North Pacific Decadal Climate Variability in CCSM3

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NCAR

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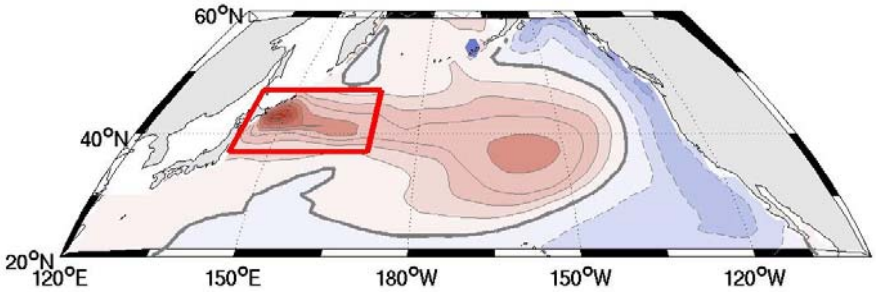
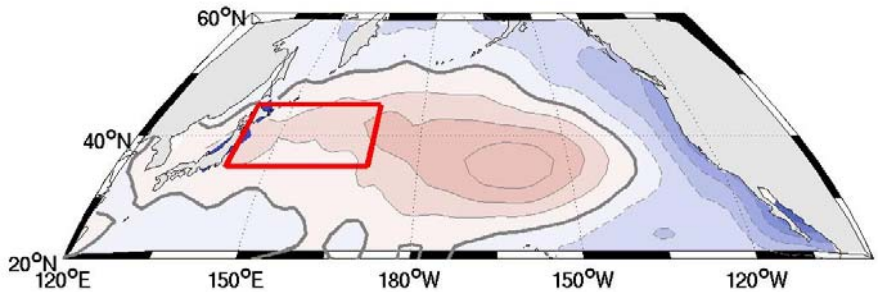
Winter SST Anomalies EOF1

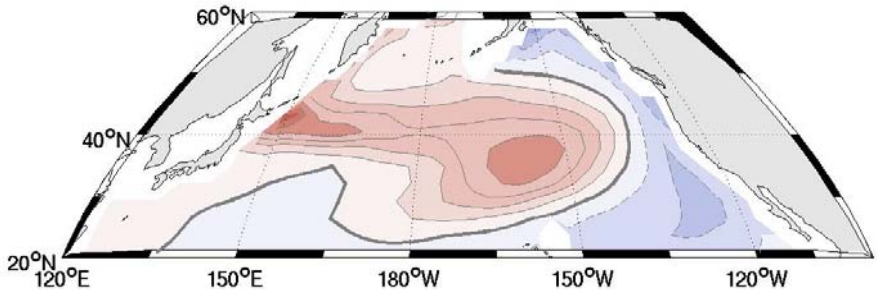
CCSM3 T85 (Yr : 100 – 599; 28 %)



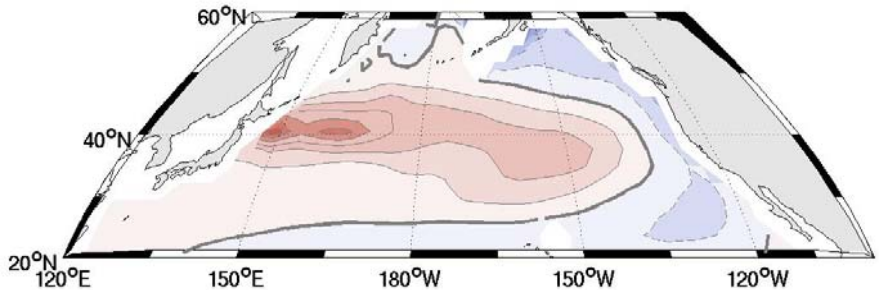
Observation (ERSST : 1901 – 2000; 28 %)

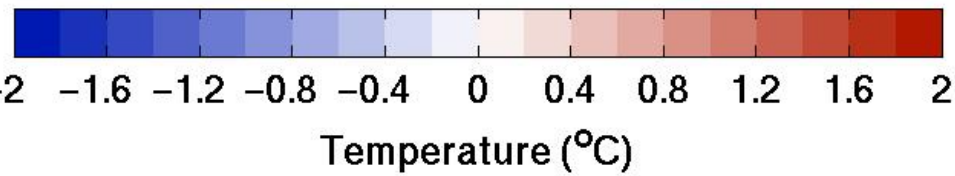


CCSM3 T42 (Yr : 100 – 999; 26 %)



