Possible mechanism of bi-decadal North Pacific ocean/climate variability in relation to 18.6-year nodal tidal cycle

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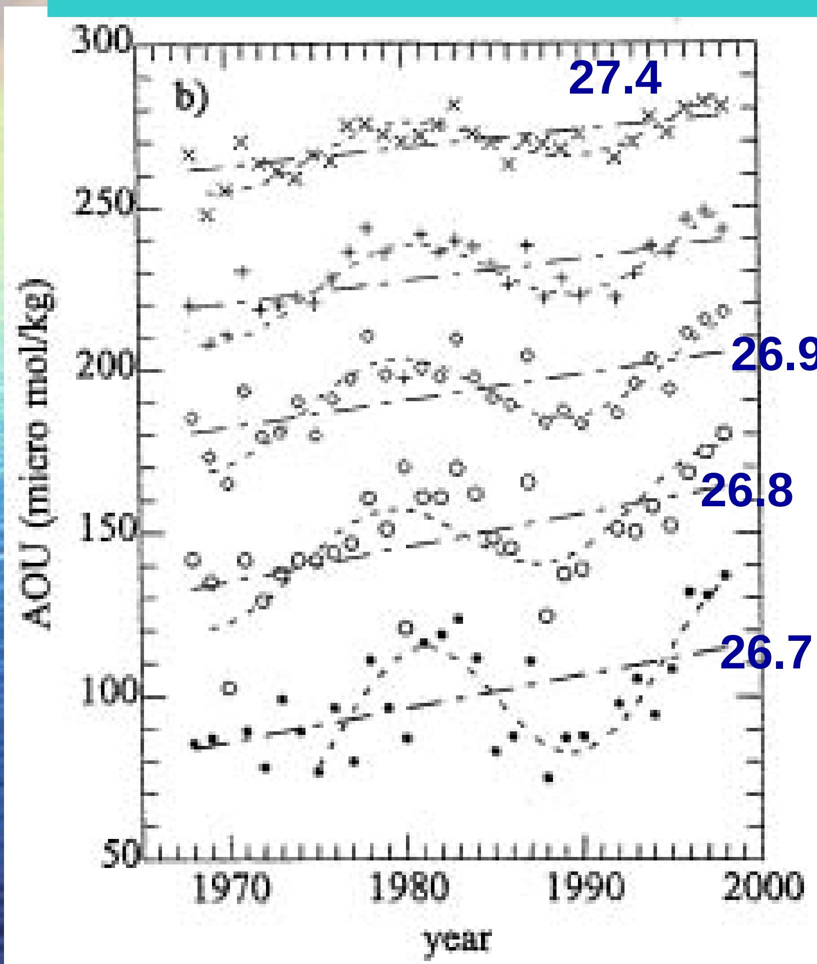
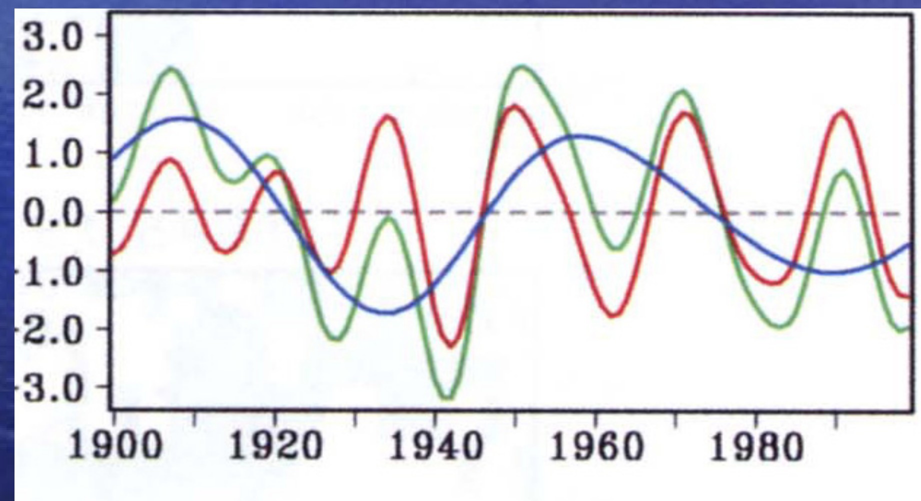
Motivation: Bidecadal variations in Oyashio intermediate water and NPI



Ono et al. (2001)

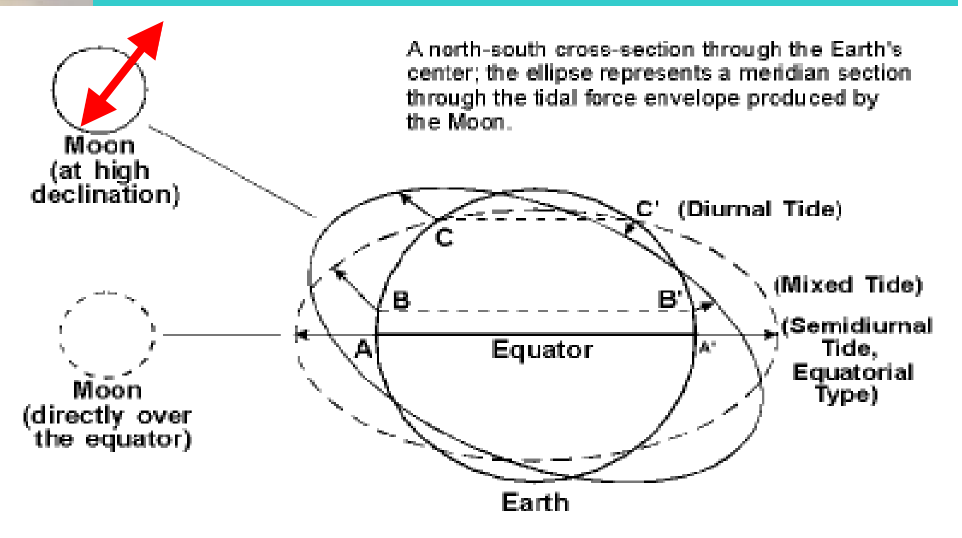
Winter-NPI Minobe (2000 PiO)

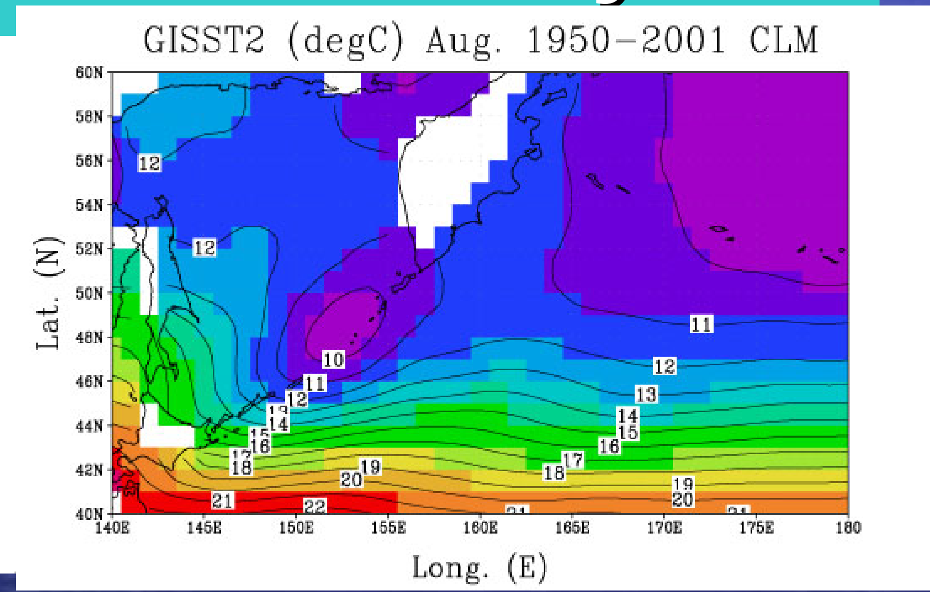


Bi-decadal period oscillation in Oyashio
Is synchronized with NPI bidecadal Osci.

However, this signal is not directly from atmosphere because the waters are not outcropped even in winter.

18.6-year period nodal tidal cycle





Inclination of moon orbit to the earth equatorial surface changes as 23.4±5deg with 18.6-year period（James Bradley, 1798）

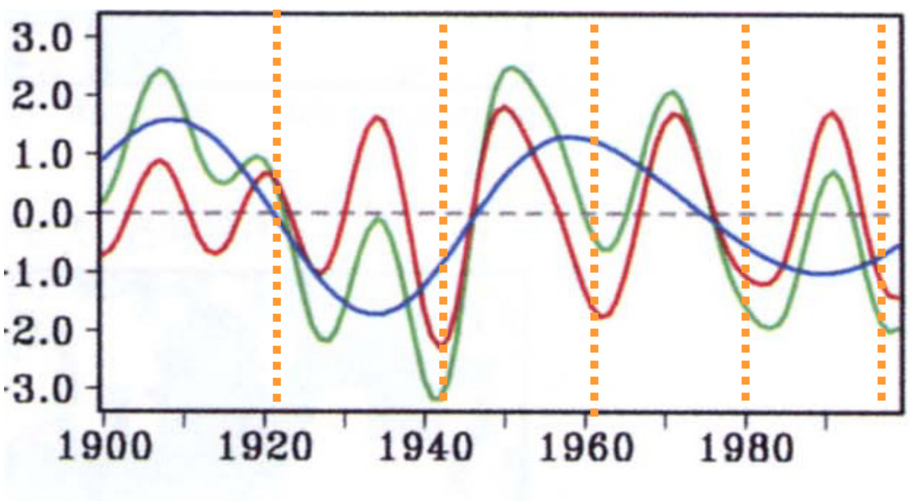
Strong tidal mixing around Kuril Islands up to Kv=1000cm2/s makes summer SST cooler.

