PICES 2012 Annual Meeting
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Role of the Kuroshio-Oyashio Extensions and Gulf Stream in decadal climate and eco-system variability

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N. Atlantic: Terry Joyce, Janet Nye, Jason Link, Xujing Davis

Story Line

- Very brief motivation
  - Why are the western boundary currents and their extensions interesting and important for climate?

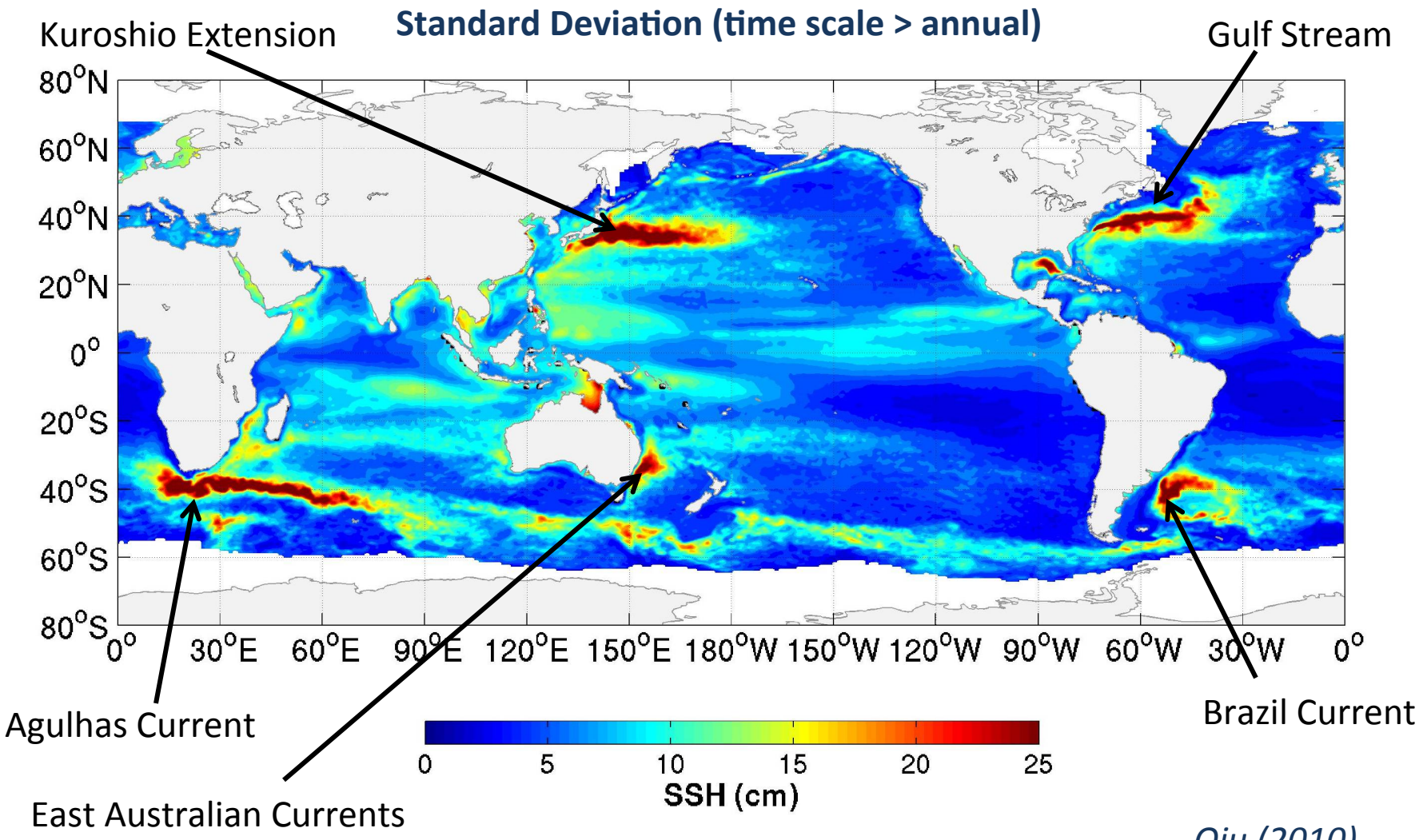
- North Pacific decadal variability:
  - Kuroshio Extension and coupled ocean-atmosphere variability
  - Kuroshio Extension vs. Oyashio Extension

- North Atlantic decadal variability:
  - Gulf Stream and fish distribution and abundance
  - Gulf Stream and North Atlantic SST variability

- Summary

Where are enhanced low-frequency ocean variability?

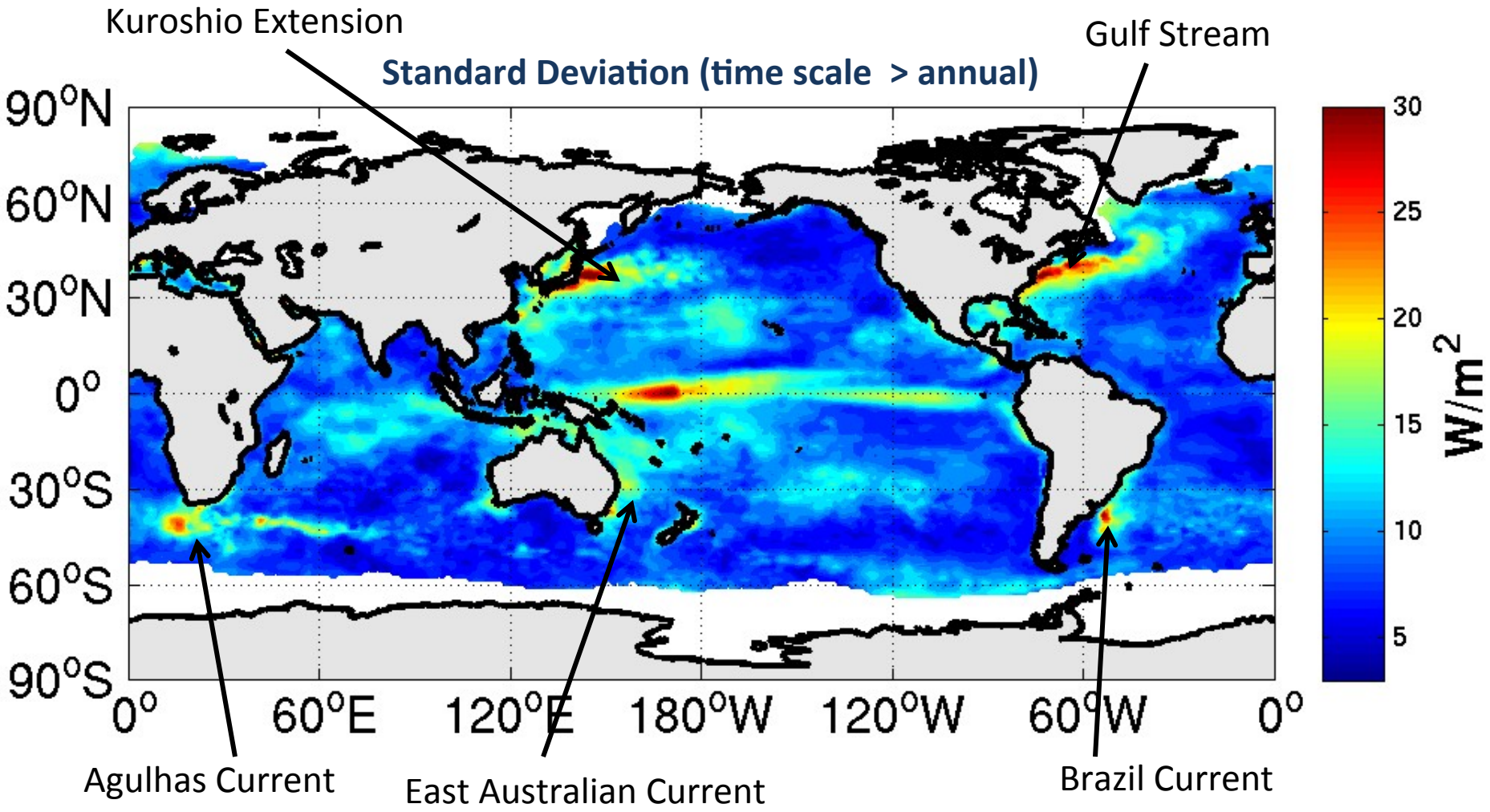
AVISO Satellite Altimeter SSH Data (1993–2010)



Qiu (2010)

Net surface heat flux: interannual-to-decadal variability

OAFlux net surface heat flux (1984 – 2007)