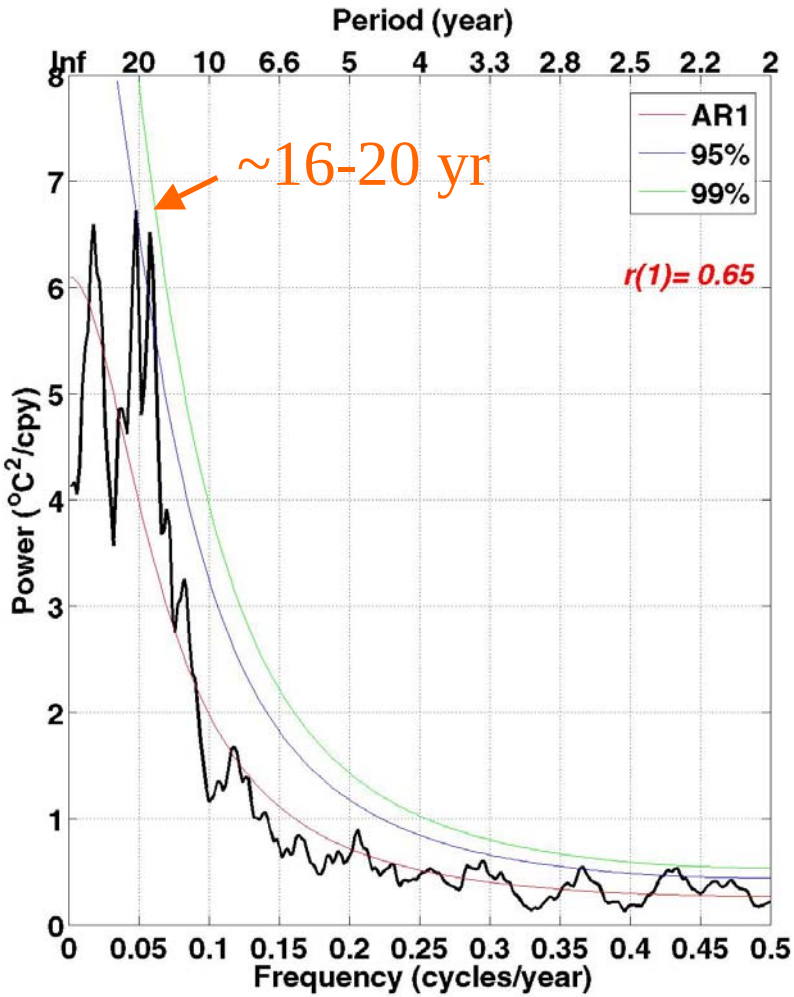
CCSM2 (T42) (Yr : 350 – 999; 20 %)



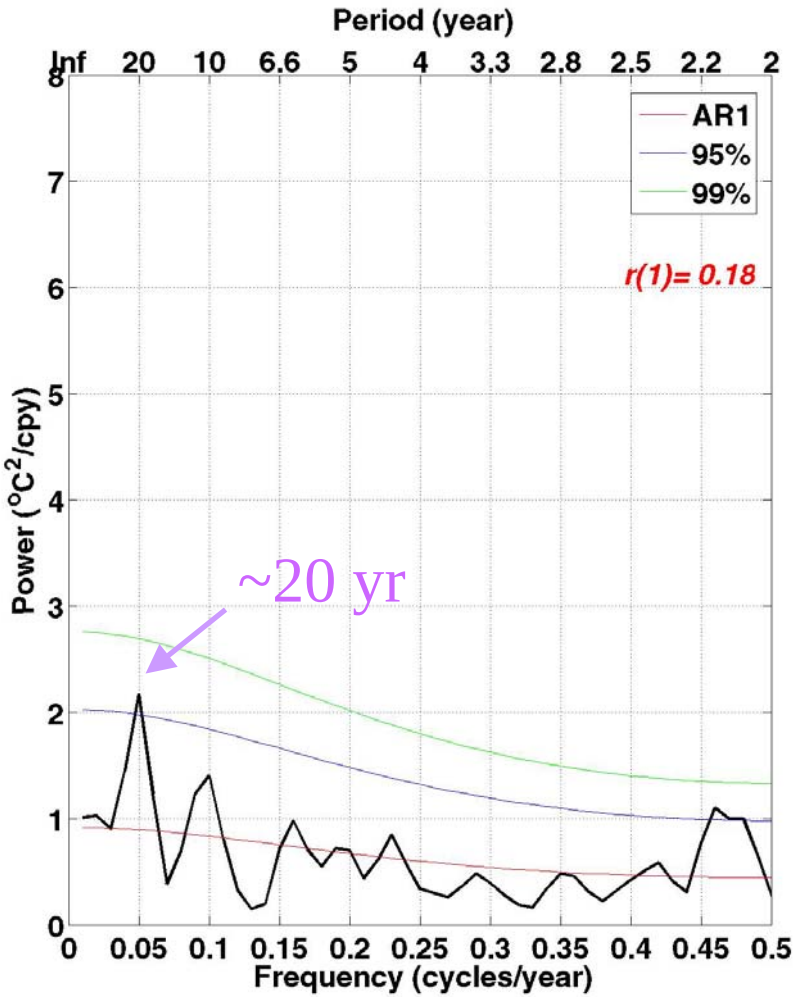


Power Spectrum
Winter SST Kuroshio Extension Index

CCSM3 T85 (100-599)



Observation (ERSST: 1901-2000)

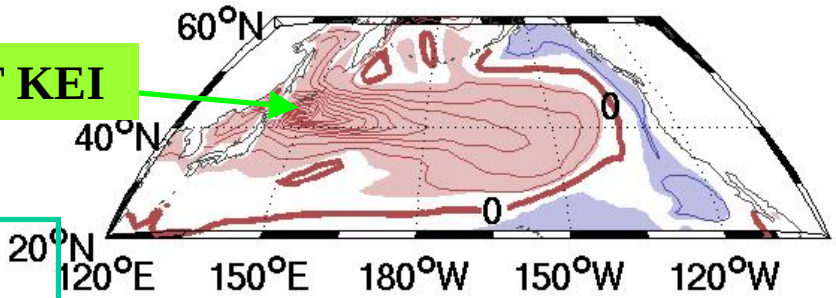


Regression on SST Kuroshio Extension Index

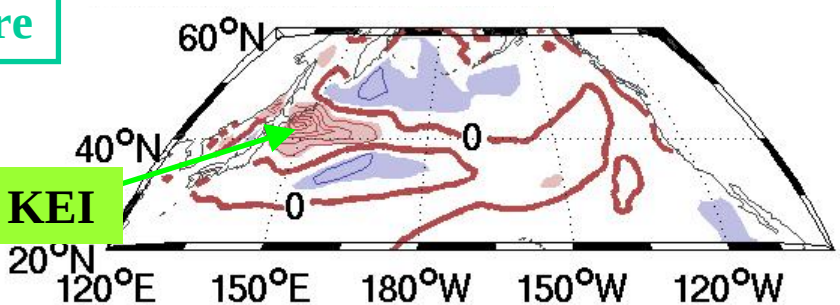
+2ºC per ºC SST KEI

Warm SST ~

Heat Flux from Ocean to Atmosphere



SST (Winter)



