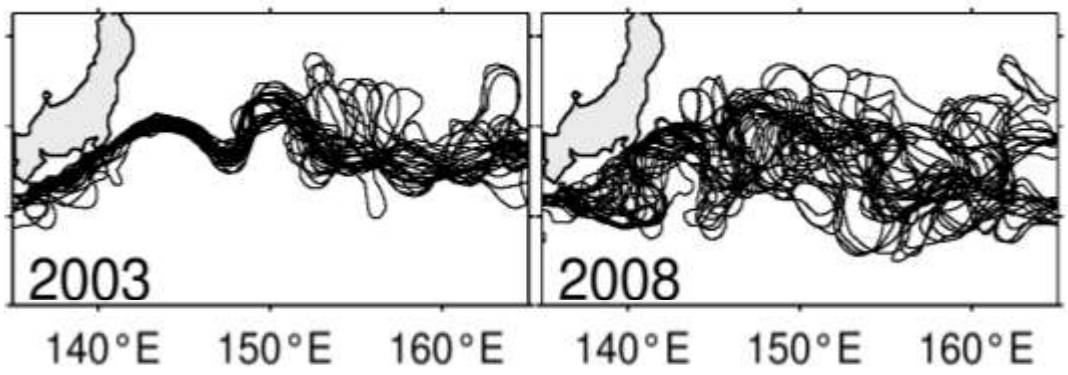



**DJF 700mb rms v'T' fluxes indicative of storm-track variability (Nakamura et al. 2004)**

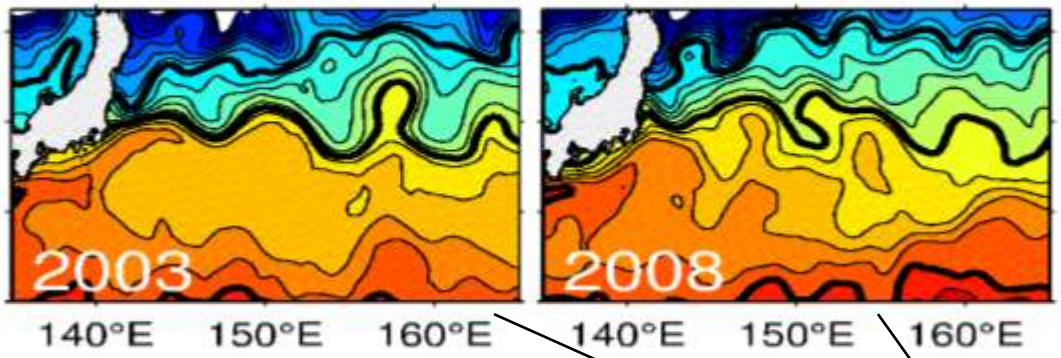
curl x τ = 0 **line/storm-tracks**

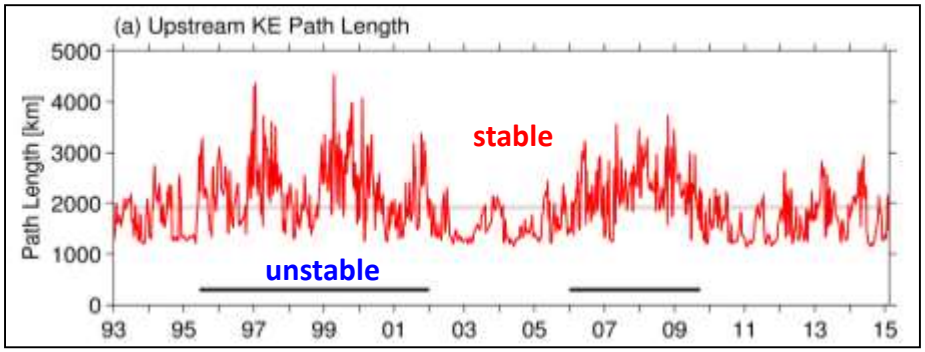
# KE dynamic state affects regional SST & cross-front SST gradient