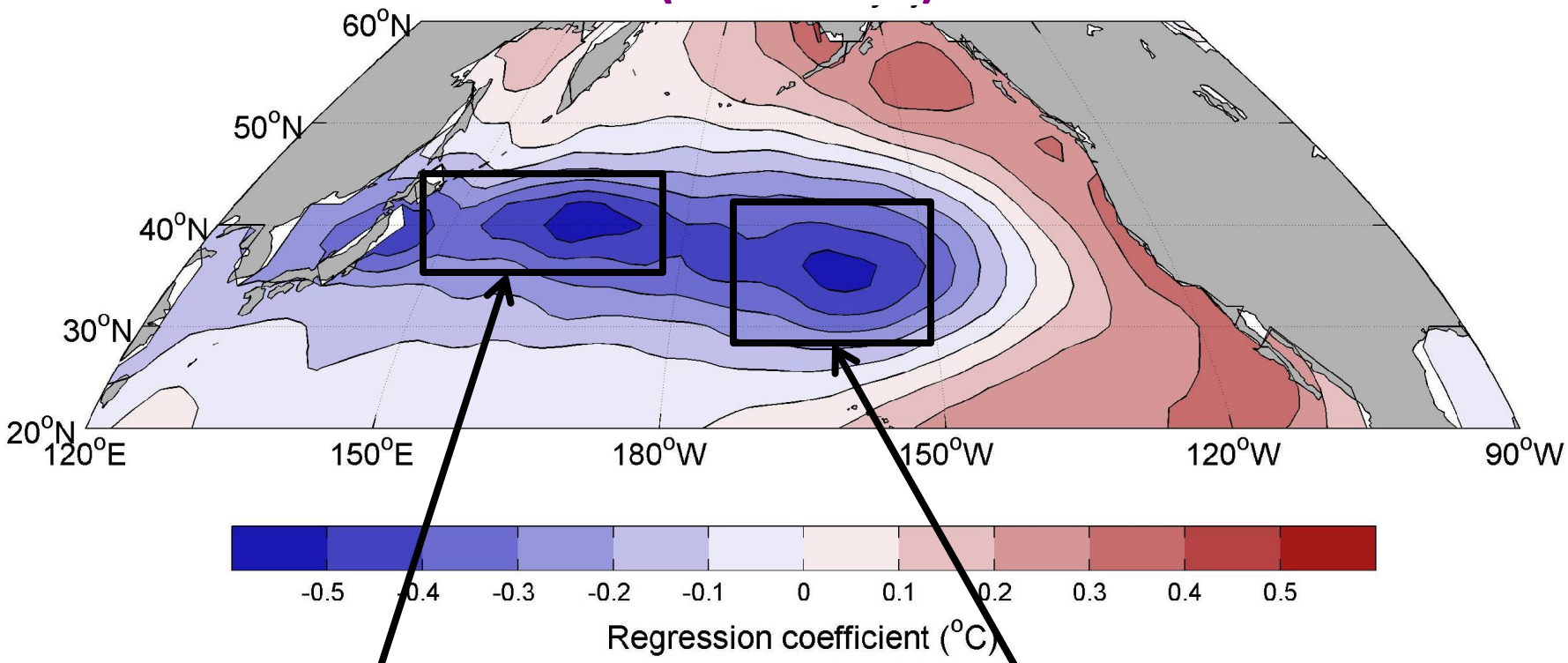


Decadal Variability of

North Pacific SST

PDO SST pattern in the North Pacific

ERSST v.3 (2°×2°) regressed on the PDO index (1900-2010)

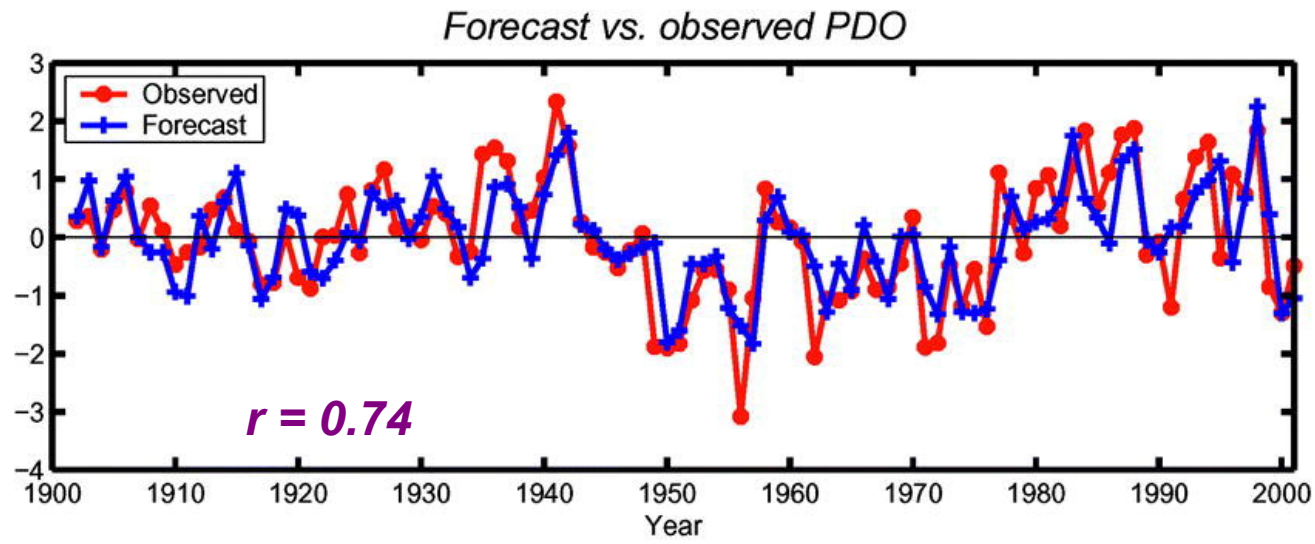


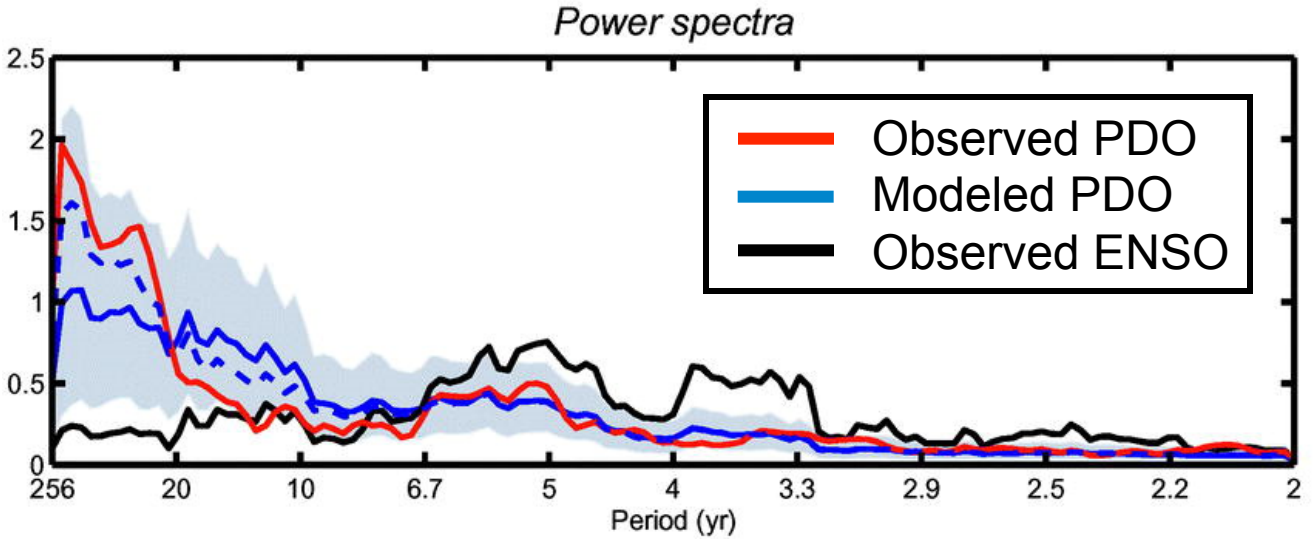
Decadal
⇐Kuroshio-Oyashio Extension
& CP-ENSO

Interannual
⇐ ENSO

ENSO ⇒ PDO: atmospheric bridge

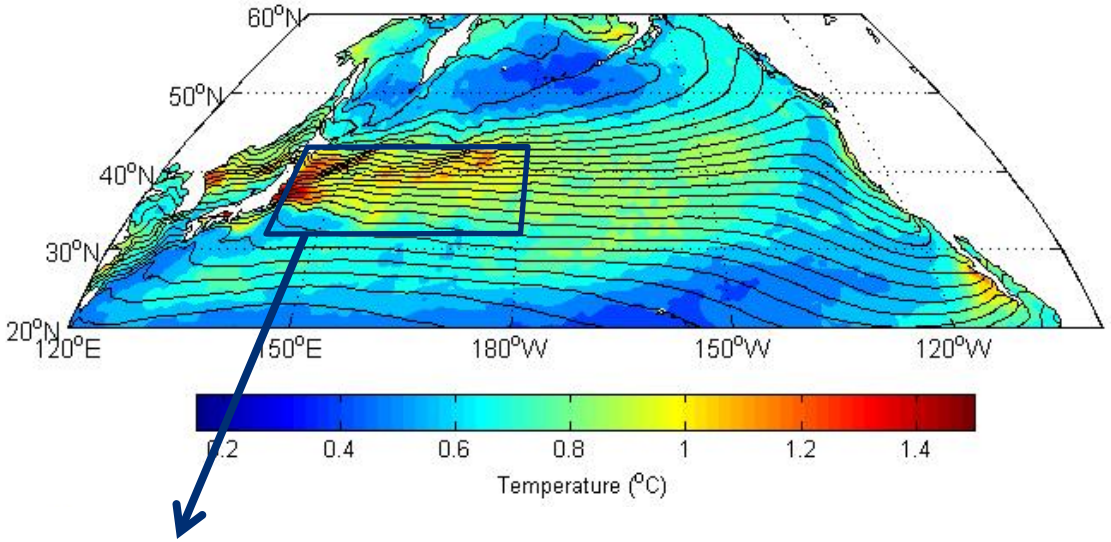
$P_n=\alpha P_{n-1}+\beta E_n+\eta_n$ *(Newman et al. 2003)*