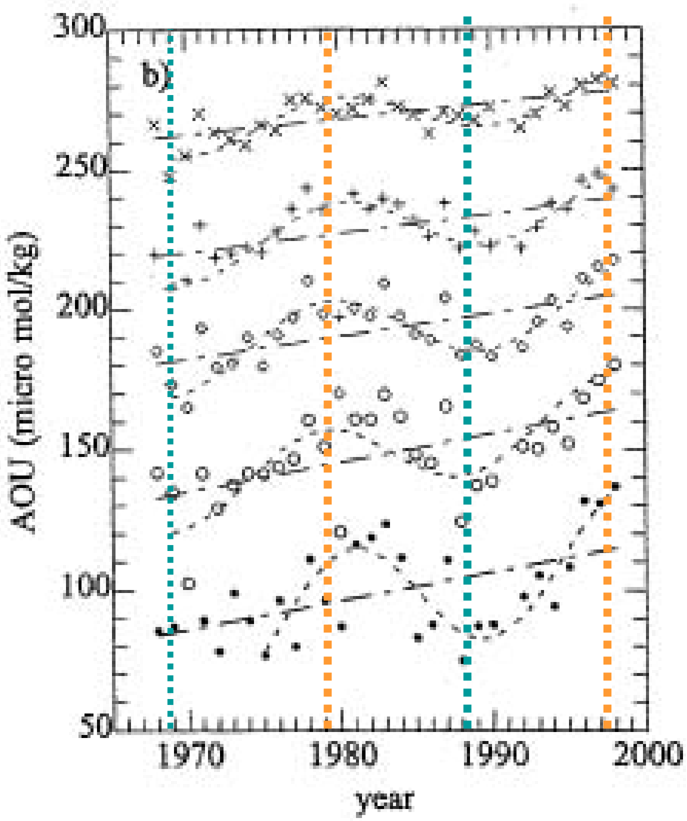
Amplitude of the diurnal tides (K1,O1) modulates by max. 20%

Many reports on the nodal cycle in the atmosphere and oceans (Maximov & Smirnov 1970; Currie 1984 etc.)
Loder & Garret (1978）Royer (1993) indicated the tidal mixing as a probable cause

NPI & Oyashio bi-decadal variation and 18.6-year nodal tidal cycle

Winter-NPI   Minobe (2000 PiO)





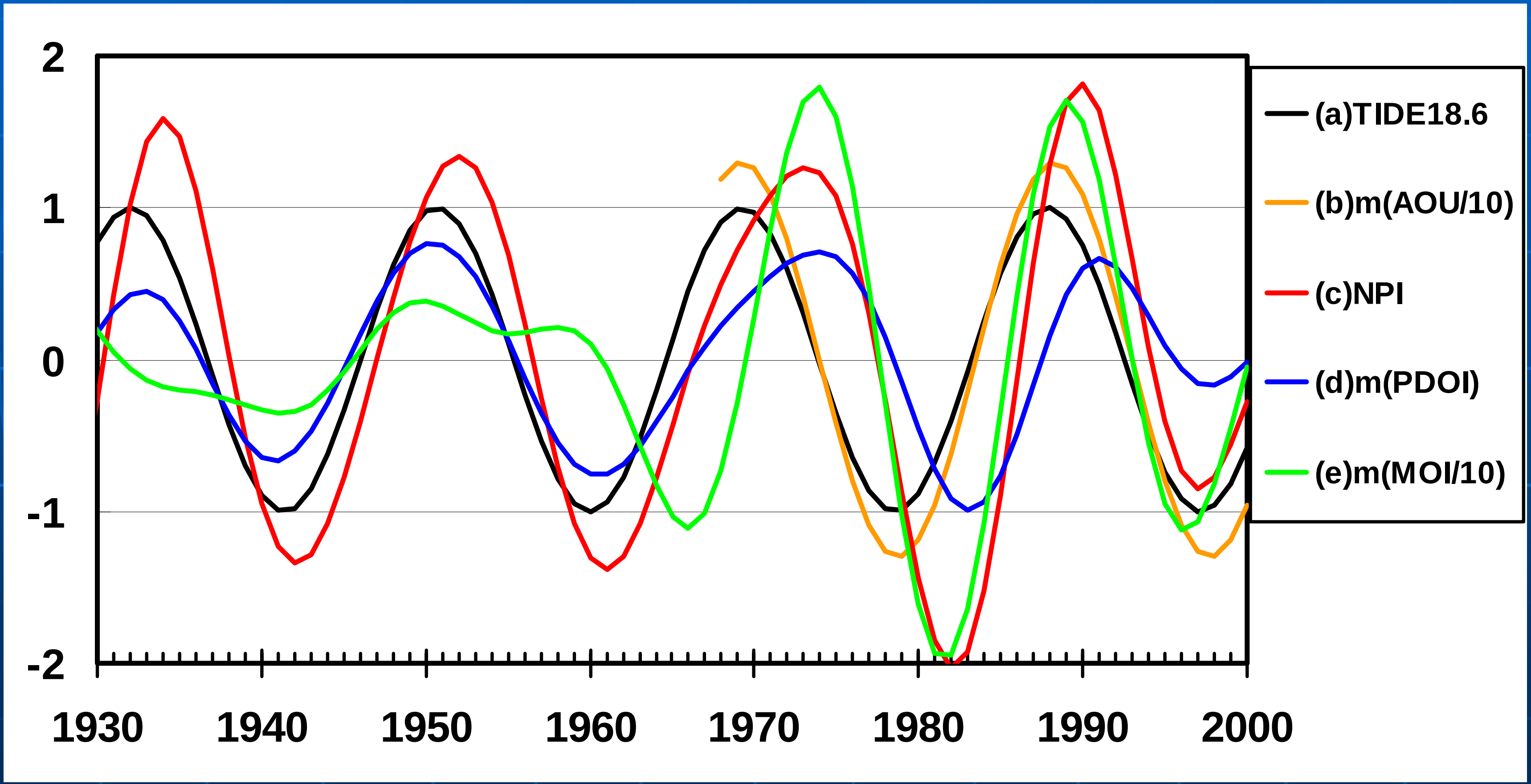
NPI and AOU are both synchronized with nodal cycle.

In the period of strong diurnal tide, Intermediate water is new and Aleutian Low is weak.

Weak-K1,O1 strong-M2
Weak vertical mixing

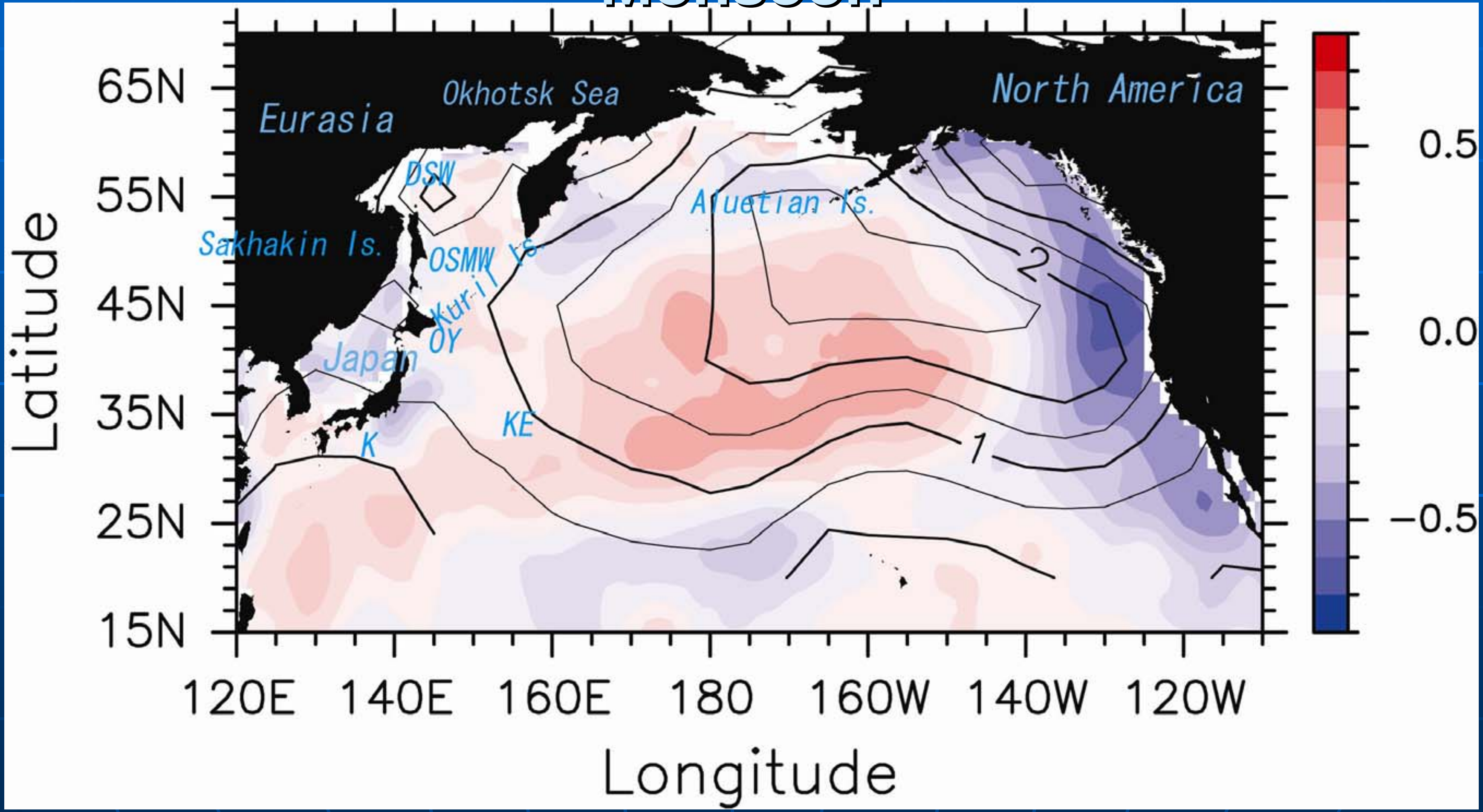
strong-K1,O1 weak-M2
Strong vertical mixing

18.6-year tidal cycle and 12-26year bandpassed winter-NPI･PDOI･MOI



In the period of strong diurnal tide, negative-PDO, positive-NPI and Weak winter East Asian Monsoon. The phase looks delayed for the nodal Cycle, implying the influence from the ocean to the atmosphere.