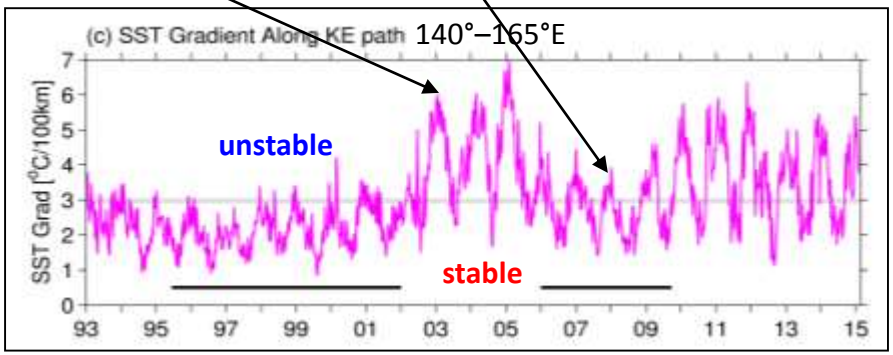
**Bi-weekly KE paths**



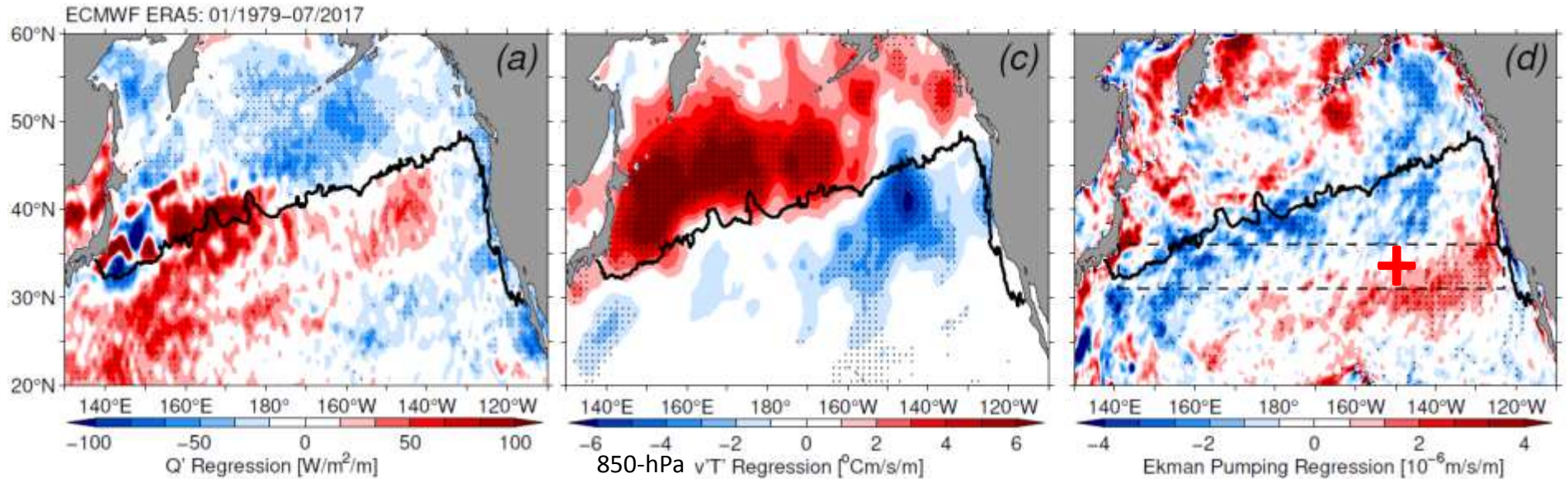

**Feb-March SST maps**



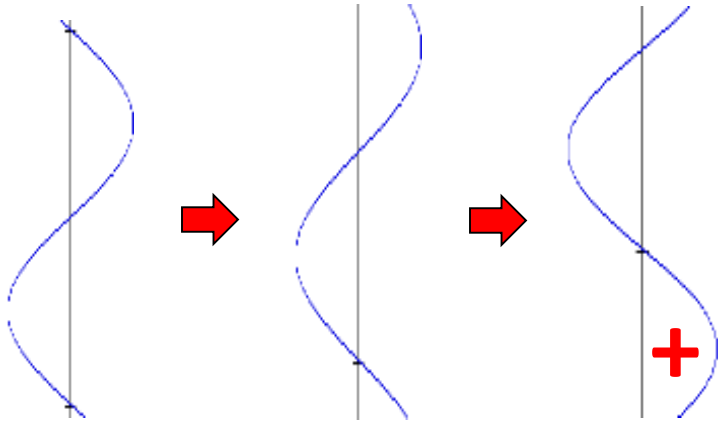



# Turbulent heat flux, storm-tracks & wind curl regressed to the KE index




- **A stable KE (warmer SST & stronger KE front) enhances upward turbulent heat flux in downstream KE**
- **This induces a poleward shift in storm-tracks as inferred from 850-hPa <v'T'> fluxes**
- **Surface wind stress pattern moves similarly poleward → positive curl anomaly in eastern basin along 31°–36°N band**