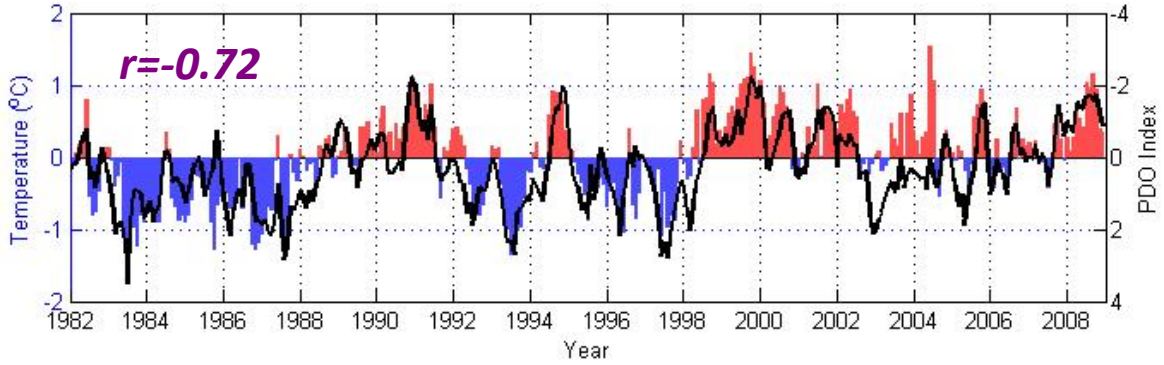


Interannual-to-decadal North Pacific SST variability

SST standard deviation (color) & mean (contour)
(1982-2008, NOAA 0.25° OISST)



Kuroshio-Oyashio Extension SST (color) & PDO Index (line)



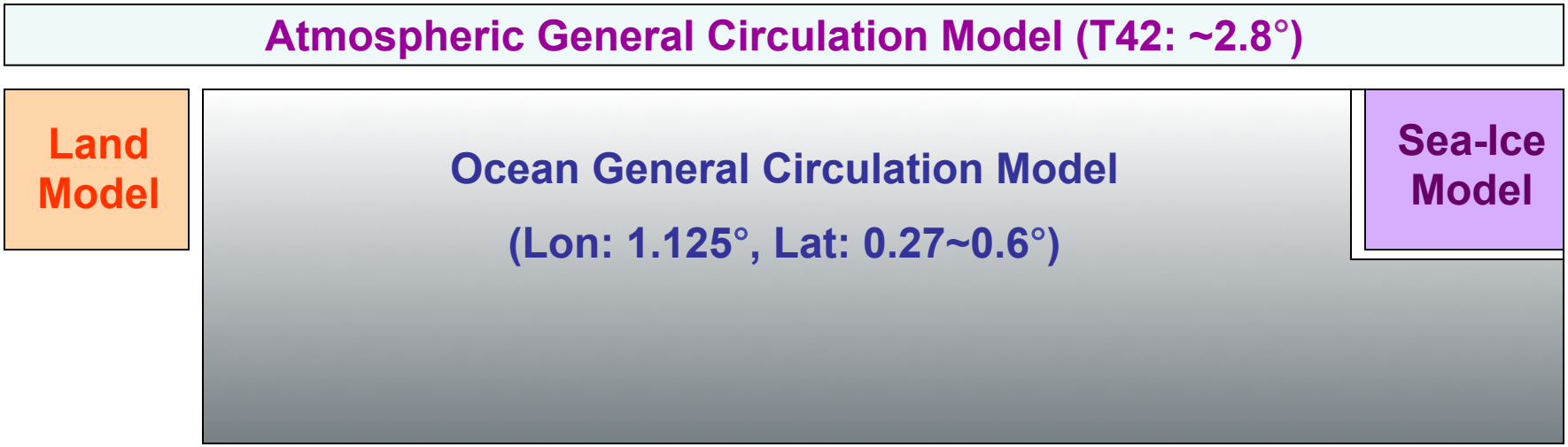
Kwon et al. (2010, J.Climate), Frankignoul et al. (2011)

North Pacific decadal variability in CCSM2

(Kwon and Deser 2007, J. Climate)

* **Community Climate System Model version 2 (CCSM2)**

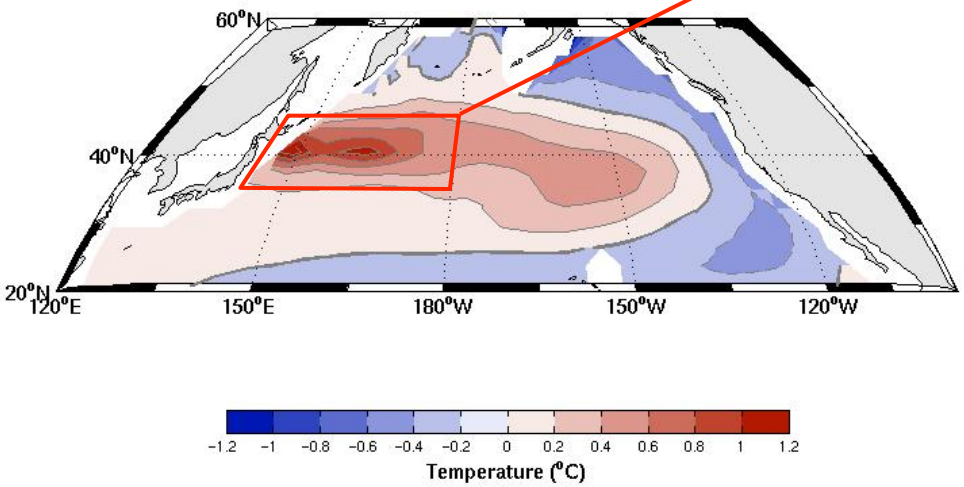
  : NCAR fully coupled global climate model.



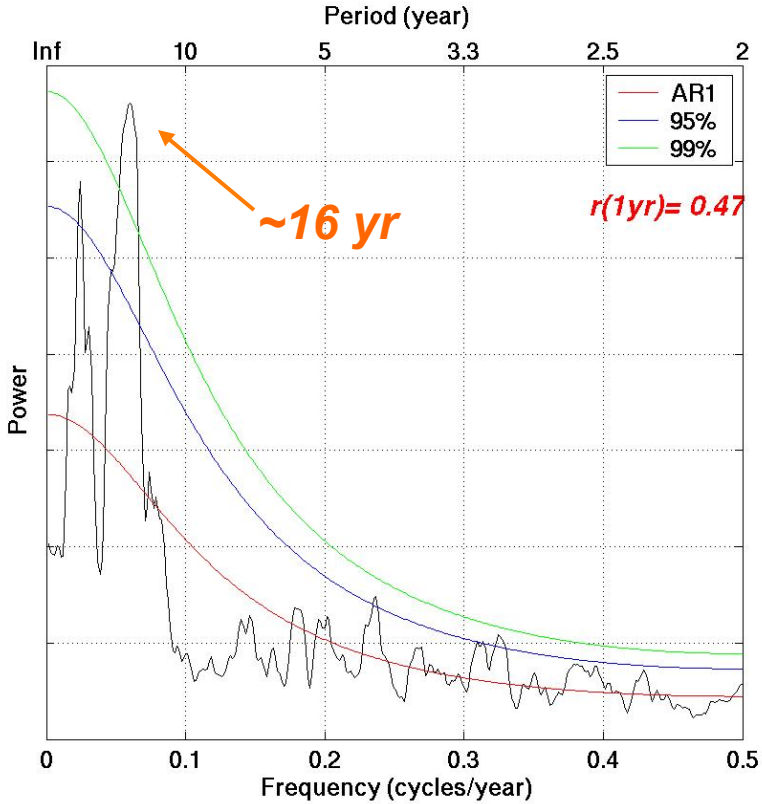
CCSM2 North Pacific decadal variability

(1990 control integration: Year 350-999)

Winter SST EOF 1 (21%)



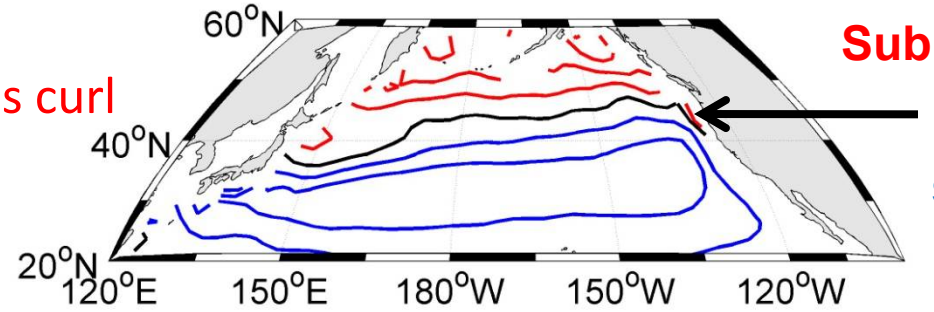
Kuroshio Extension SST Index



Kwon and Deser (2007, J. Climate)