Difference in Feb-SST and Sea-level pressure between stronger and weak diurnal tides : warm KOE SST -weak winter-Aleutian Low & Monsoon

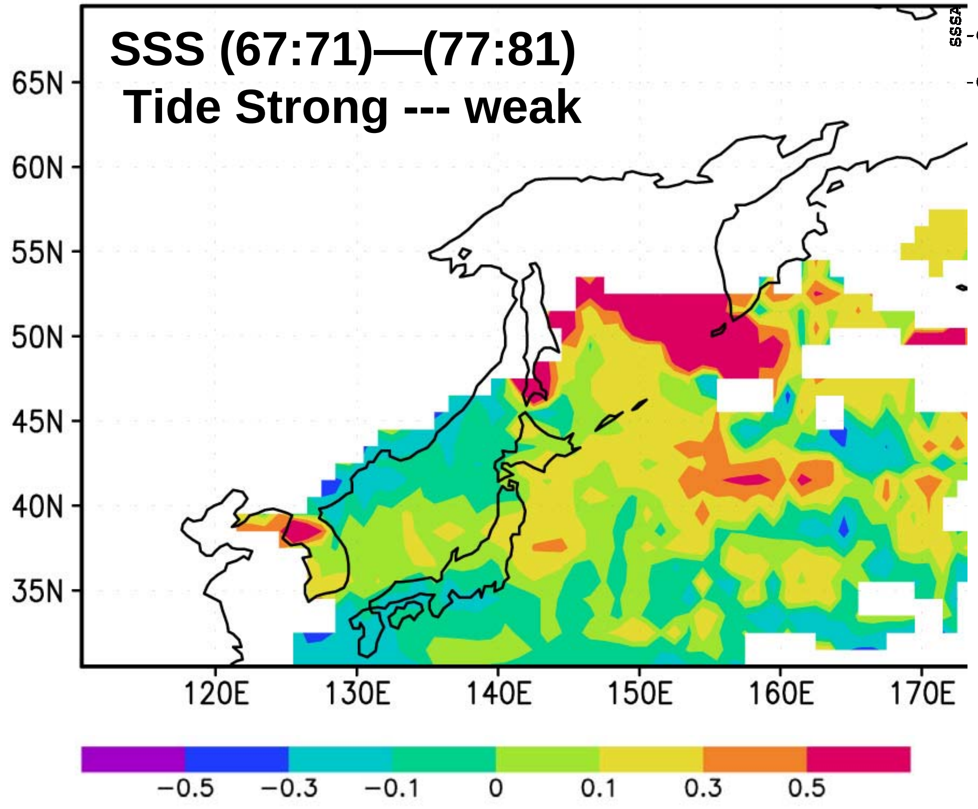


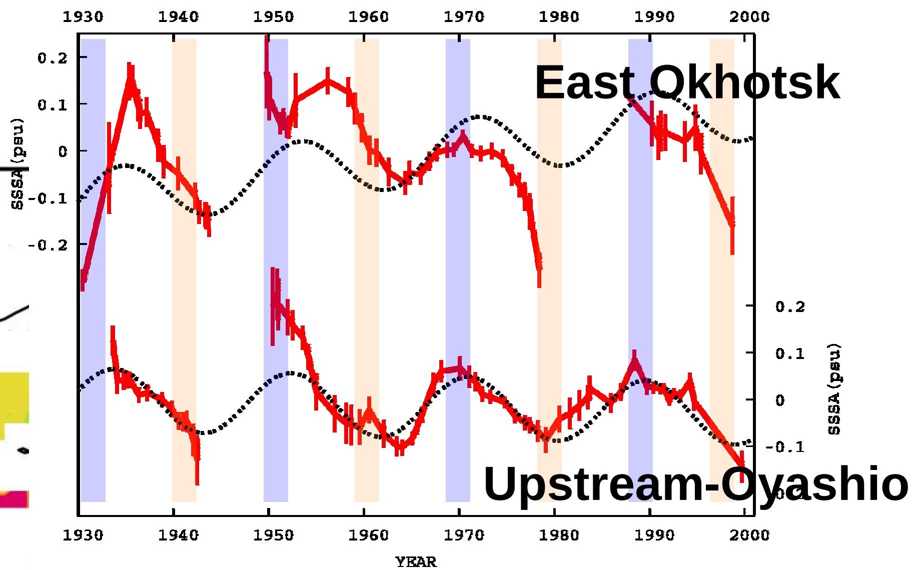
12-25-year bandpassed Feb-SST/SLP difference（strong-weak tide）

Look at ocean data further

focus on the variations in SSS and isopycnal depth from WOD2001

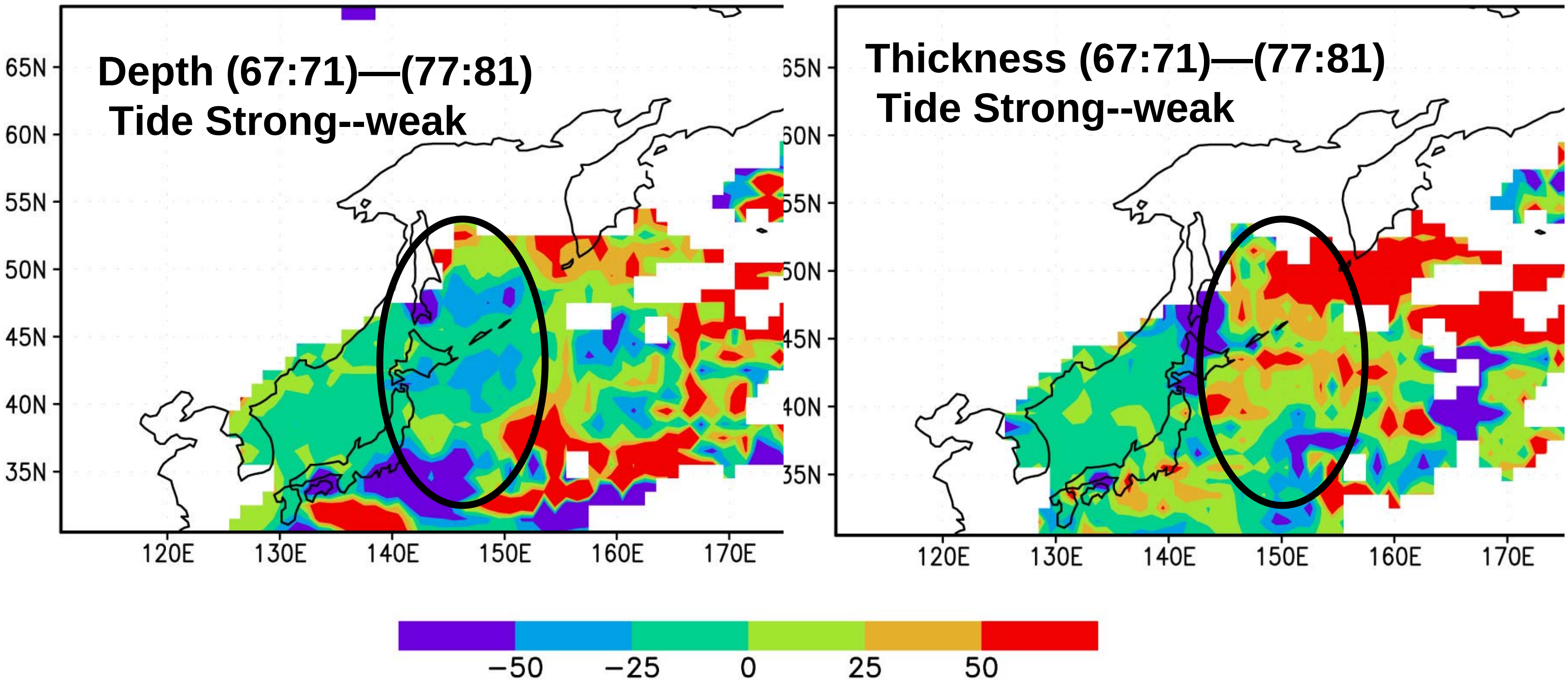
SSS-difference





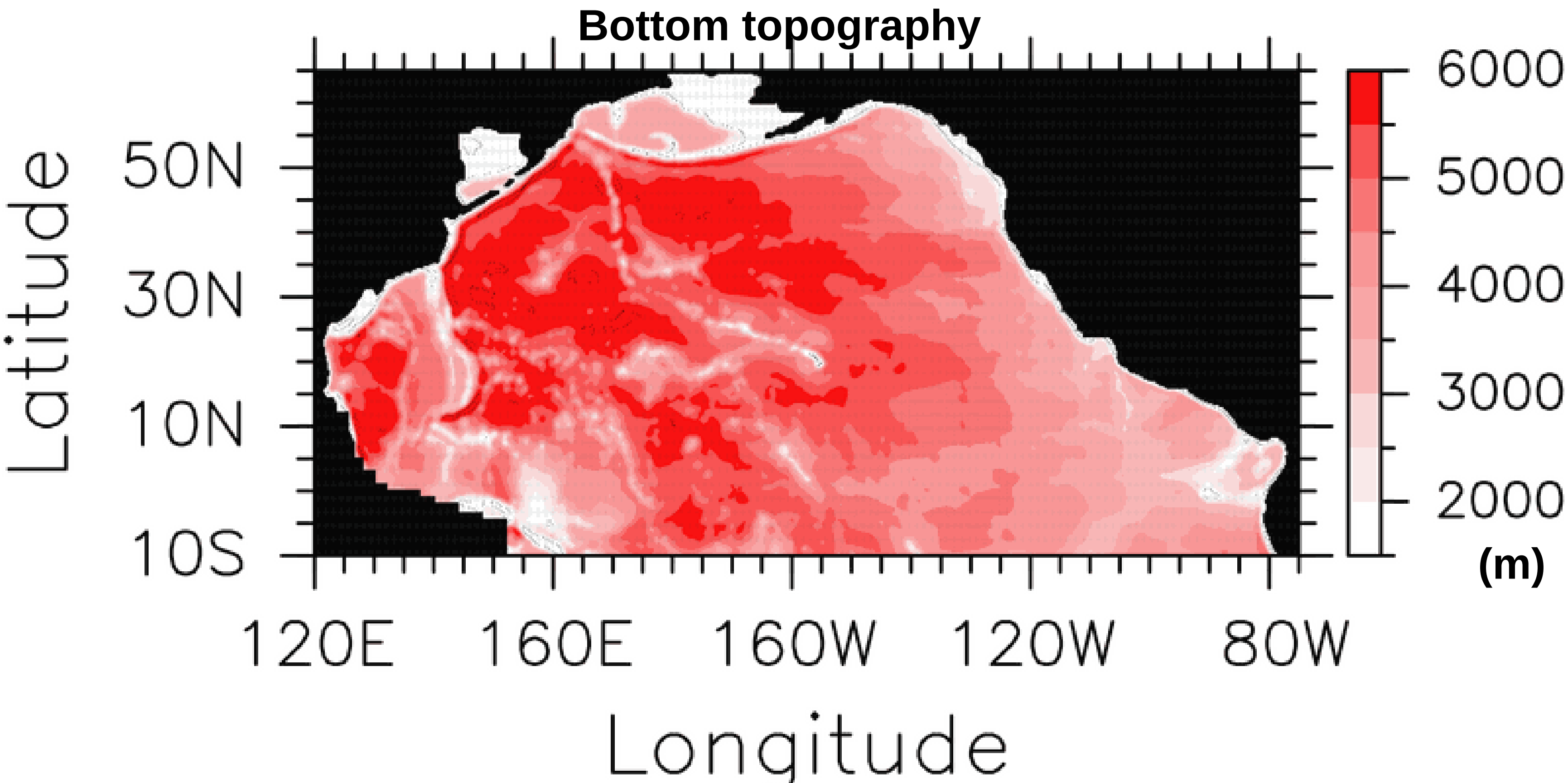
In the period of strong diurnal tide, SSS is higher in the Okhotsk Sea and in the area east of Japan.