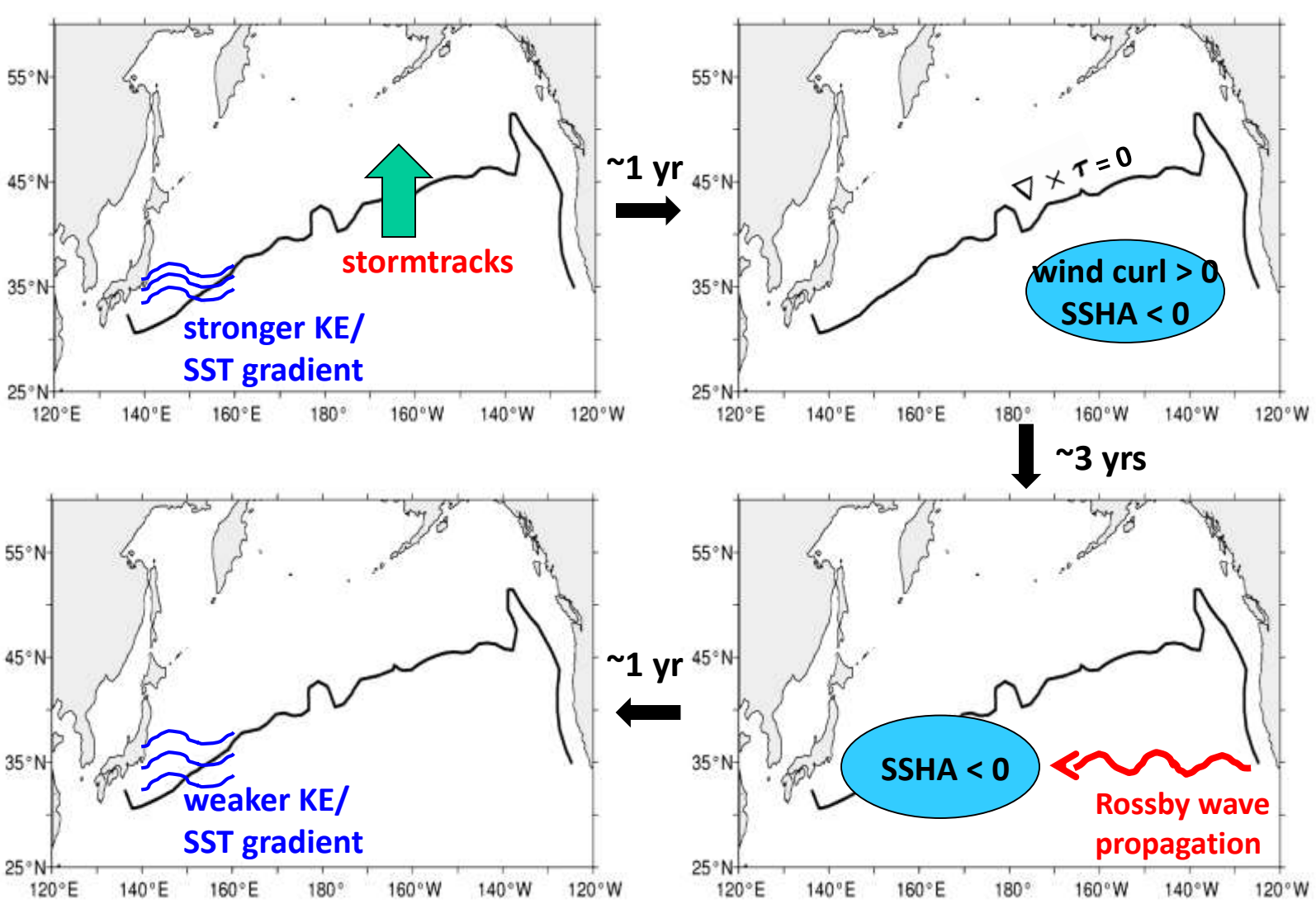


**mean** curl x τ **pattern**

**poleward-shifted** curl x τ

curl x τ **anomaly**

# KE interaction with stormtracks favors a delayed negative feedback loop

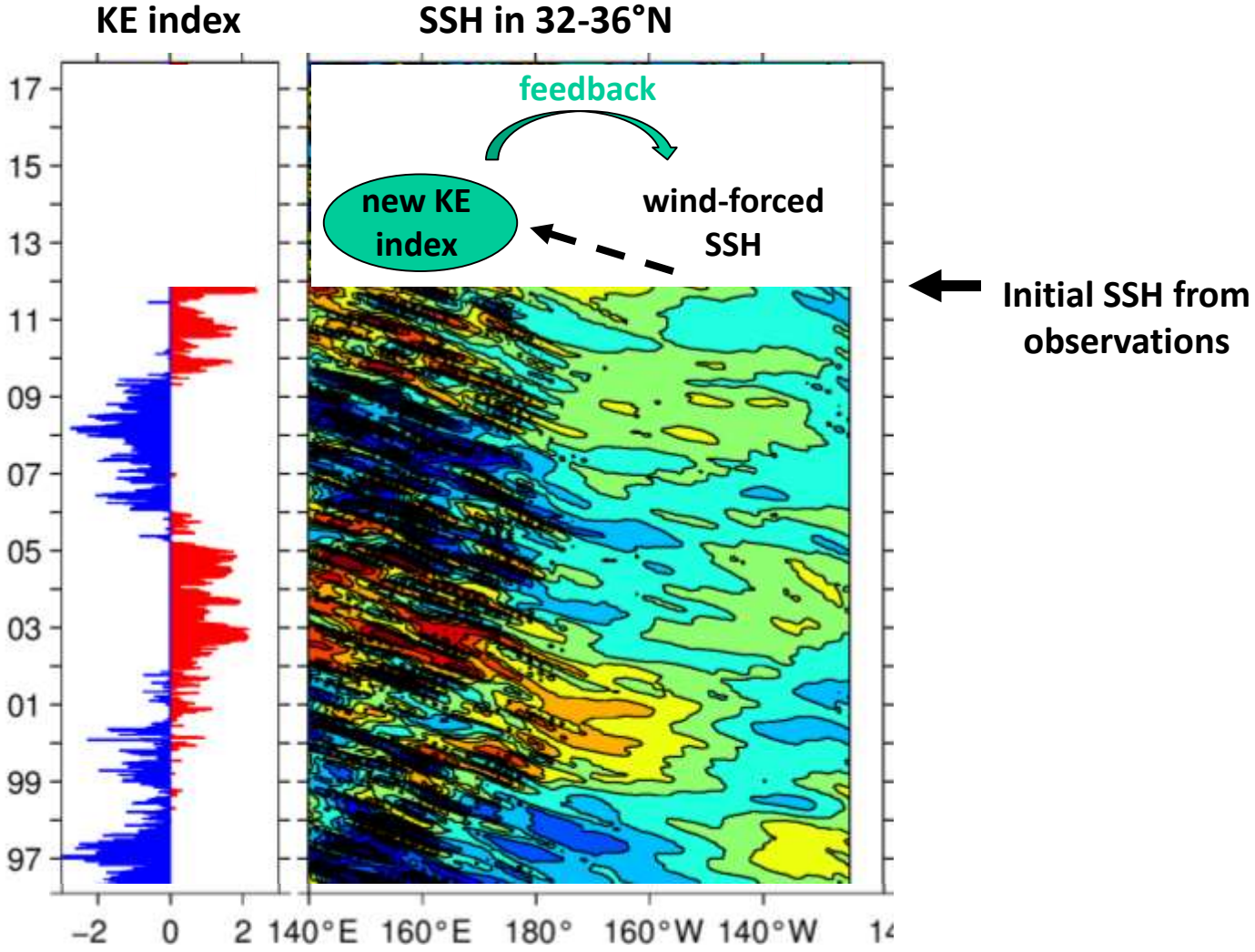