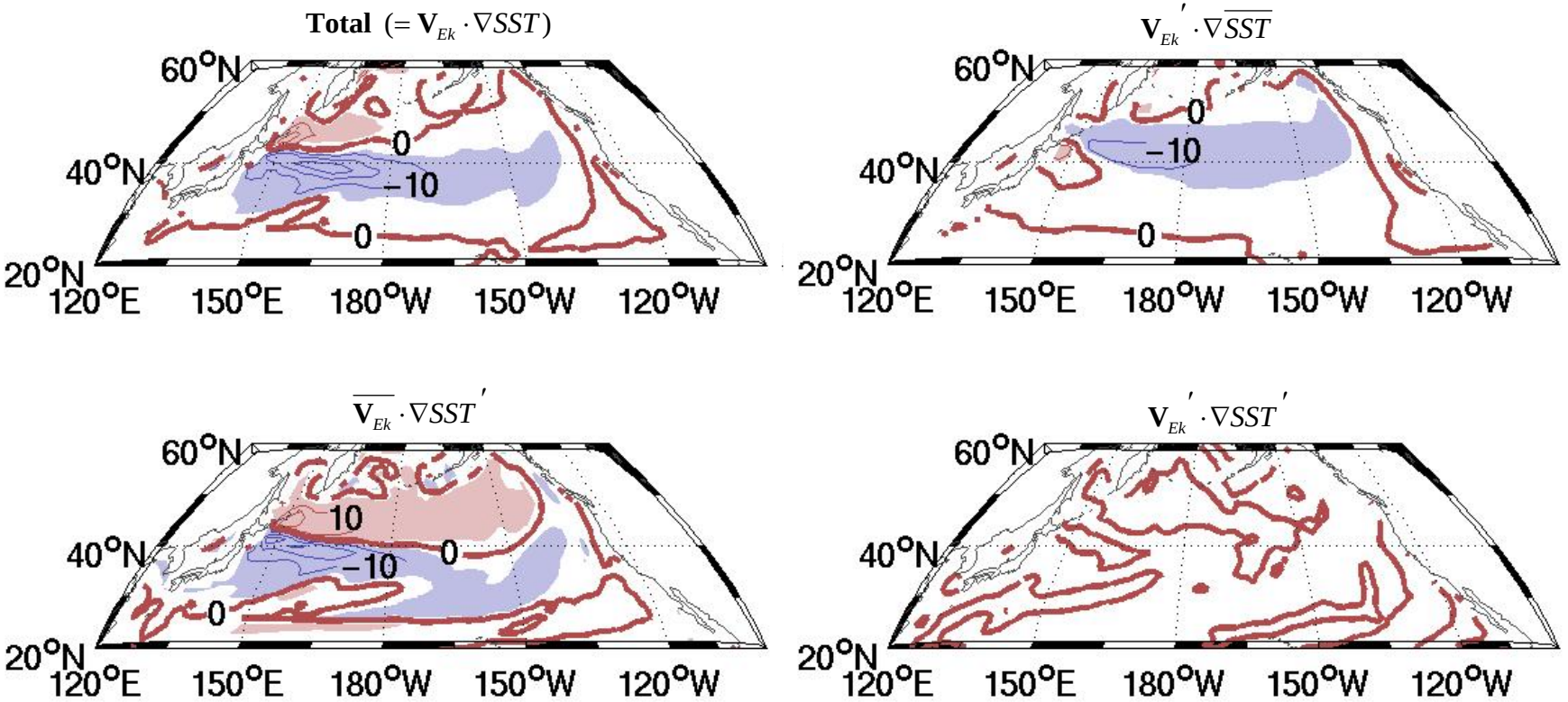
Q_{NET} (Winter)

+50 W/m^2 per ºC SST KEI

(Contour Interval: 0.2ºC/ºC, 10 W/m^2/°C ; Shading: significant at 99 %)