Change in isopycnal depth at 26.7 and thickness 26.7-27.2



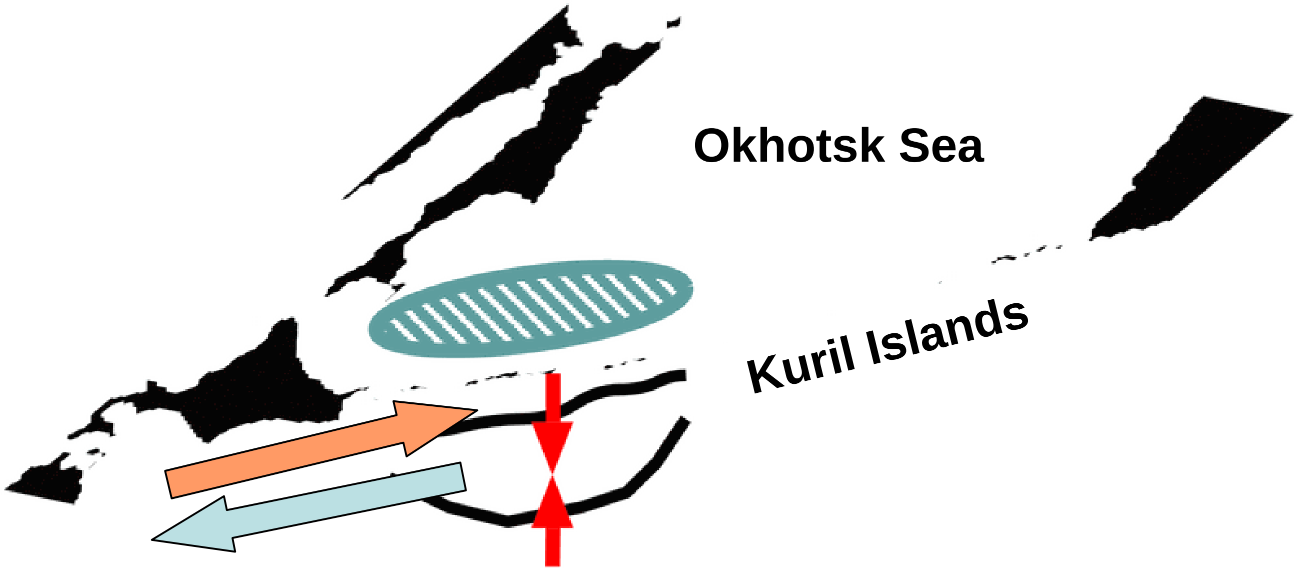
In the period of strong diurnal tide, the upper-layer thickness is shallow and intermediate-layer thickness is large in the Okhotsk Sea and western boundary regions.

Model diagnostics on the influence of layer thickness changes on the ocean circulation



Three-layer Primitive Equation Model with horizontal 1/4X1/4 deg, realistic bottom and coastal topography.
Upper layer: density < 26.7, intermediate: 26.7-27.2
Annual mean climatological wind-stress from NCEP/NCAR reanalysis

Restoring upper and intermediate layer thickness in the Okhotsk Sea Kuril Basin to observation



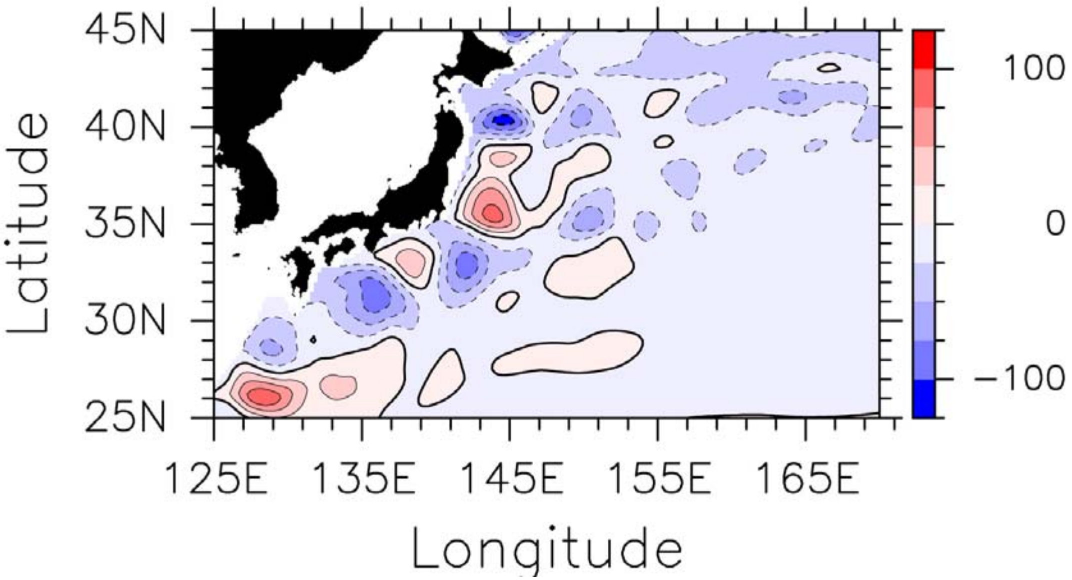
Observed thickness difference (Strong – Weak tide):
Upper-layer: - 50m   Intermediate-layer: +100m

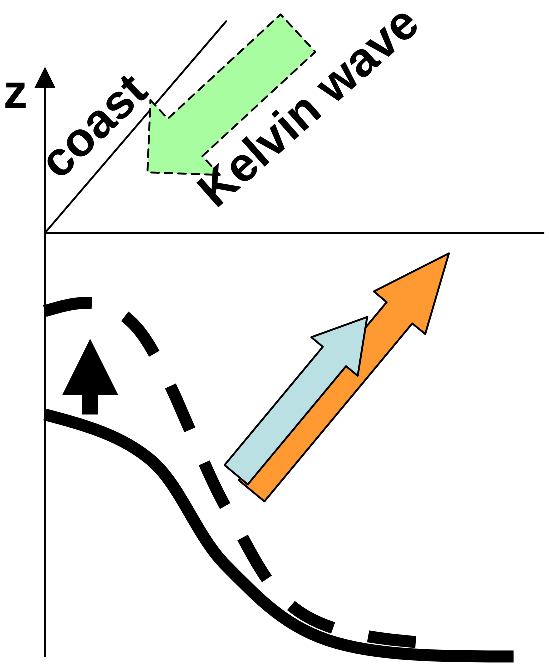
Evaluated diapycnal transport in the Okhotsk Sea:

	Strong	Weak
From upper to intermediate layers W1:	2.8Sv	1.2Sv
From deep to intermediate layers W2:	1.0Sv	0.5Sv

Model upper-layer depth difference

Difference in upper-layer thickness (Strong – Weak tides)

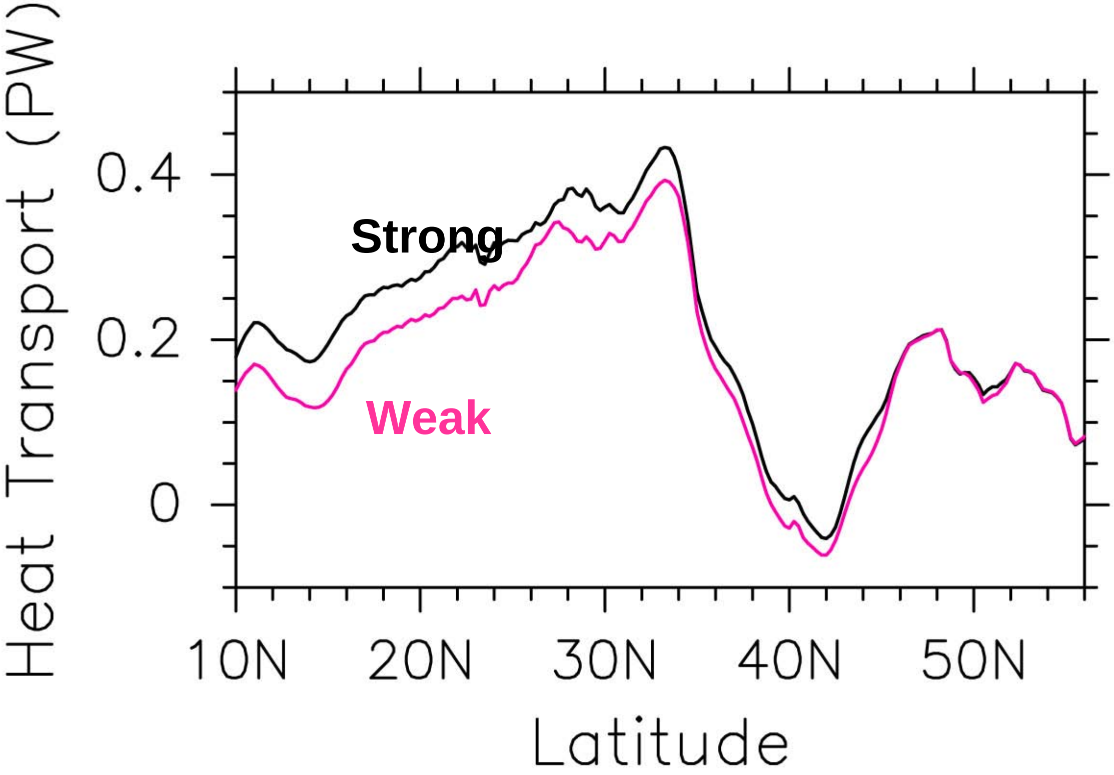




The model reproduced the shallower upper-layer thickness along the western boundary. This shallow depth causes Stronger northward WBC in the upper layer.