Wind stress curl forcing and responses for KE decadal variability in CCSM2

Mean wind stress curl pattern

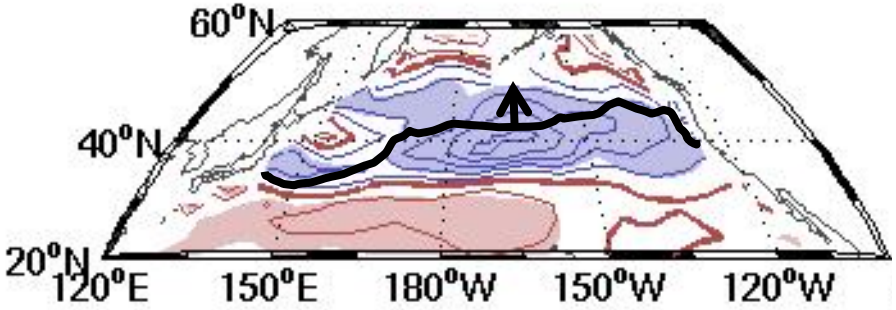


Subpolar gyre: cyclonic

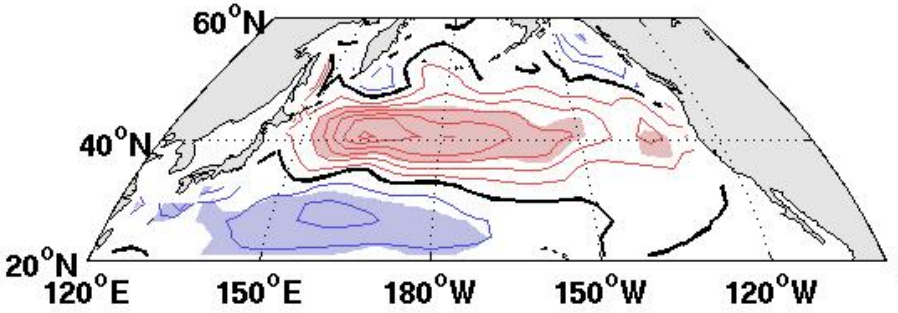
zero $\nabla \times \tau$

subtropical gyre: anti-cyclonic

CCSM2 ***forcing*** pattern from regression



CCSM2 ***response*** pattern from regression



Nearly opposite patterns

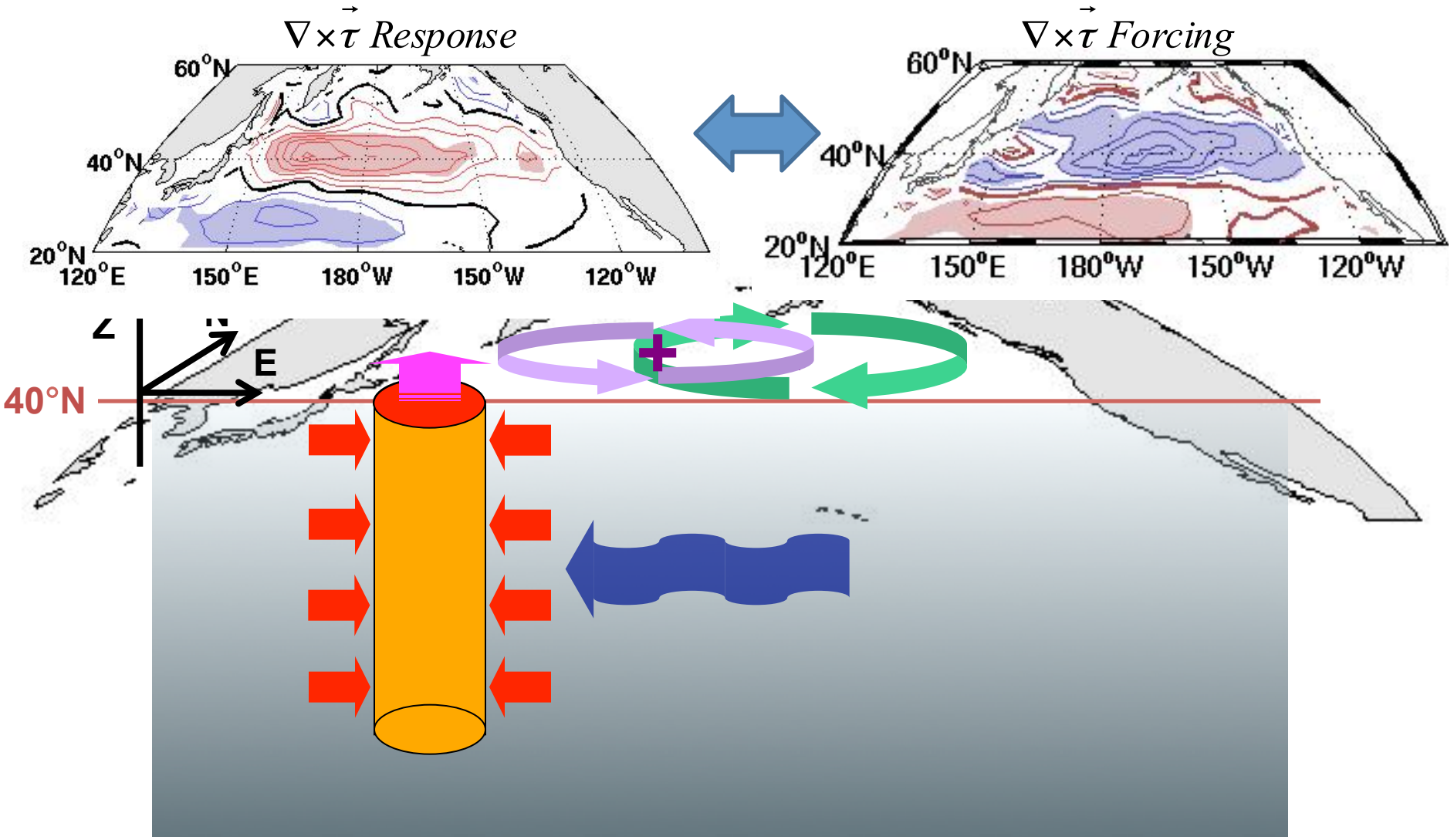
(0.2 x 10^{-8} N/m^3)

ocean – atmosphere coupled mode

Kwon et al. (2010, Climate Dynamics)

Ocean-atmosphere coupled mode in CCSM2

(~16-yr time selection: first mode baroclinic adjustment)



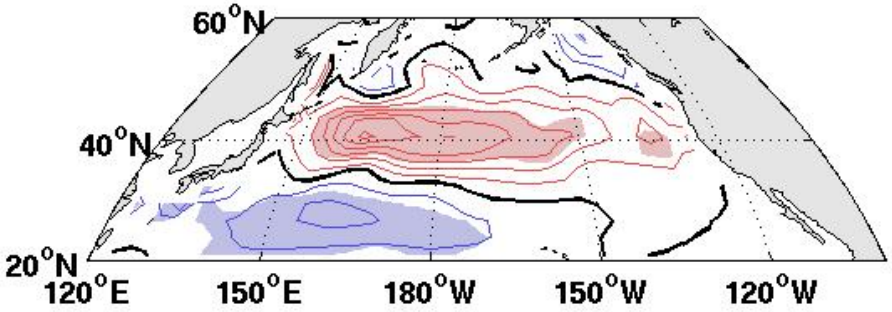
Kwon and Deser (2007, J. Climate)

Wind stress curl responses to KE variability

(Tropical influences are filtered out)

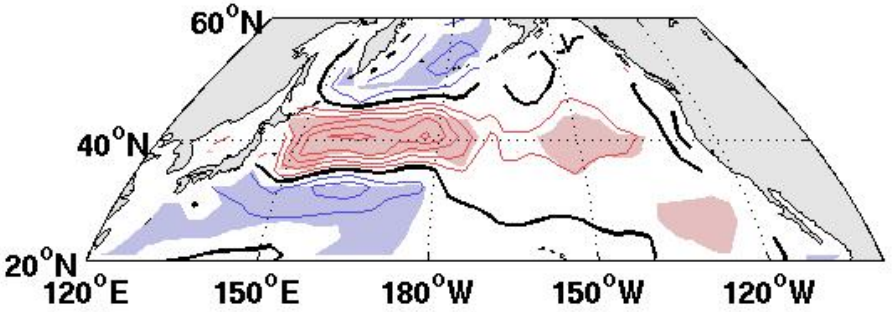
CCSM2

(Kwon and Deser 2007)



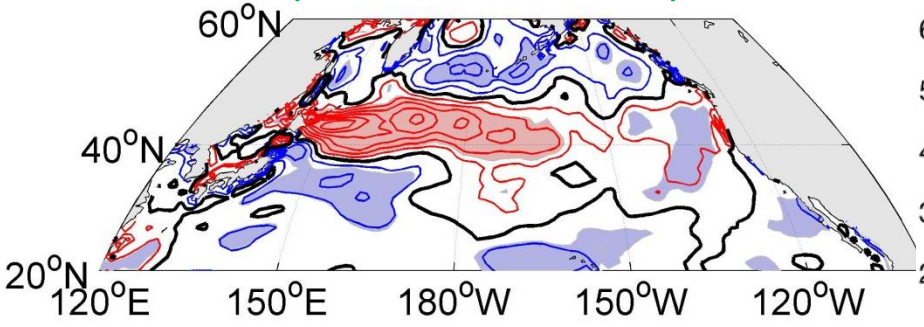
CAM2-Mixed Layer Ocean

(Kwon et al. 2010)