⇒ ***Local Q_{NET} responds to the SST anomaly, rather than forcing it.***

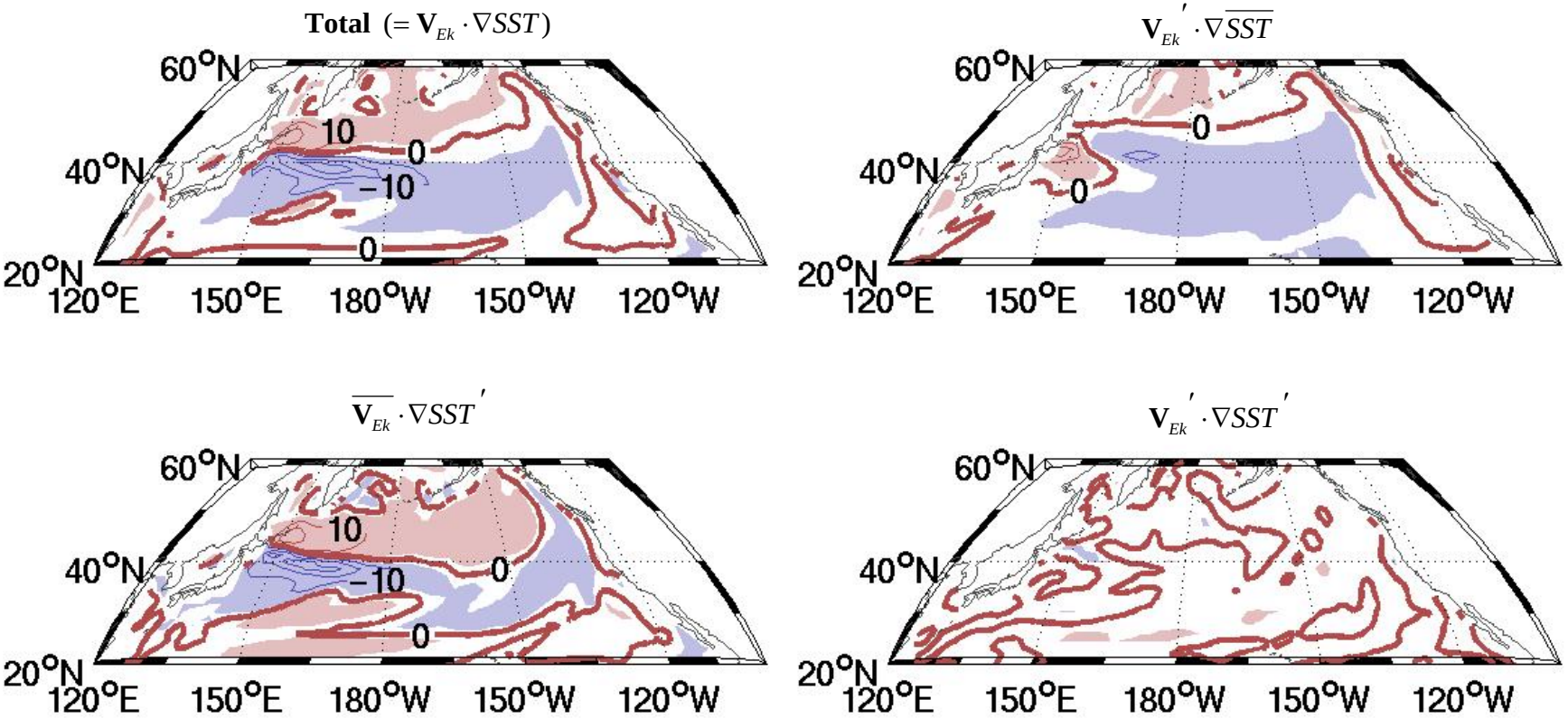
Winter Q_{Ekman} regressed on SST Kuroshio Extension Index



(Contour Interval: 10 W/m²/°C ; Shading: significant at 99 %)

Winter Q_{Ekman} regressed on SST Kuroshio Extension Index

(Low-pass filter > 10 yr)



(Contour Interval: 10 W/m²/°C ; Shading: significant at 99 %)

⇒ ***Anomalous Q_{Ekman} acts as a positive feedback to the SST anomalies.***

Upper 200 m Heat Budget in the Kuroshio Extension

$$\frac{\partial HC}{\partial t} = -Q_{net} - u\frac{\partial HC}{\partial x} - v\frac{\partial HC}{\partial y} + w\frac{\partial HC}{\partial z} + \text{Residual} \quad [W/m^2]$$