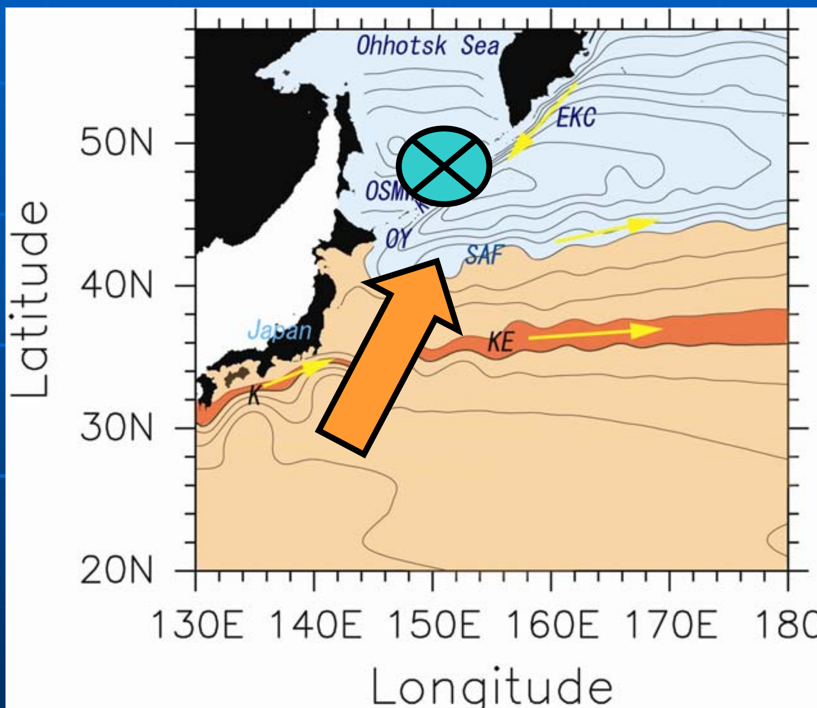
Upper-layer northward WBC is intensified.

Estimate of poleward heat transport using the model velocity and annual-mean temperature data from WOA98

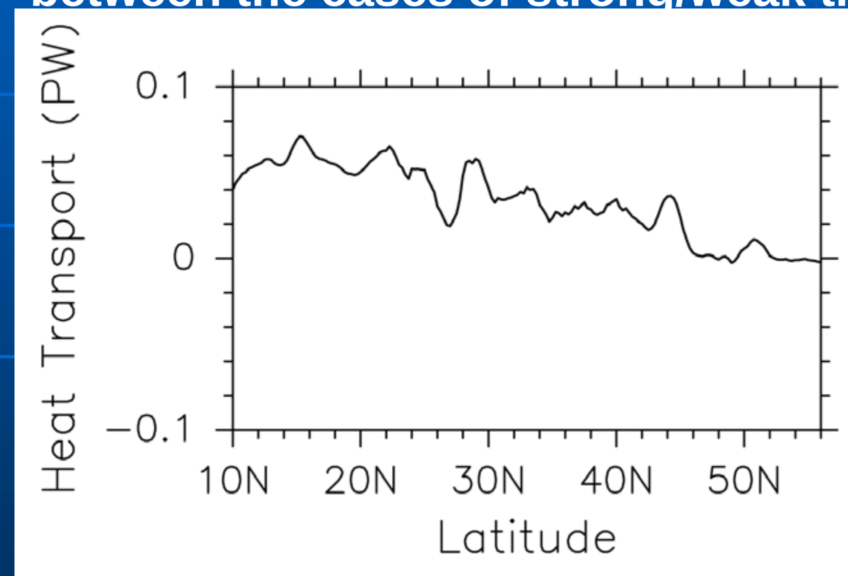


Poleward heat transport is greater in strong tide case than in the weak tide case. Thermohaline circulation is enhanced In the strong tide case.

Influence on the ocean circulation: Increased diapycnal transport and NPIW circulation would enhance poleward heat transport

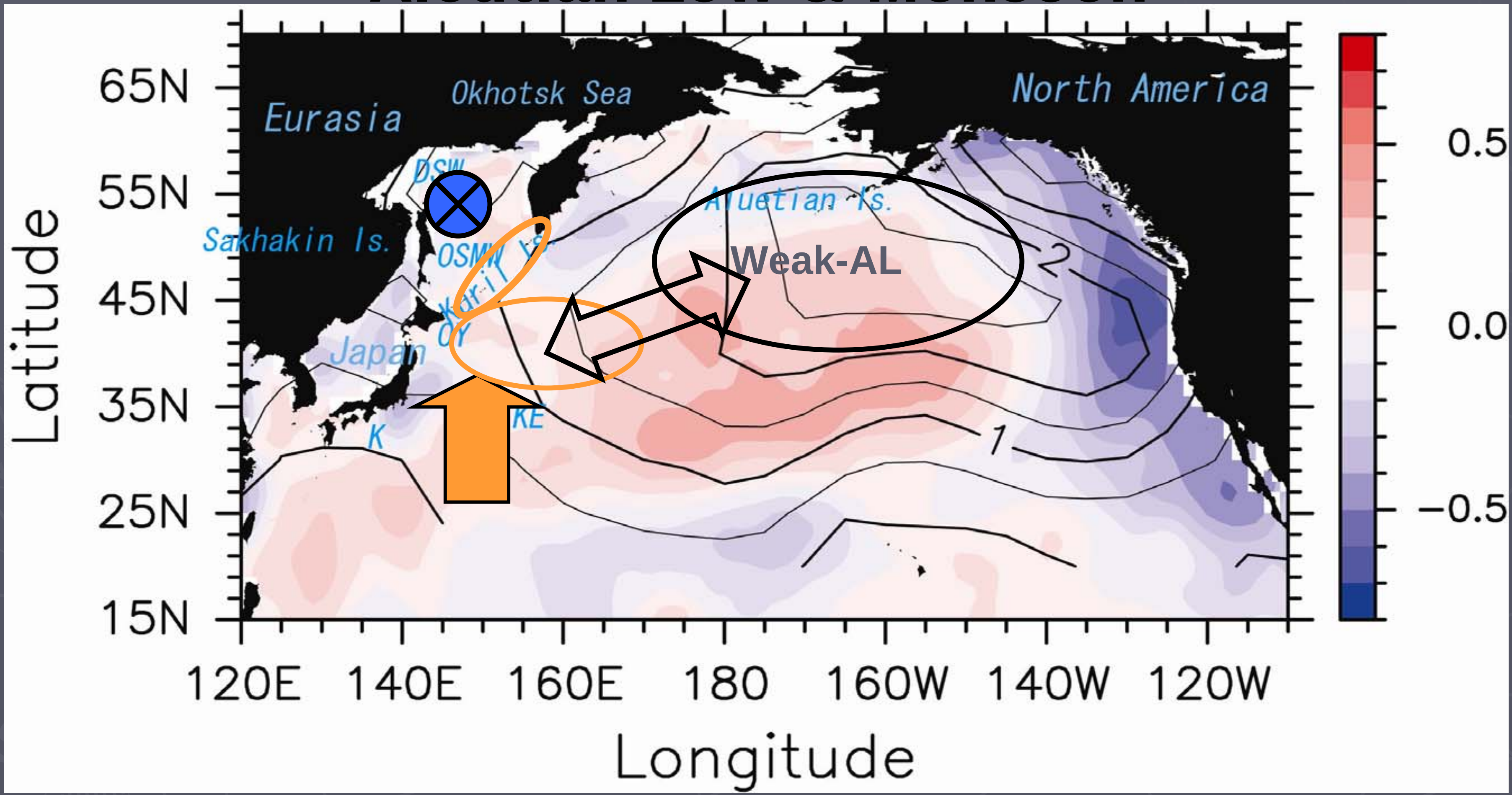


Poleward heat transport difference between the cases of strong/weak tide



Increased sinking rate in the Okhotsk Sea (∼1Sv) increases the northward volume transport and poleward heat flux along the WBC (0.05PW∼O(10%) of poleward heat transport in the North Pacific) compared with the case of weak diurnal tide phase. Now coupled model experiment is going on with Prof. Hasumi (CCSR, Univ. Tokyo)

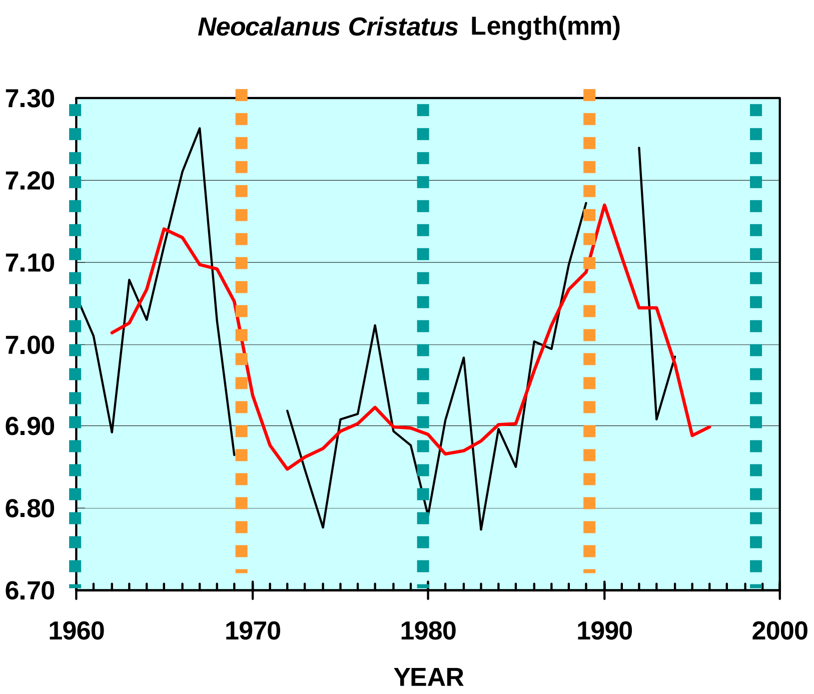
Possible scenario: Stronger tidal mixing—enhanced sinking—increased poleward heat transport – warm KOE SST ←→weak winter-Aleutian Low & Monsoon