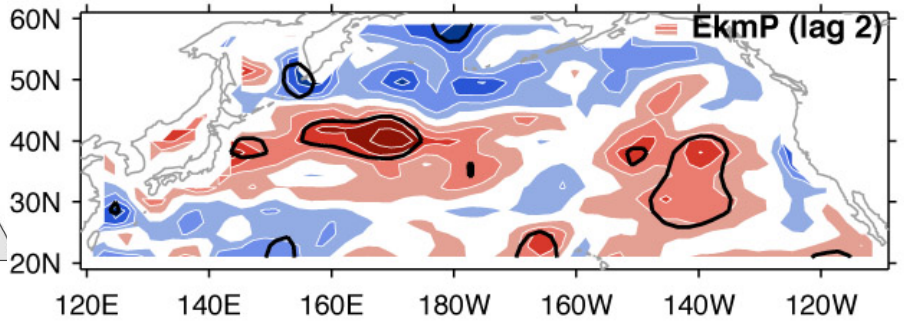
CCSM4

(Deser et al. 2011)



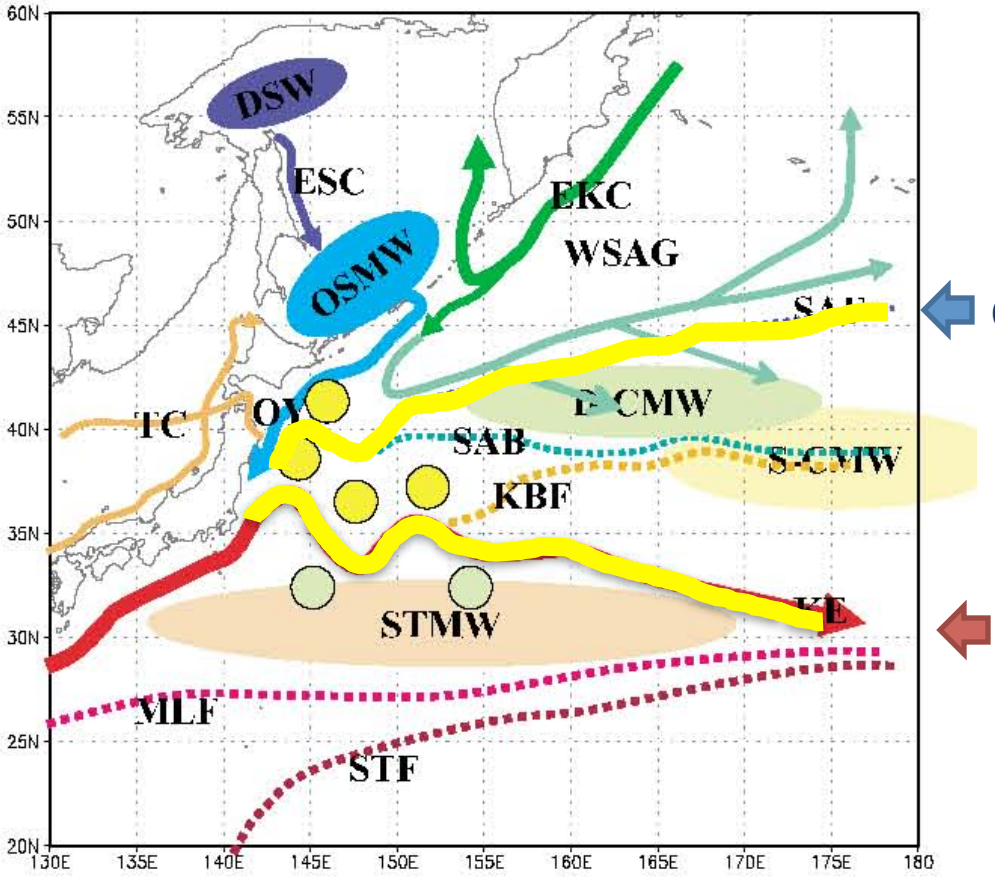
Observation

(Frankignoul et al. 2011)



Supports existence of an coupled ocean-atmosphere North Pacific decadal mode

Kuroshio-Oyashio Extensions in reality



Oyashio Extension: Surface front (SST)

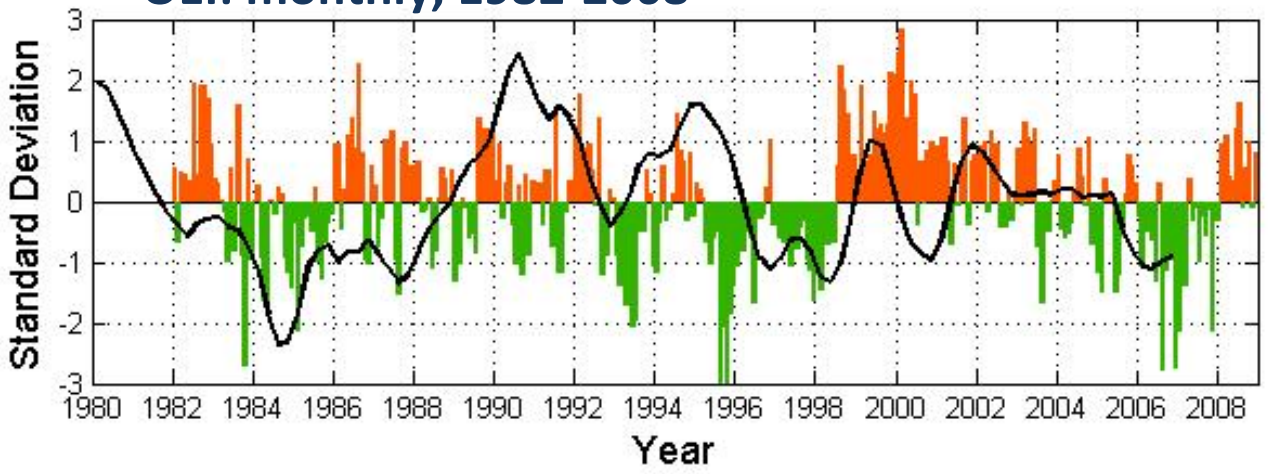
Kuroshio Extension: Subsurface front (Zonal Velocity, SSH, Dynamic Height)

Yasuda (2003)

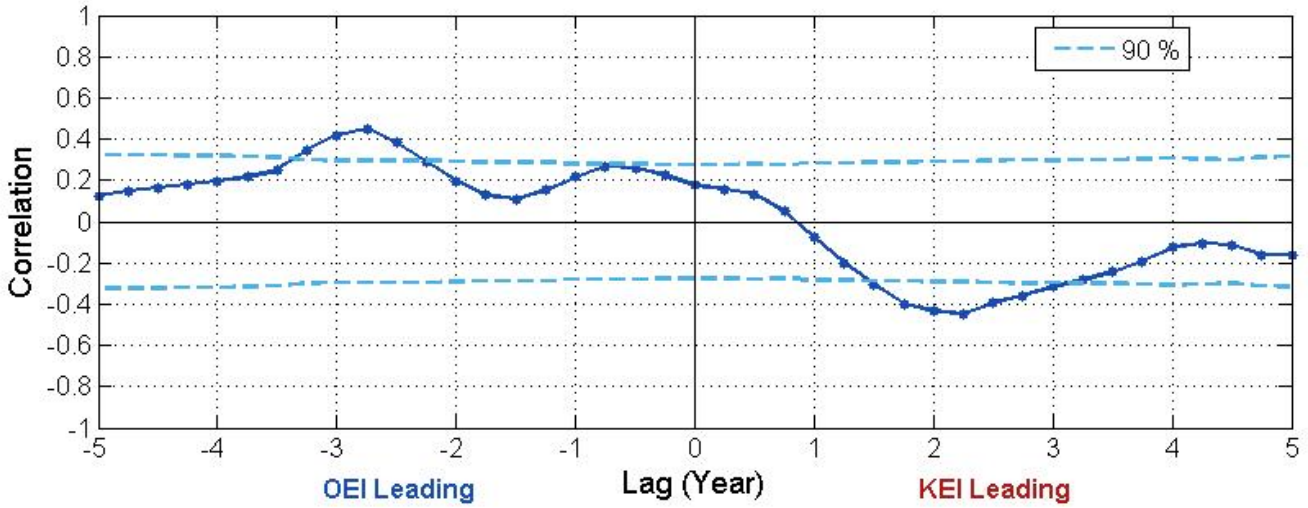
KOE ⇒ ***KE and OE***

KE latitude index (line) vs. OE latitude index (color)

KEI: seasonal but effectively annual, 1980-2006
OEI: monthly, 1982-2008

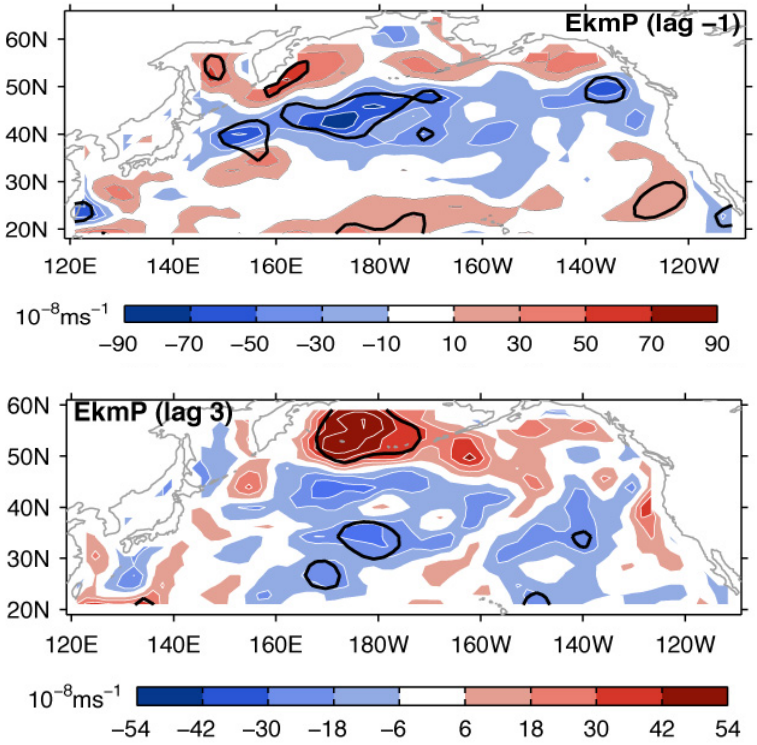


Lag correlation between KEI & OEI



Frankignoul et al. (2011)