curl x τ
**anomaly**

**Half a cycle = ~ 5 yrs with Pacific basin crossing + adjustment times**

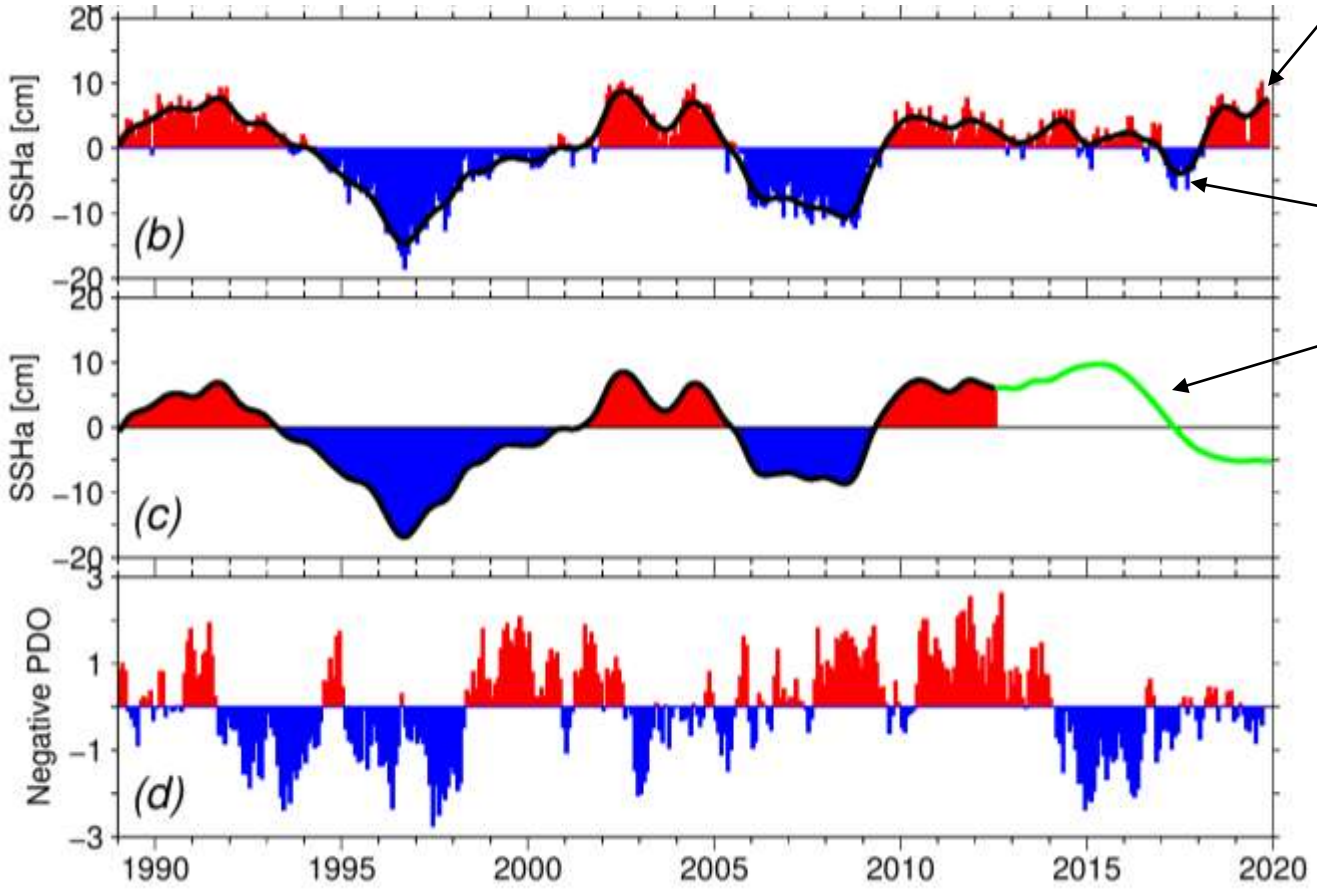
# Predicting KE index based on the negative feedback mechanism