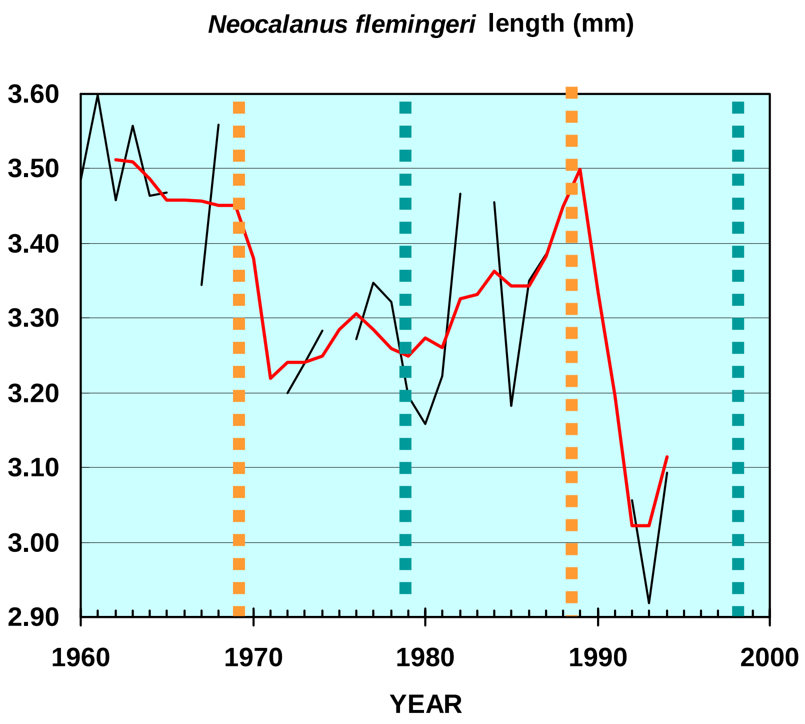


12-25-year bandpassed Feb-SST/SLP difference（strong-weak tide）

18.6-year nodal cycle acts as a basic forcing for the bi-decadal ocean/climate

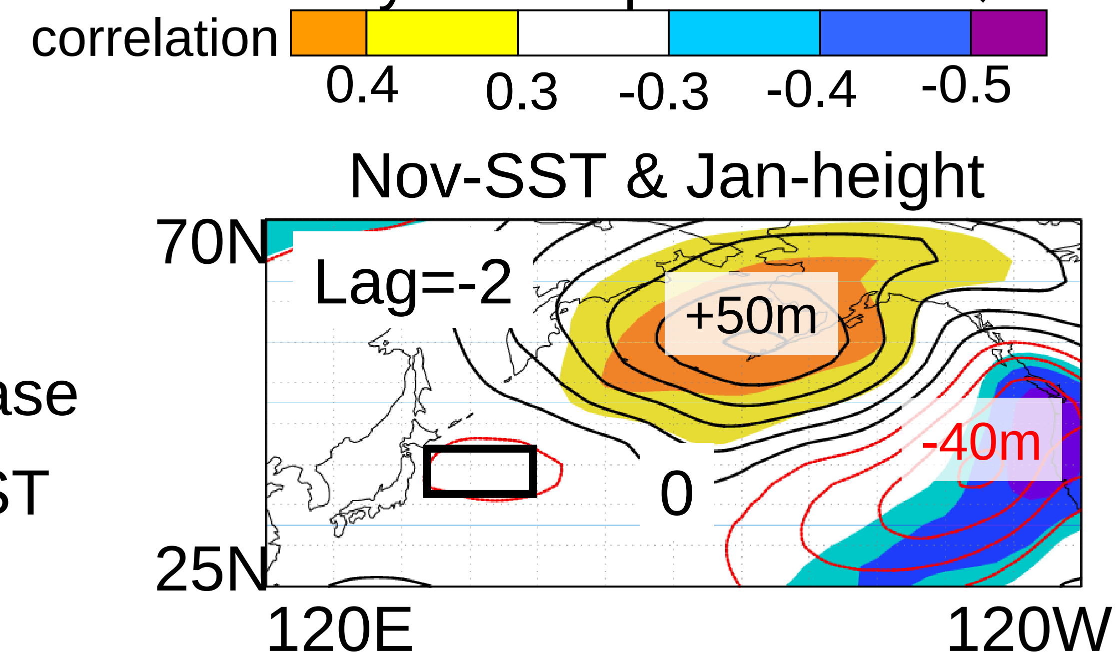
C5-stage Body length variations in *Neocalanus Cristatus & flemingeri* from Odate-collection (Dr. Sugisaki)





In the period of strong diurnal tide and greater Okhotsk Sea outflow, C5-body length is large. Possibly large Okhotsk Sea species Occupies in larger component.

Correlation between Nov-SST east of Japan and Jan-925hPa height anomaly
（Gotoh & H. Nakamura Univ. Tokyo 2005 pers. comm.）



Contours

Black

Height_925hPa increase

in m for the 1degC-SST

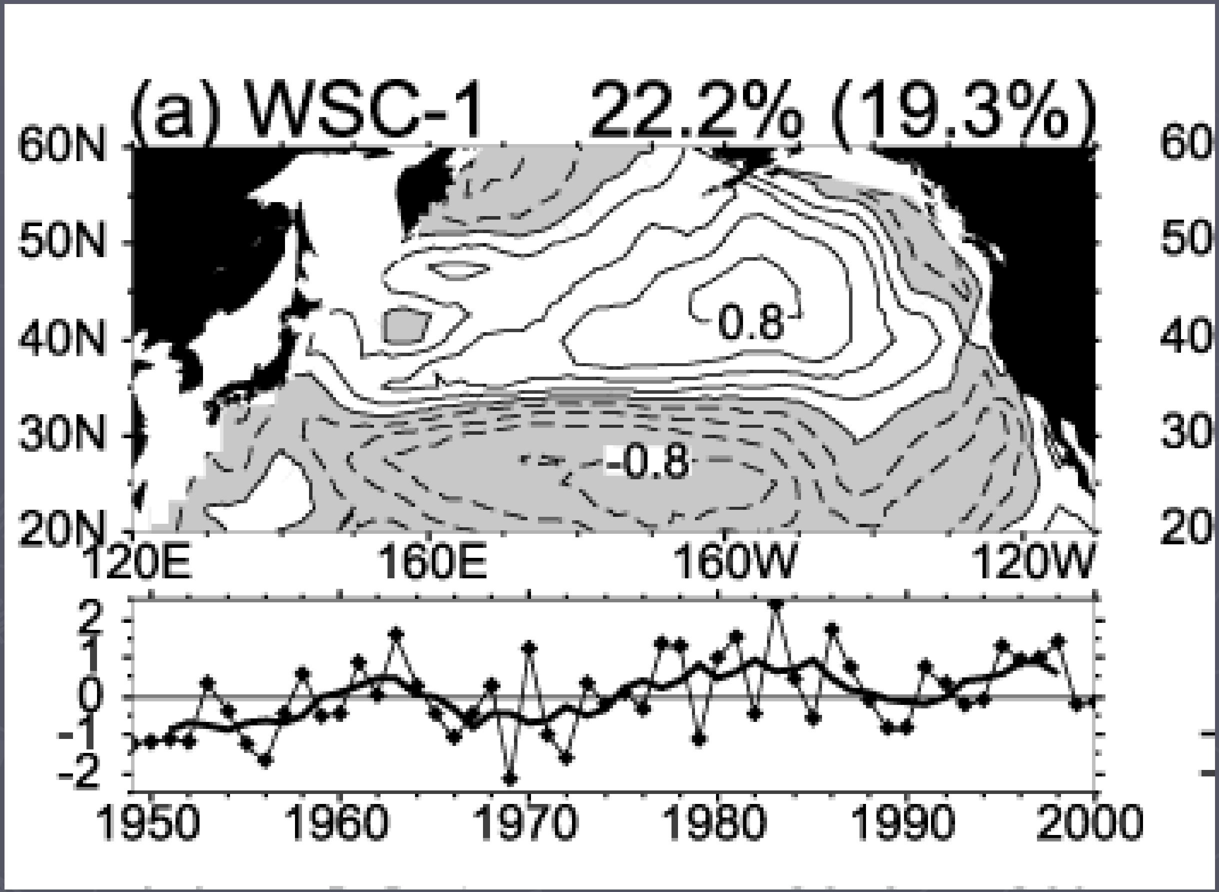
increase

red

Height_925hPa increase
in m for the 1degC-SST
increase

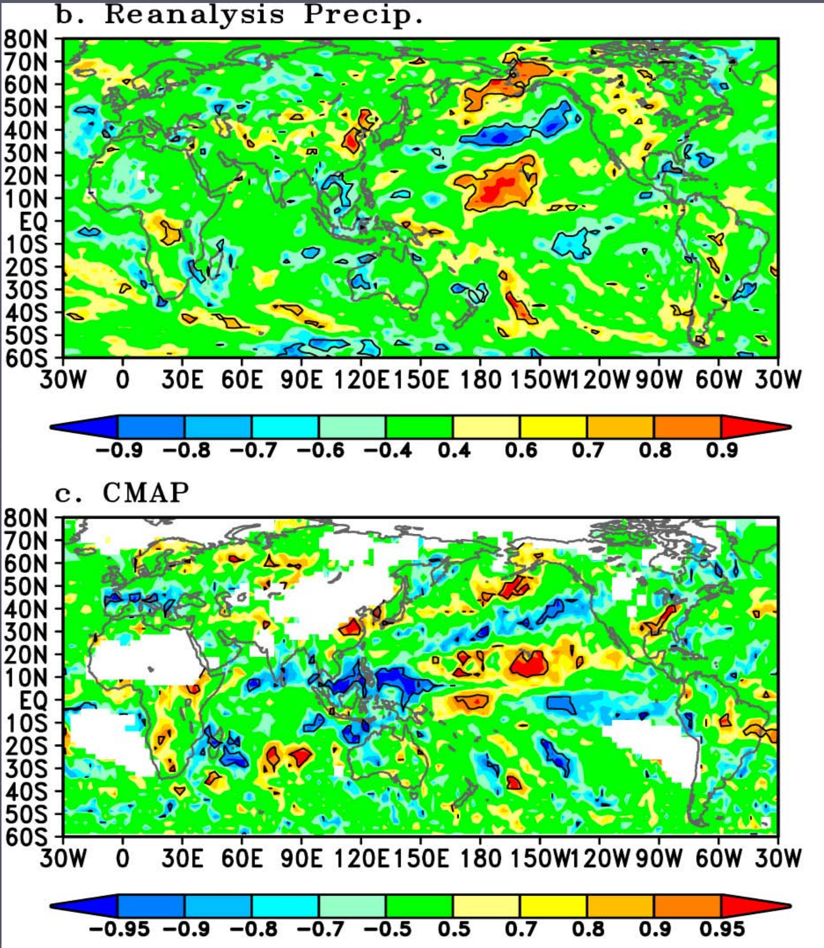
Warmer-SST east of Japan in Autumn corresponds to weaker Aleutian Low in winter. -→ weaker Aleutian Low further amplify the positive SST.
➔Suggest positive feedback as shown in air-sea coupled model (Latif & Barnnet 1996)

Wind-stress curl EOF-1 (Ishi & Hanawa 2005GRL)



In the period of strong diurnal tide, negative wind-stress curl anomaly suggests that the surface layer tends to be thicker. However, the surface layer is thin from observation, suggesting that the tidal mixing effect is Important.