Wind stress curl forcing and response for observed Oyashio Extension variability



Forcing Pattern

Response Pattern
(almost opposite sign to the KE response pattern)

Similar forcing and response patterns indicate weak positive feedback

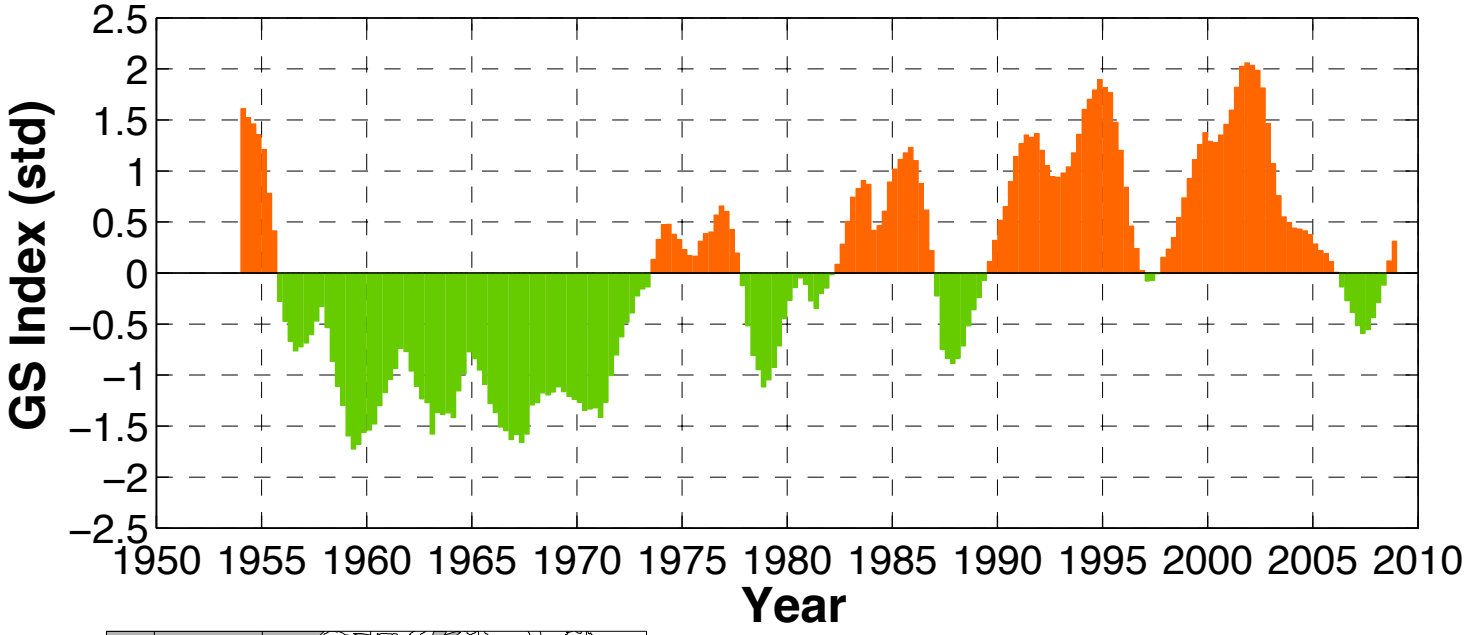
Frankignoul et al. (2011)

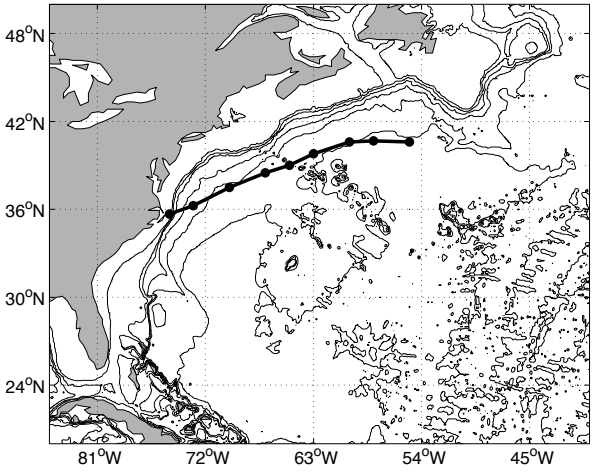
Decadal Variability of

the Gulf Stream,
U.S. Northeast Shelf Ecosystem,
and North Atlantic SST

Gulf Stream Index: north-south shift of the GS position

(Seasonal values since 1954)



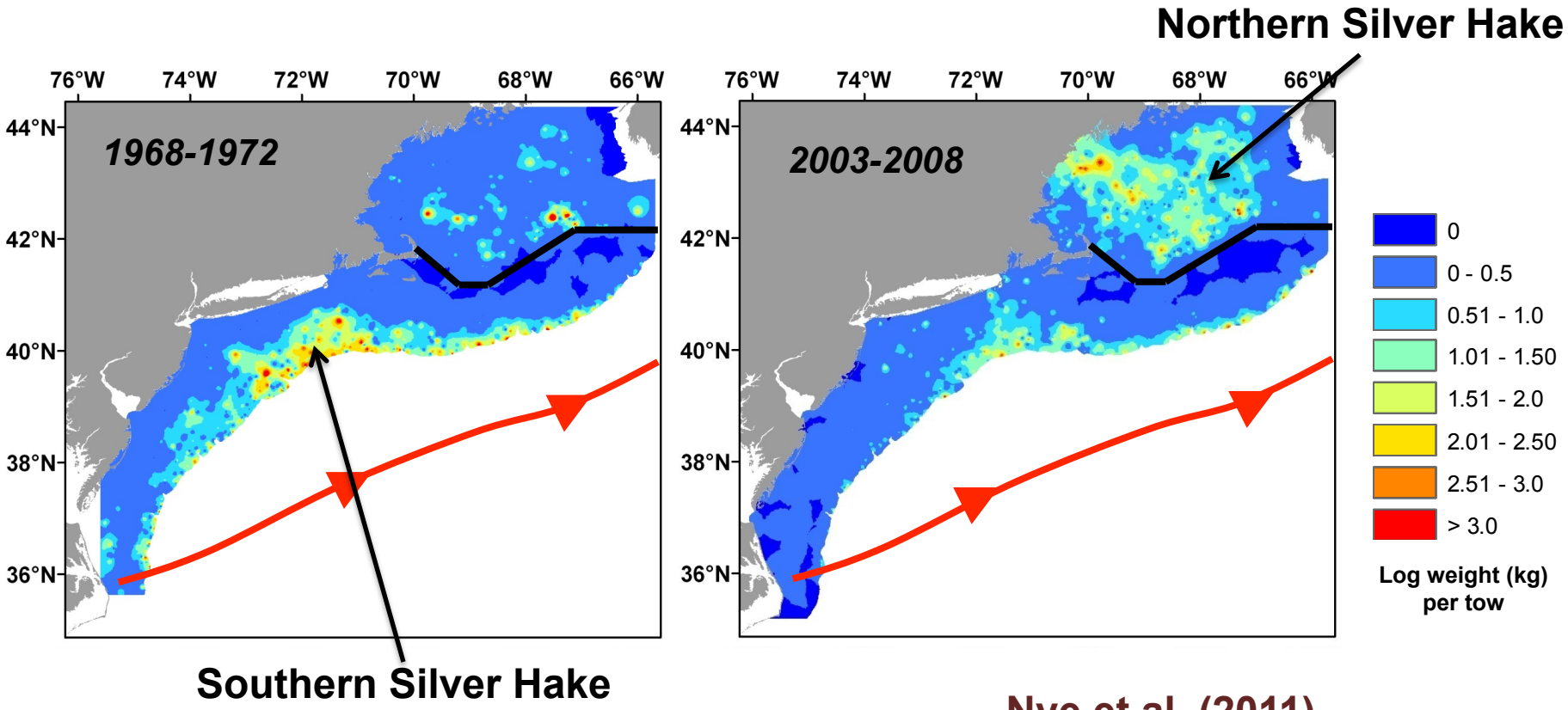


GS Index definition: *EOF-1 time series of the 200m temperature anomalies at the mean GS position (Joyce et al. 2000)*