- Prediction to KE index can be made by taking into account the SSH signals propagating from the east, plus the SSH signals generated by the KE-induced wind forcing across the Pacific basin:



# Verification of the predicted KE index based on 2012 AVISO SSH data

AVISO data

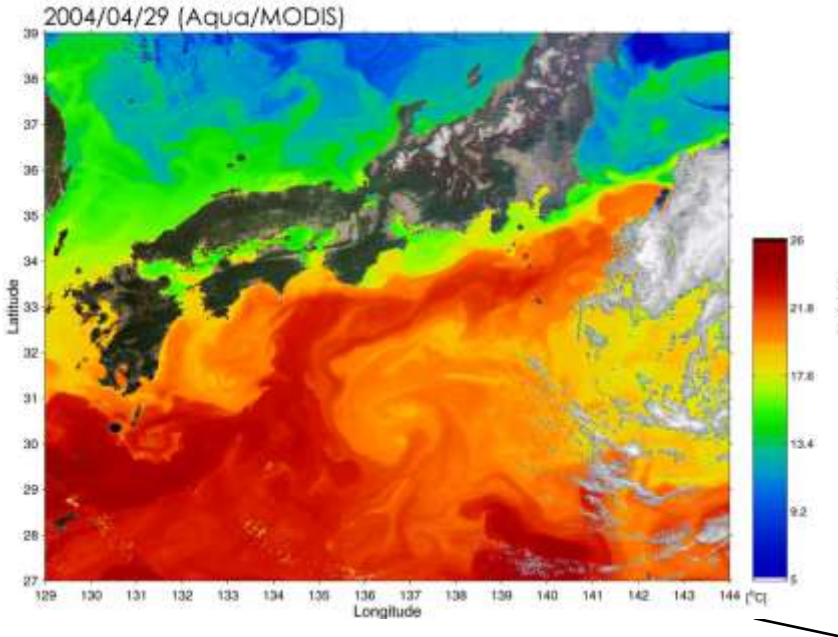


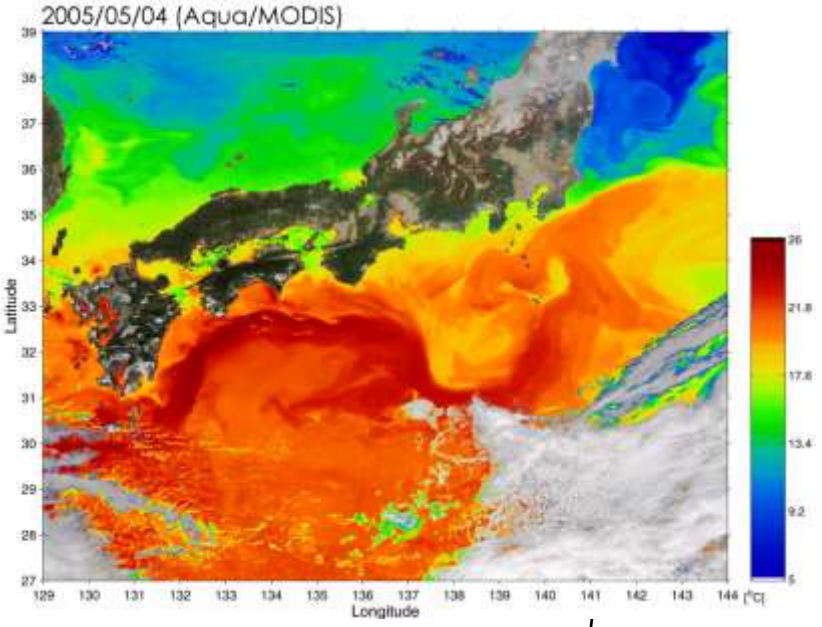

Prediction failed after late 2017

Favorable prediction by 2017

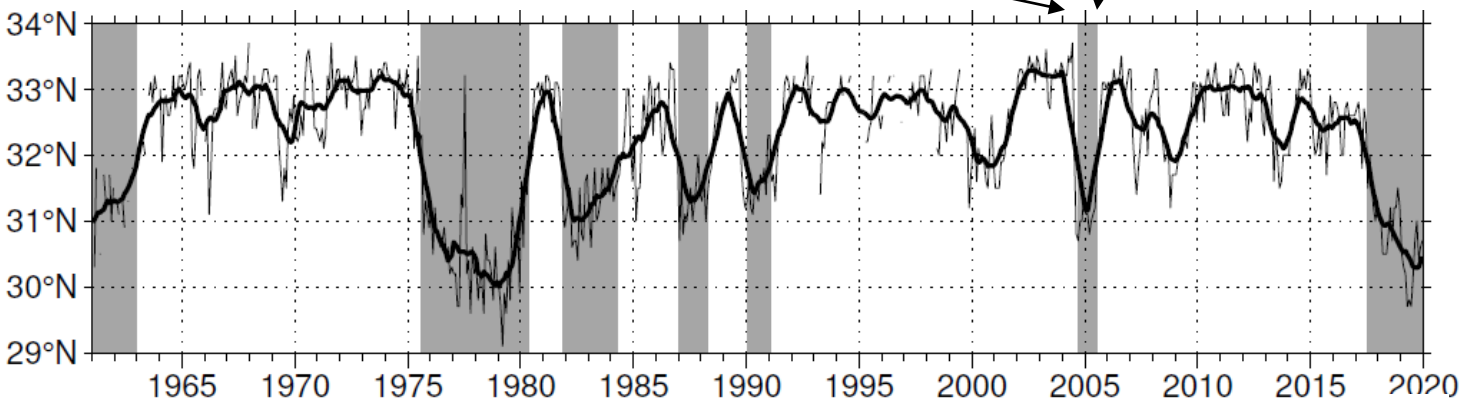
Predicted KE index using 2012 observed SSH