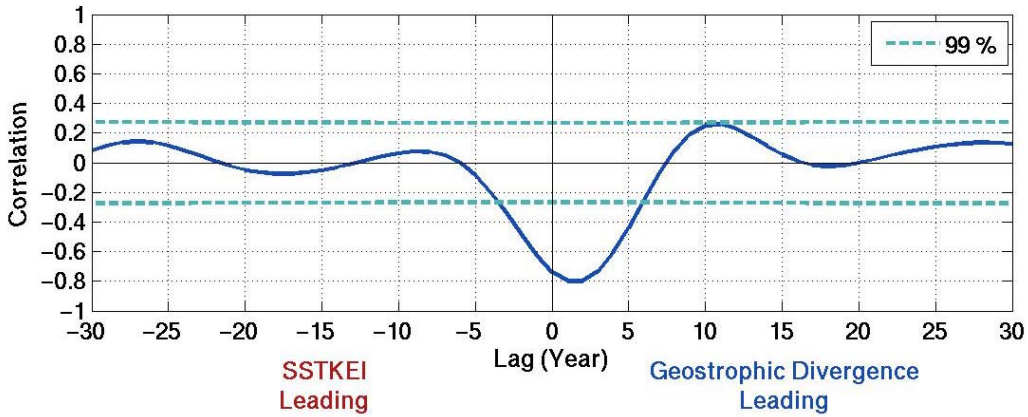
where $HC = \rho_0 C_p \int_0^z T(z)dz$

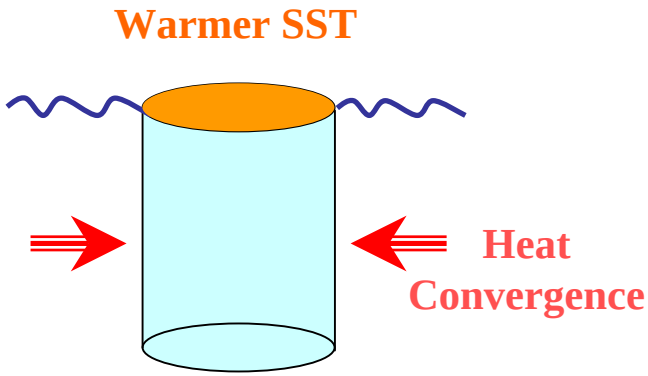
Lateral Ocean Heat Divergence

Surface Heat Flux

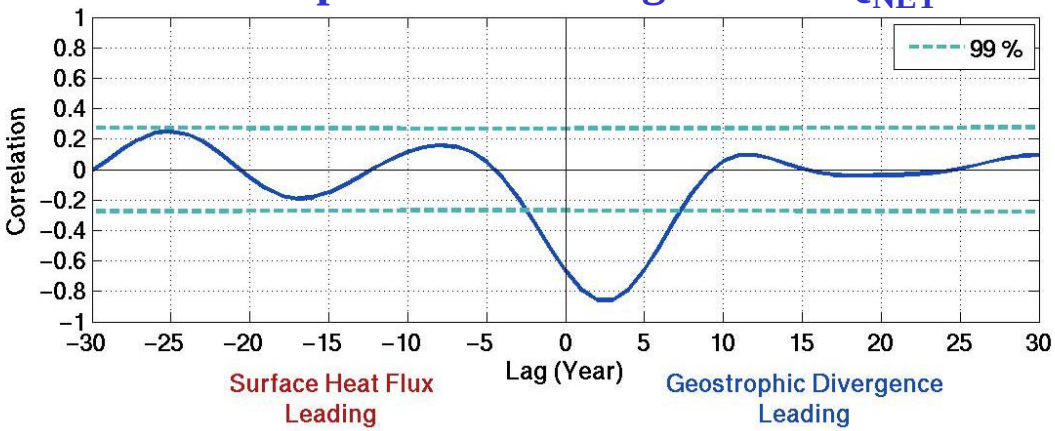
Correlation in the Kuroshio Extension

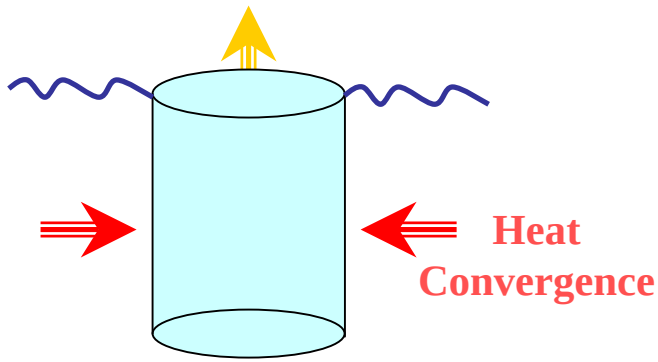
Geostrophic Heat Divergence vs. SST





Geostrophic Heat Divergence vs. Q_{NET}





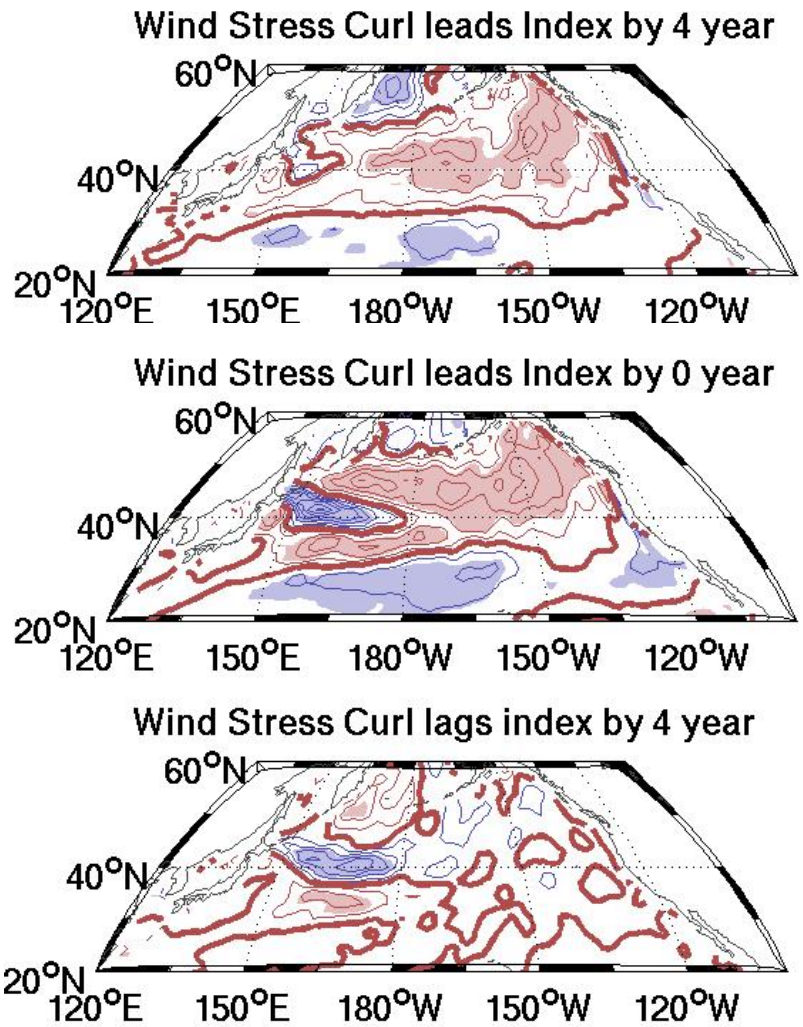
(Low-pass Filter > 10 yr)