Mean GS position: *15°C isotherm at 200 m*

Changes in the spatial distribution of Silver Hake

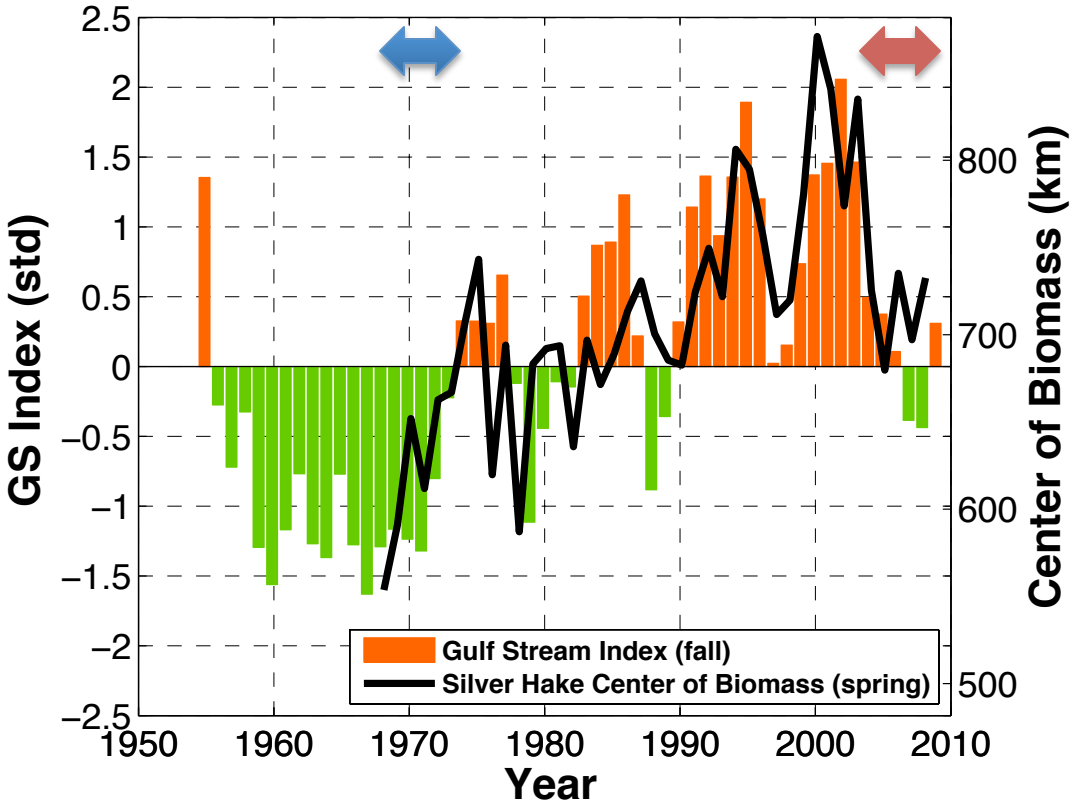
(Silver Hake biomass in March-May from NOAA NEFSC trawl survey)

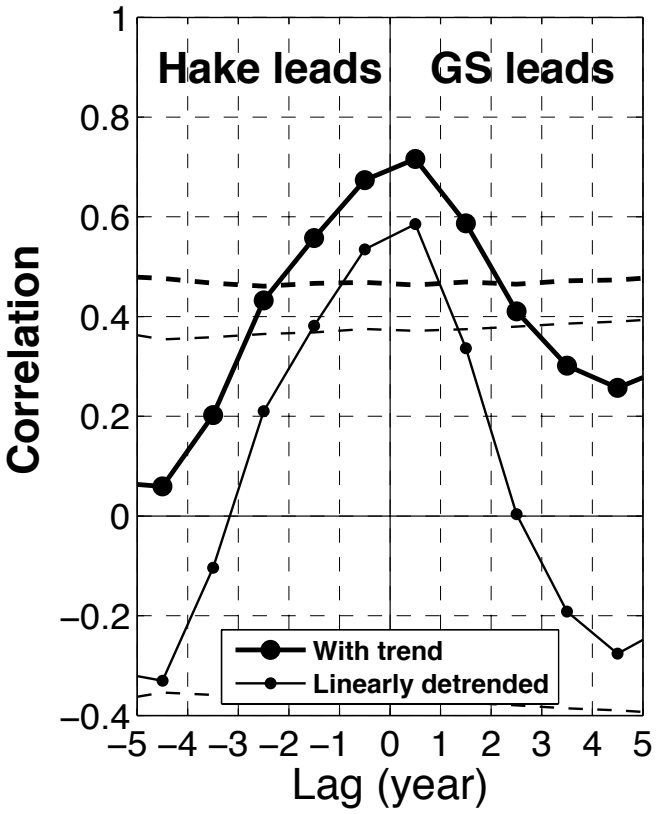


Nye et al. (2011)

Silver Hake: *Merluccius bilinearis*

Gulf Stream latitude (fall)
vs.
Southern Silver Hake center of biomass (spring)





Silver Hake Center of Biomass:
biomass weighted distance from the Cape Hatteras

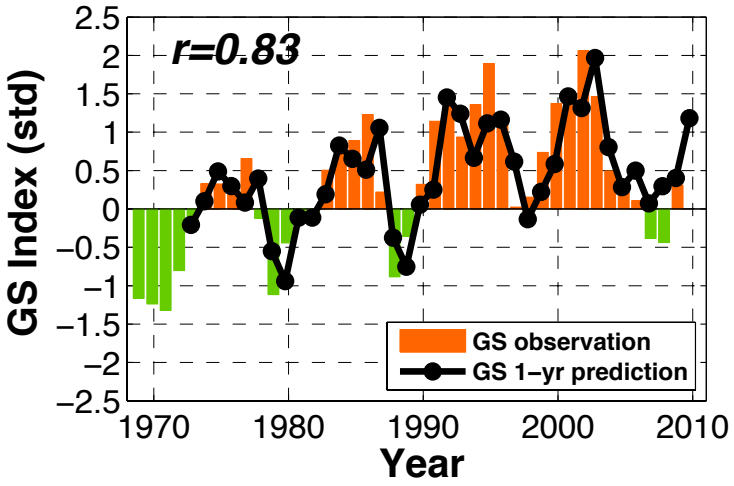
– – – significance at 5%

Nye et al. (2011)

Potential predictability: 5th order auto-regressive model

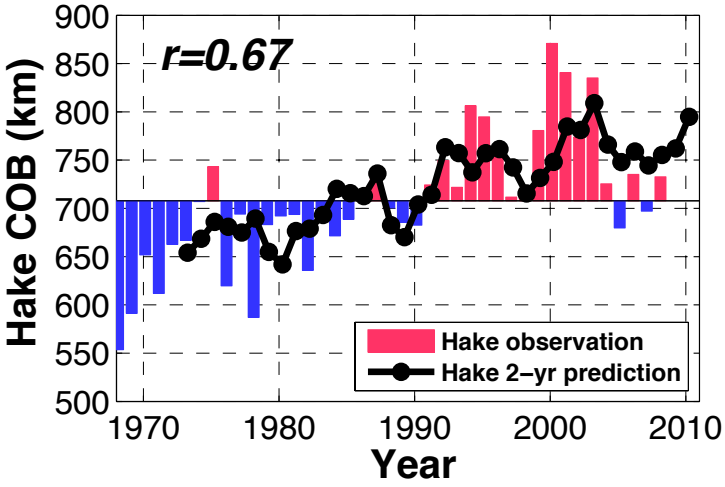
1-yr prediction of fall Gulf Stream Index

(AR-5 with the observed de-trended GSI in previous 5-yrs ➔ add the GS trend)



2-yr prediction of spring Hake COB

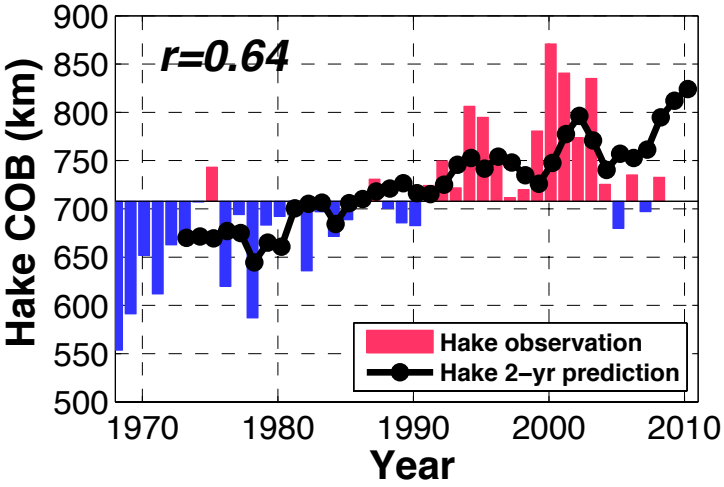
(Apply observed lag=1yr linear regression with the 1-yr prediction of GSI)



<u>Alternative approach</u>

2-yr prediction of spring Hake COB

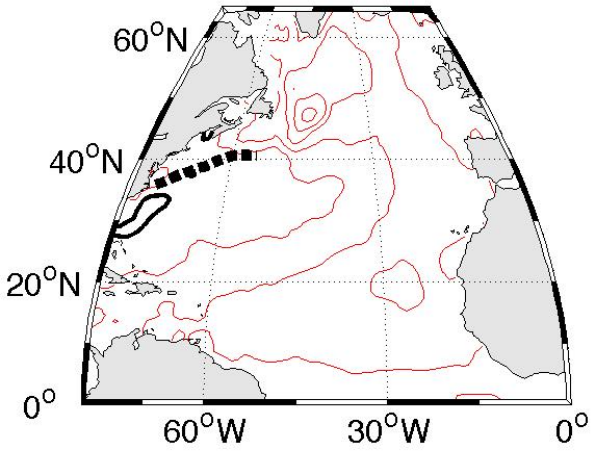
(AR-4 with the observed de-trended Hake COB ➔ add the Hake COB trend)