# Bimodal paths of the Kuroshio south of Japan



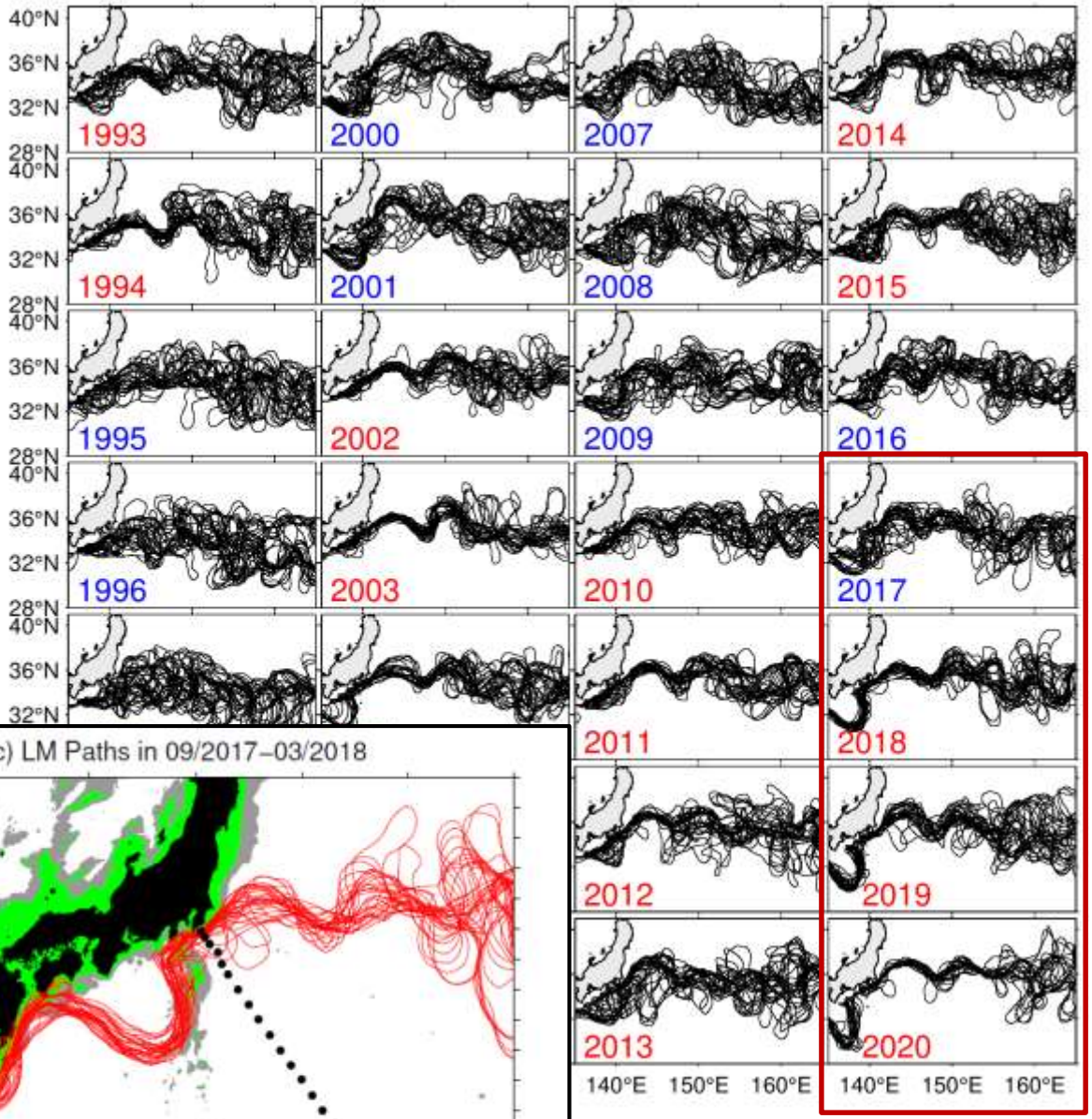

**Southernmost Kuroshio latitude from Japan coast (JMA)**

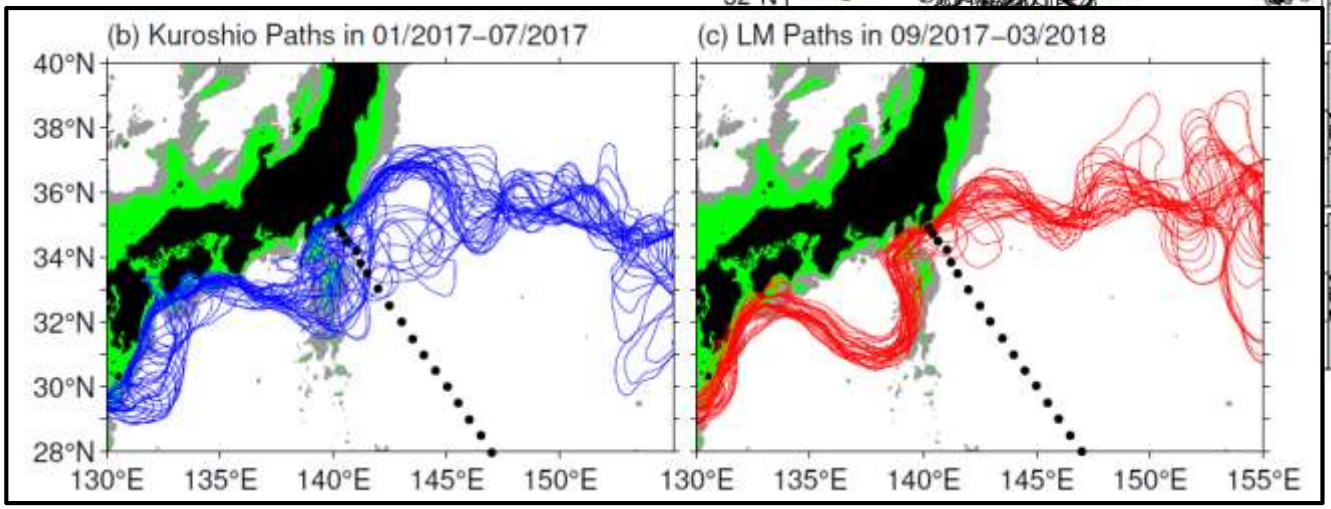



- **Irregular path fluctuations** on interannual & longer timescales