Ocean heat convergence ⇒ +1-2 yr ⇒ warmer SST ⇒ +1~2 yr ⇒ ocean-to-atmosphere Q_{NET}

Summary

- Leading EOFs of CCSM3 & CCSM2 winter SST have PDO-like horse-shoe pattern.
- Robust decadal (16-20 yr) variability of SST along the Kuroshio Extension.
- Ocean heat divergence driven by stochastic wind stress curl forcing is likely causing the decadal SST anomaly along the Kuroshio Extension.
- Local Q_{net} and Q_{Ekman} are response to the SST anomaly.

Wind Stress Curl regressed on Heat Divergence in the Kuroshio Extension



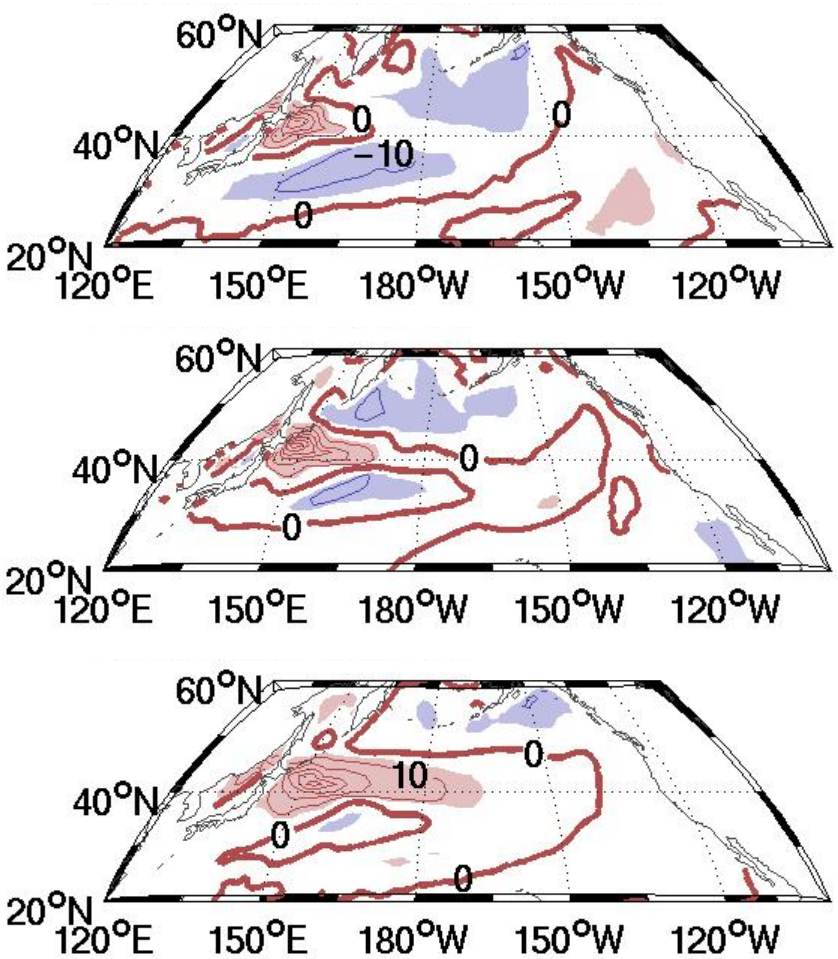
Atmosphere Leads

Simultaneous

Ocean Leads

(Contour Interval : 5 x 10^{-9} N/m^3 ; Shading : significant at 99 % ; Low-pass filter > 10 yr)

Winter Q_{NET} regression on SST Kuroshio Extension Index



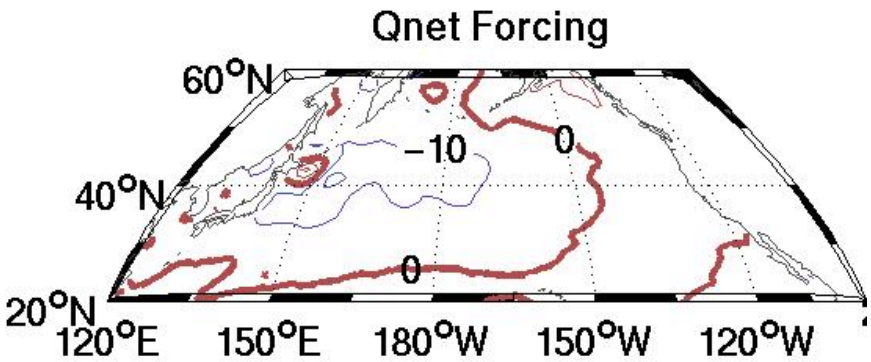
Q_{NET} Leads (+1 Yr)