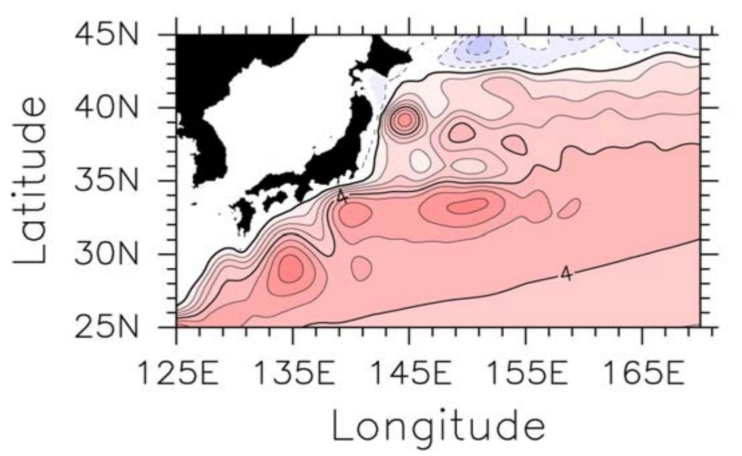
Correlation of precipitation with bi-decadal NPI



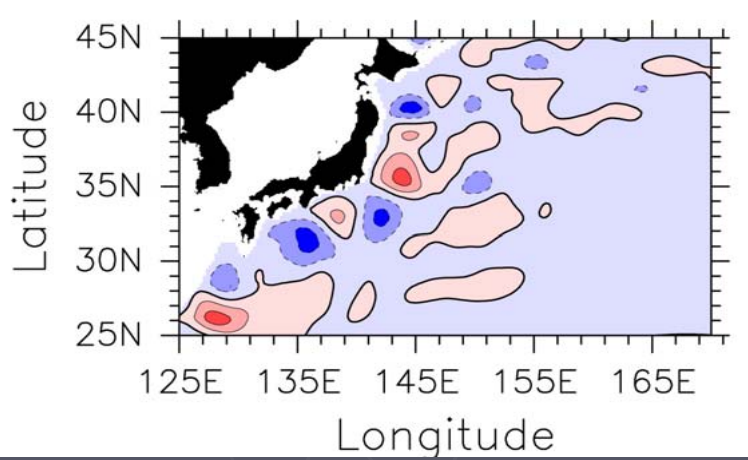
Minobe and Nakanowatari (2002)

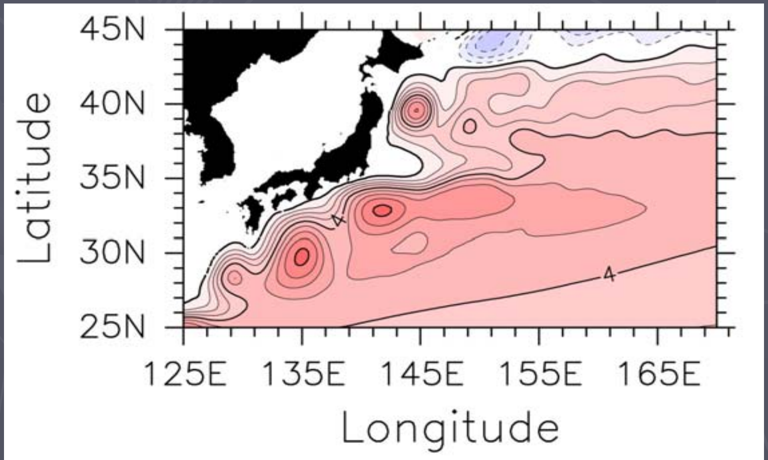
Upper-layer pressure field

Strong tide



Difference (S—W)

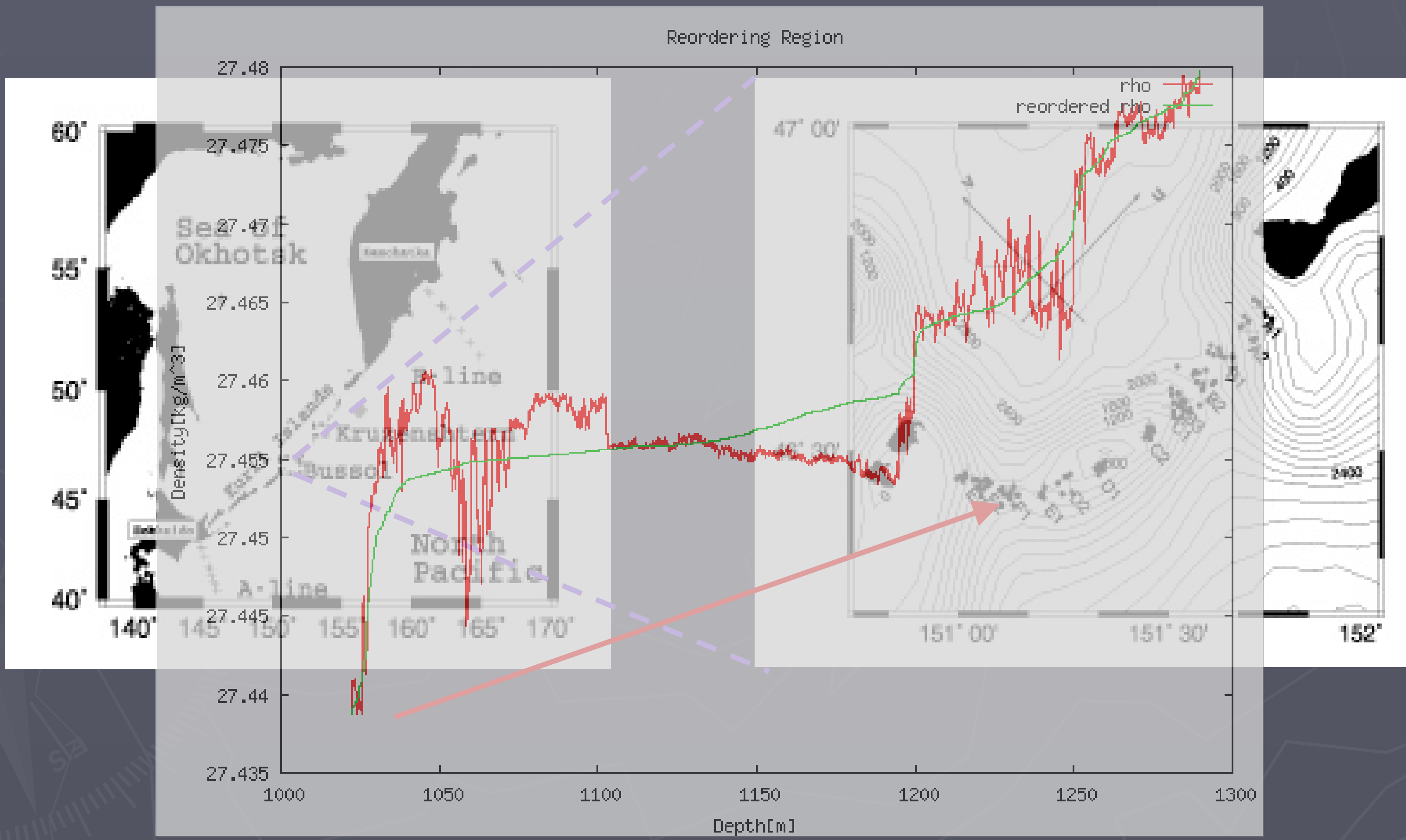




Weak tide

Difference of upper-layer velocity appears along the western boundary current in the Kuroshio, the Kuroshio Extension and the Oyashio.