# Annual maps of bi-weekly paths of the Kuroshio/KE jet

- **Occurrence of the Kuroshio LM in August 2017 forced the KE path poleward, avoided the shoaling Izu Ridge & switched KE's dynamic state back to a stable state**

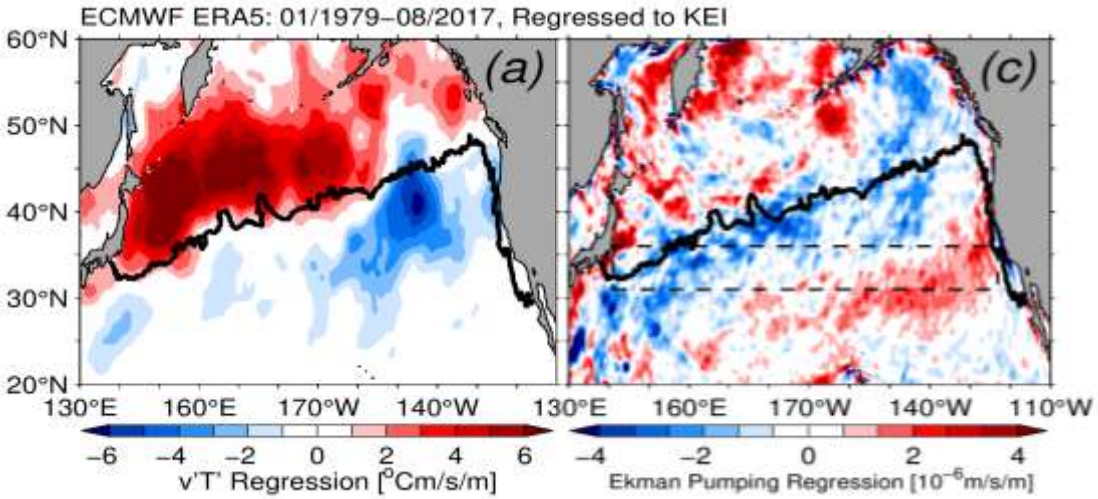



Qiu et al. (2020, JC)