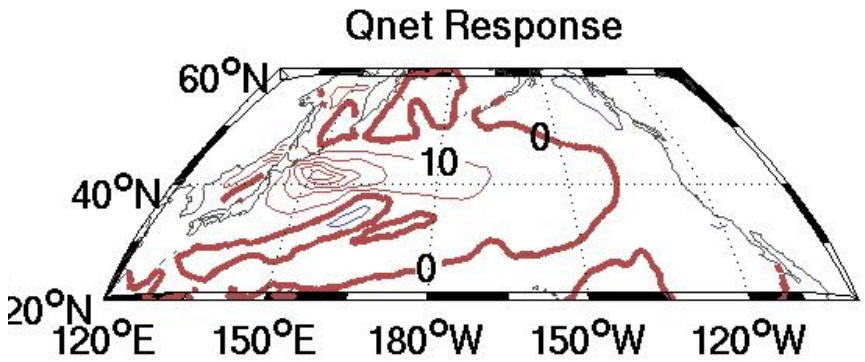
Simultaneous

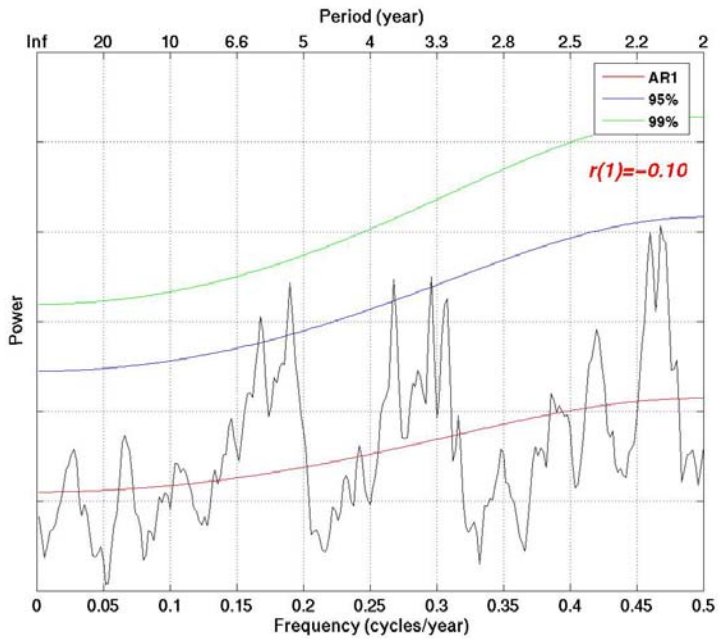
Q_{NET} Lags (-1 Yr)

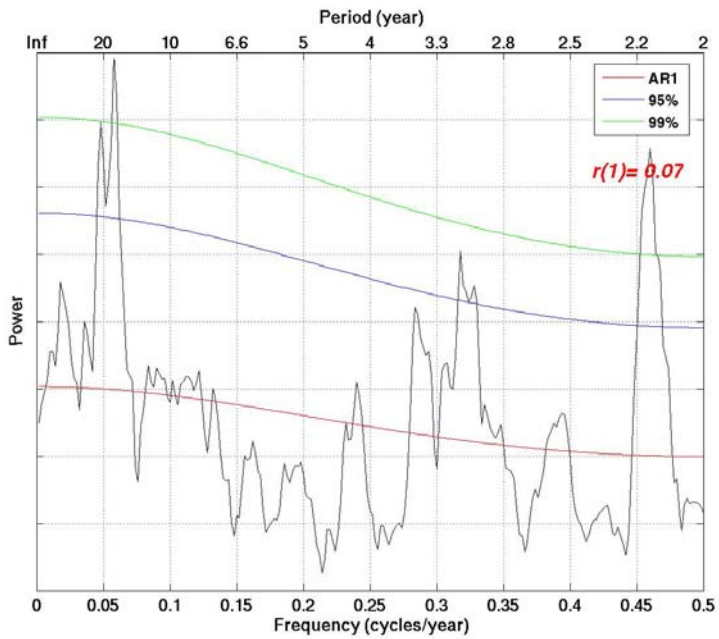
(Contour Interval: 10 W/m^2/°C ; Shading: significant in 99 %)