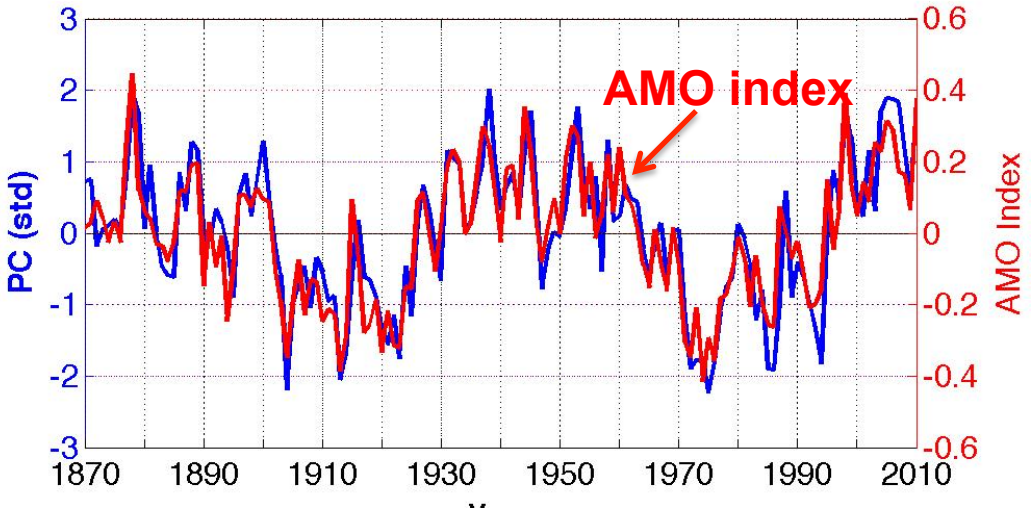
1st and 2nd EOF of North Atlantic SST

(Annual Mean HadISST-1, 1870-2010)

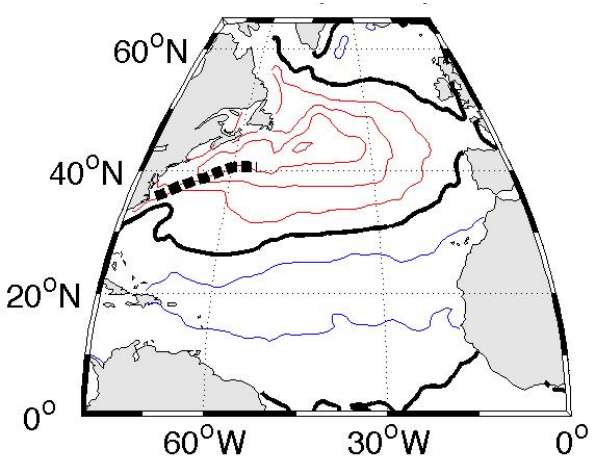
EOF 1 (38.5 %)



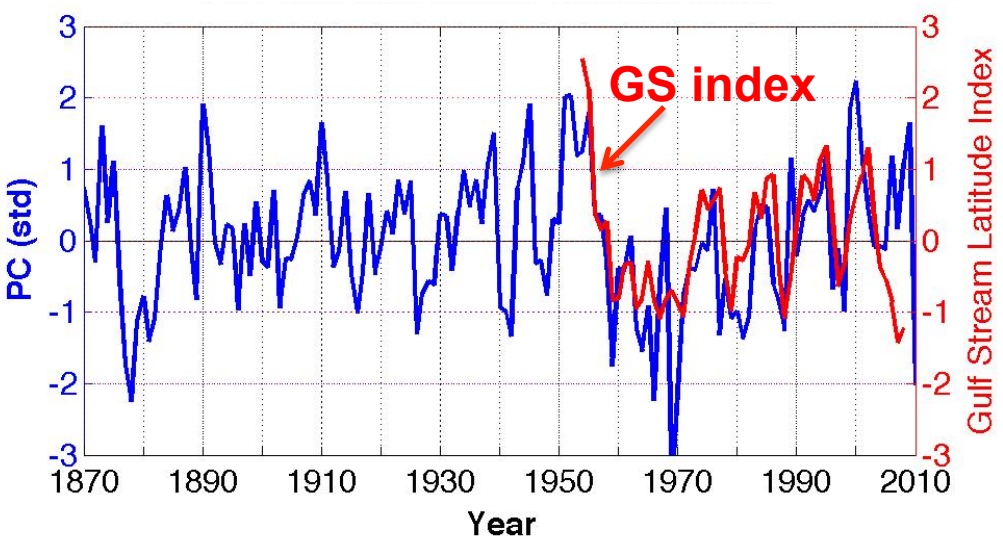
PC 1



EOF 2 (14.1 %)

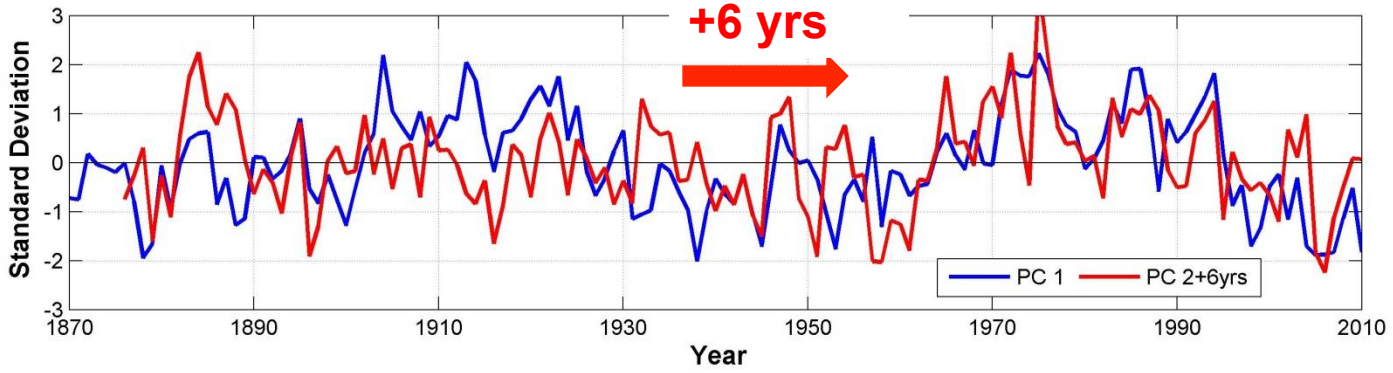


PC 2

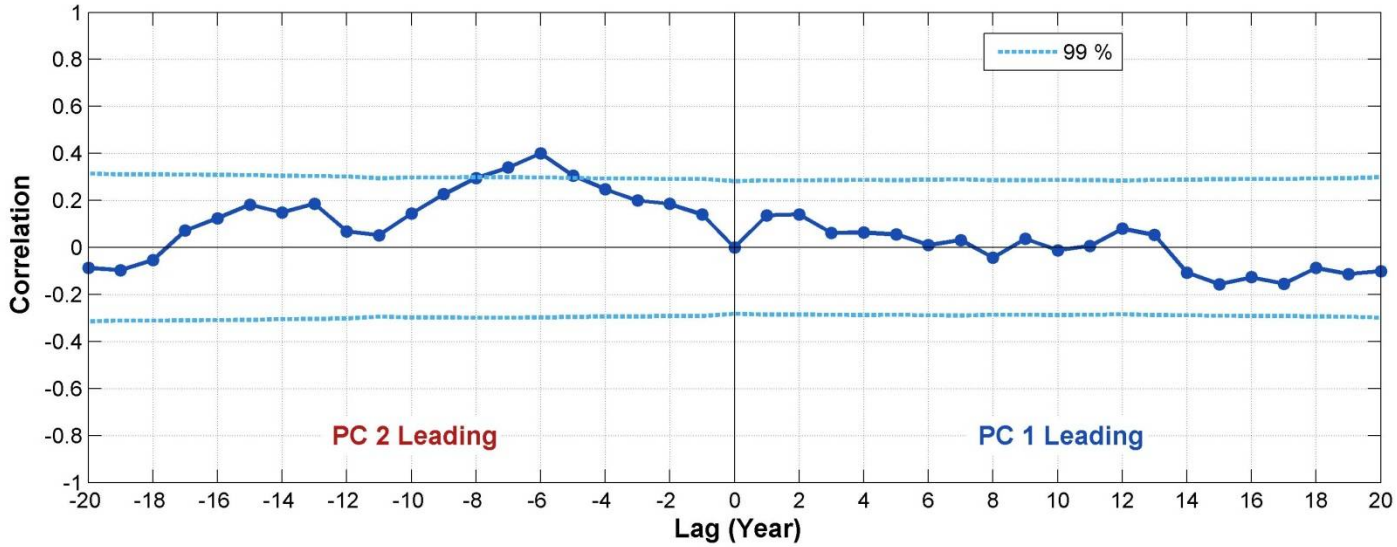


1st and 2nd PC time series of North Atlantic SST

PC 1 & PC 2 Time Series



Lag-Correlation between PC 1 & PC 2



Summary

- **Kuroshio Extension exhibits strong decadal variability primarily due to the north-south shift of the KE front, for which associated forcing and response patterns of wind stress curl suggest existence of a coupled ocean-atmosphere decadal mode in the North Pacific.**
- **Oyashio Extension and Kuroshio Extension variability are not significantly correlated and wind stress curl response and forcing associated with the Oyashio Extension shift suggest a weak positive ocean-atmosphere feedback.**
- **Gulf Stream latitude and silver hake distribution (and abundance) in the Northeast U.S. shelf are highly correlated with the GS leading by 1 year, thus implies some potential predictability of silver hake based on the GS index.**
- **SST EOF-1 in the North Atlantic is highly correlated with AMO, while SST EOF-2 in the North Atlantic is correlated with the shift of the Gulf Stream.**

Thank you.