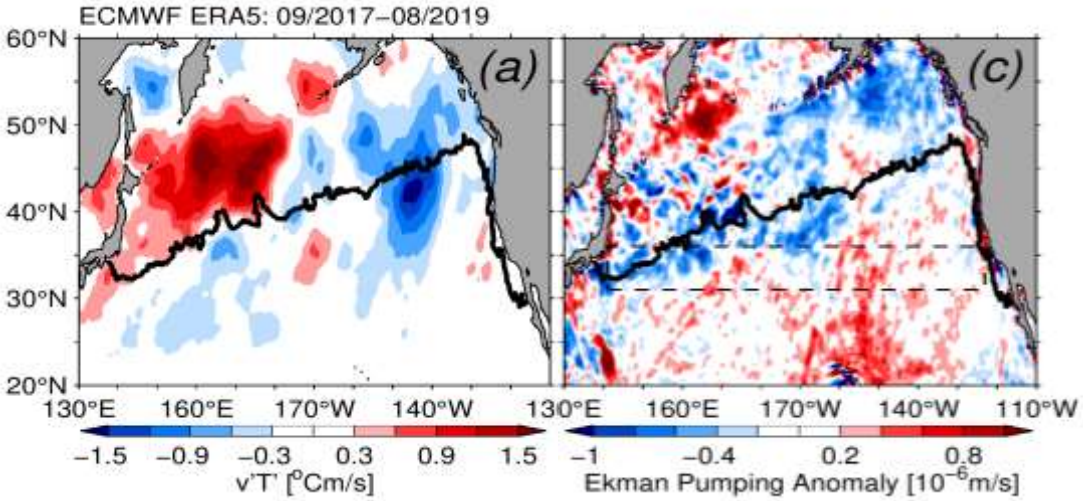
# Many questions remain to be addressed & answered

**Do the LM-induced KE change after 2017 alter the basin-wide atmospheric circulation in a similar way as the wind-forced KE change ?**




**Storm-tracks & Ekman pumping variations regressed to the KE index of 01/1979–08/2017**

**wind-forced KE**

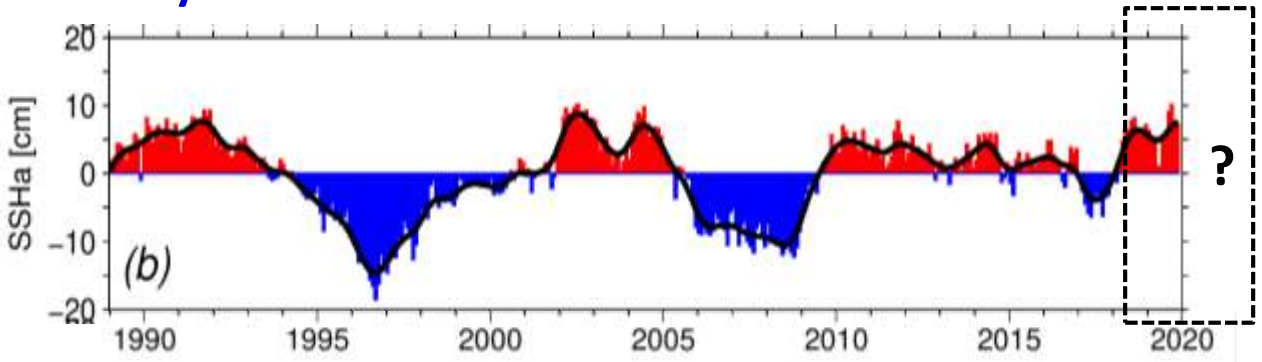



**Storm-tracks & Ekman pumping anomalies in 09/2017–08/2019**

**LM-forced KE**

# Summary

- **The KE dynamic state & the PDO index after 1980s are dominated by decadal variations as a result of emergence of a coupled negative feedback loop**
- **This feedback loop is disrupted in 2017 due to the formation of Kuroshio large meander south of Japan**
- **Similar basin-wide atmospheric responses are generated by the KE variability, irrespective if it is LM-forced or wind-forced**
- **Implications: KE dynamic state has likely entered a newly-set decadal cycle**




- **It remains a challenge to simulate intrinsically-forced Kuroshio path changes off Japan → a hindrance for decadal KE prediction**

For more details, Qiu et al. (2020): On reset of the wind-forced decadal Kuroshio Extension variability in late 2017. *J. Clim.*, accepted. www.soest.hawaii.edu/oceanography/bo