Q_{NET} Forcing / Response to SST Kuroshio Extension Index



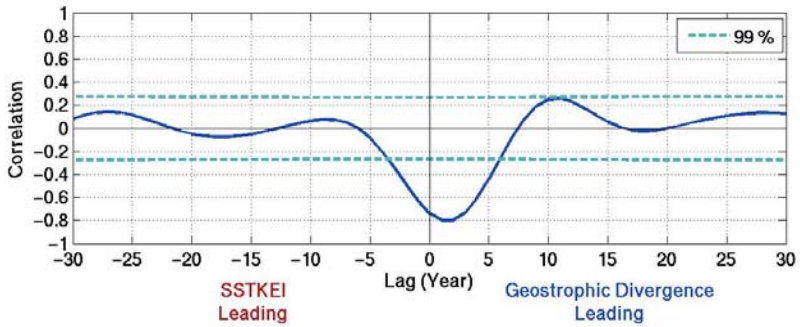


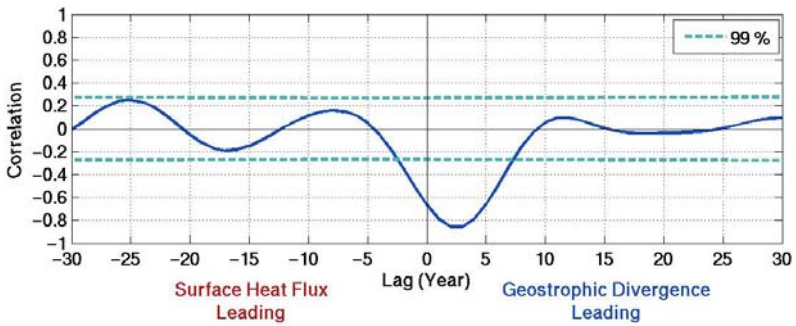




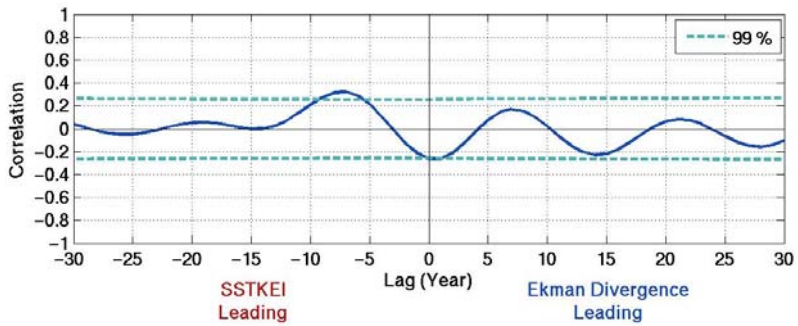
Correlation in the Kuroshio Extension
Geostrophic / Ekman Heat Divergence vs. SST / Q_{NET}

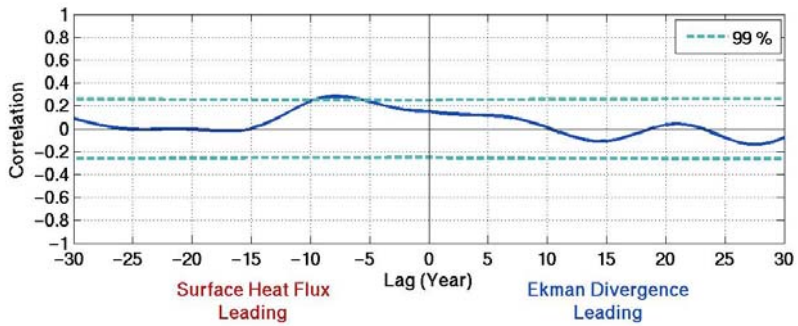
Geostrophic Heat Divergence





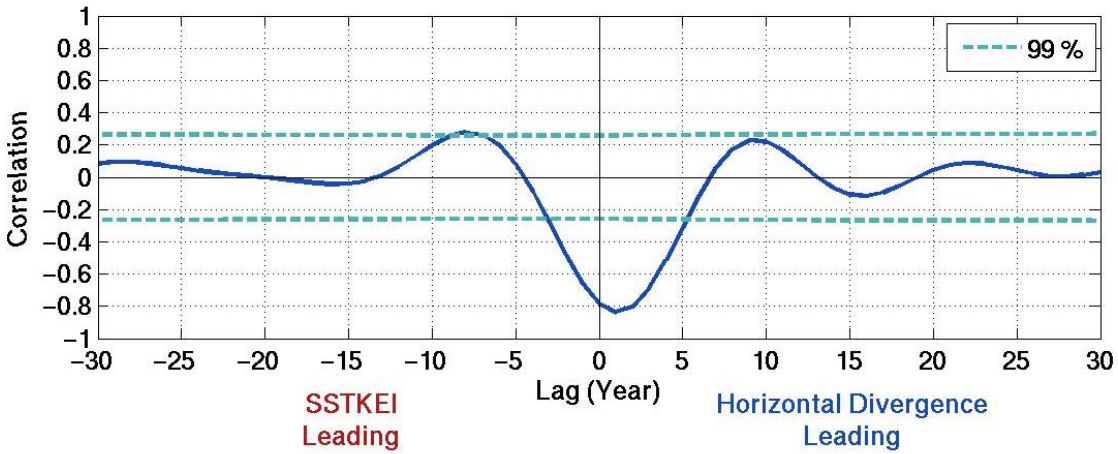
Ekman Heat Divergence

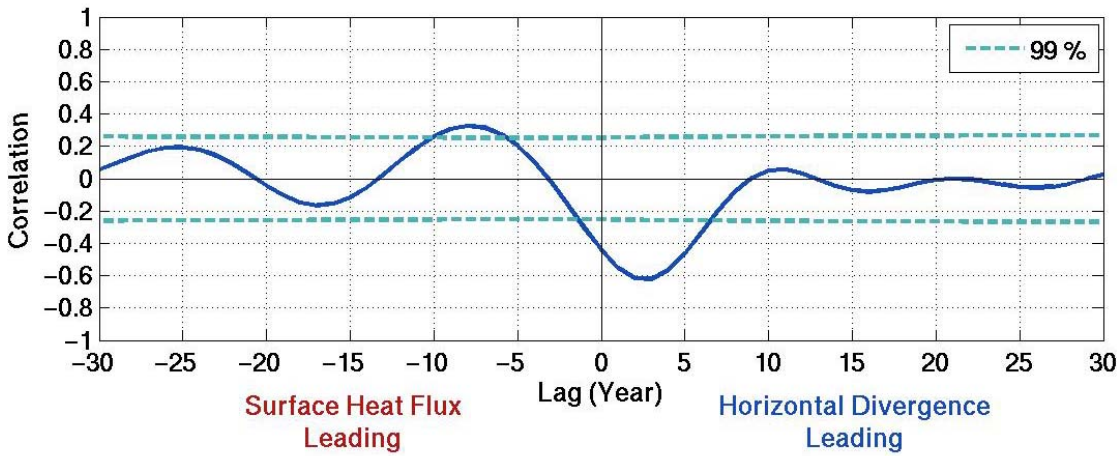




(Low-pass Filter > 10 yr)

Correlation in the Kuroshio Extension
Total Horizontal Heat Divergence vs. SST / Q_{NET}





(Low-pass Filter > 10 yr)