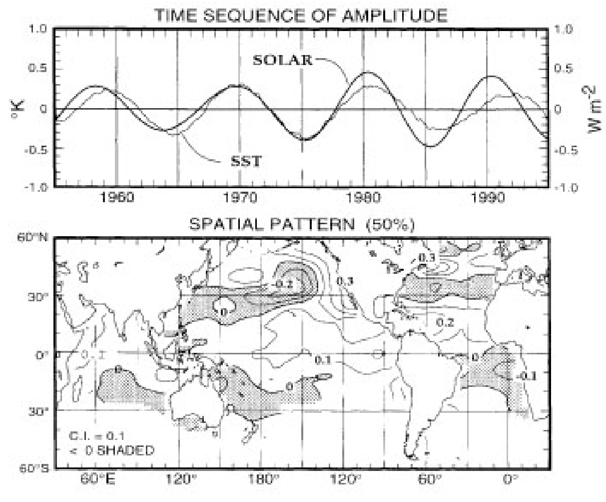
Large density inversions at Bussol' Strait (Khromov data from Ohshima)



Thorpe scale analysis suggests that this inversion brings about Diapycnal mixing coefficient is O($10^3 cm^2/s$)

PDO,IPDO vs Hale 11/22yrs cycle

3262 WHITE ET AL.: GLOBAL-AVERAGE TEMPERATURE RESPONSE



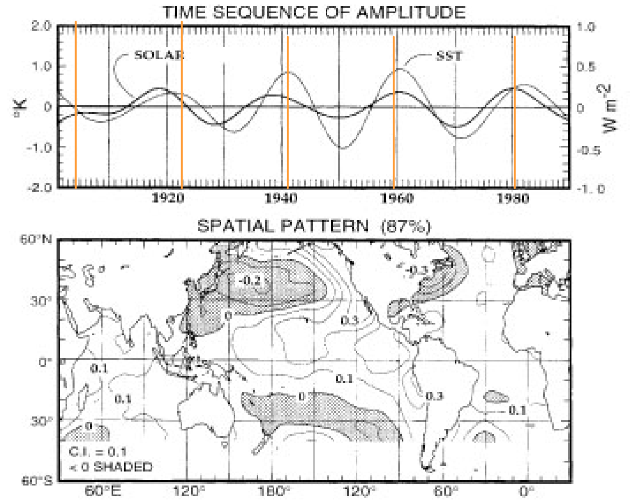
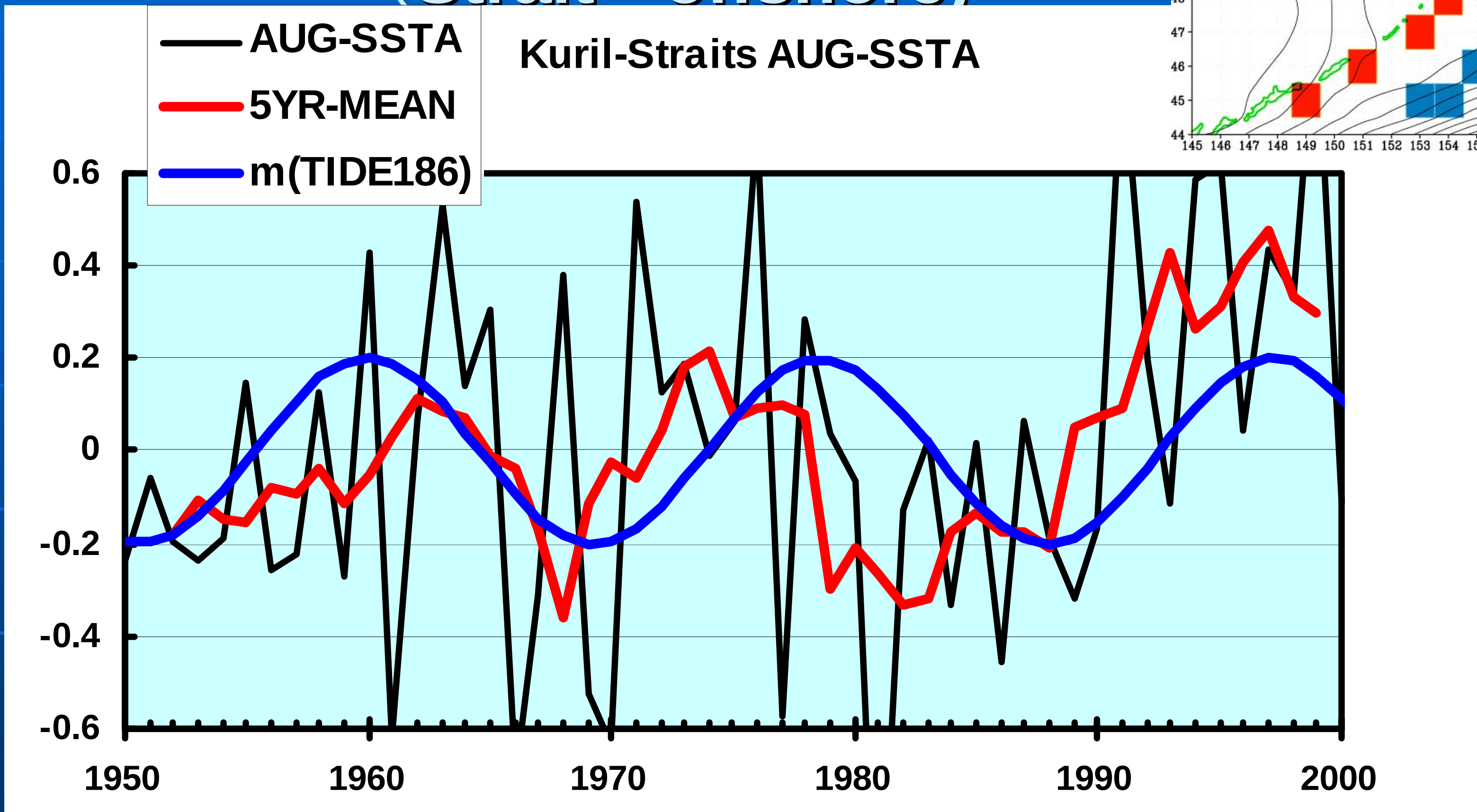
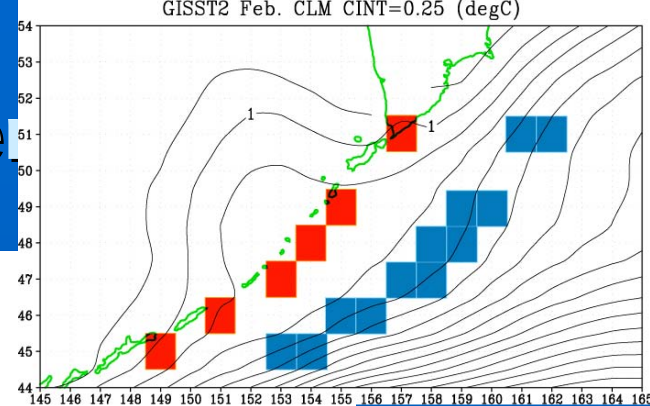


Figure 6. (top) Time sequence and spatial pattern of the first-mode empirical orthogonal function [*Preisendorfer*, 1988] applied to decadal BT sea surface temperature anomalies. This mode, together with its quadrature pair, explains 50% of decadal variance from 1955 to 1994. (bottom) Same as above, but for interdecadal GISST sea surface temperature anomalies, explaining 87% of interdecadal variance from 1901 to 1990. Superimposed on both time sequences are corresponding decadal and interdecadal anomalies of reconstructed solar irradiance anomalies at the top of the atmosphere. In each spatial pattern, negative weightings are shaded, and positive weightings are unshaded.

White et al. 1997 JGR(C2) 3255-3266

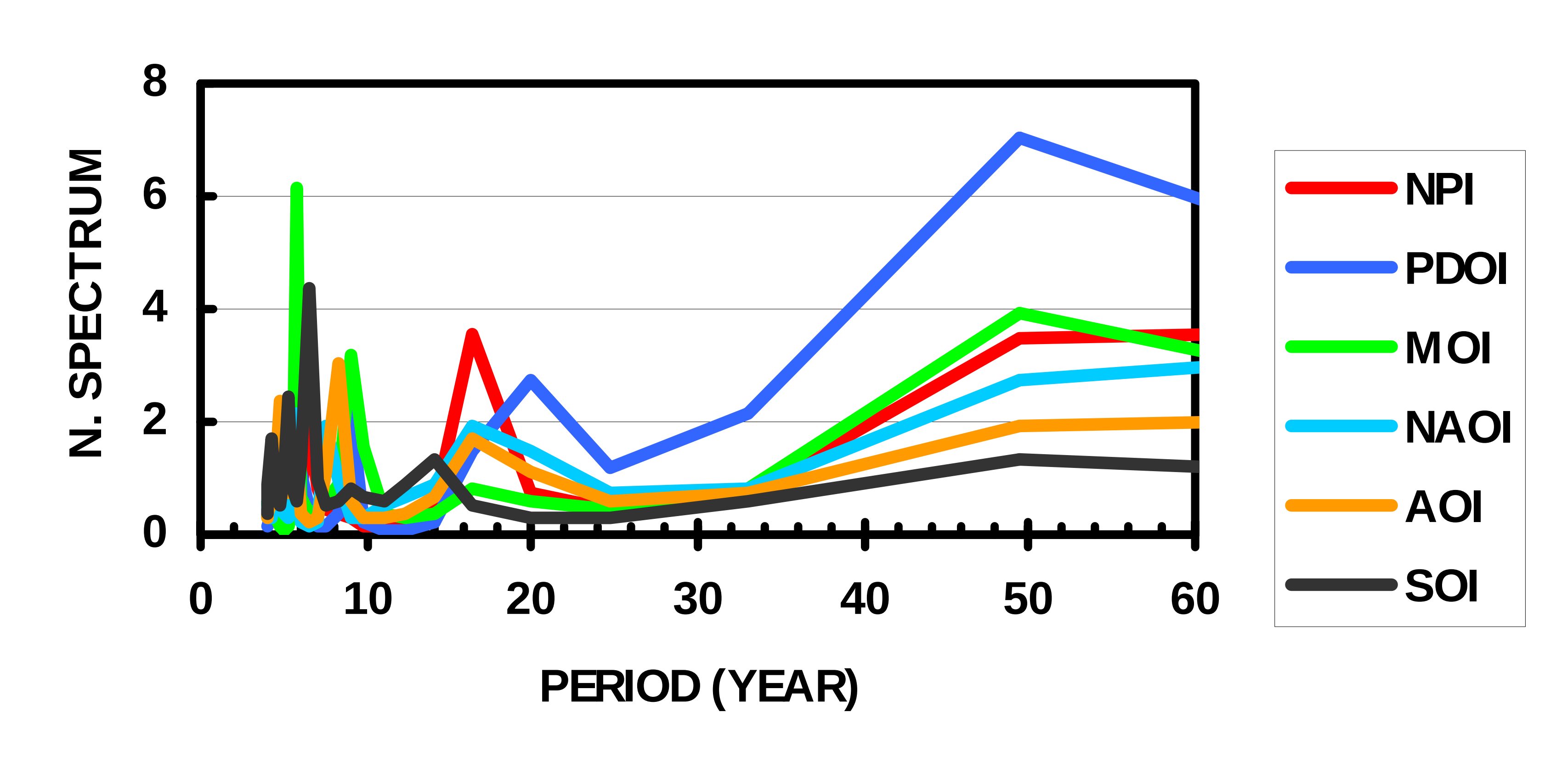
Aug-SST-anomaly differ
(Strait—offshore)





In the period of stronger diurnal tide, Aug-SST difference is lower. This is because subsurface temperature is colder than in surface in the subarctic North Pacific and this cold water is entrained into surface layer due to stronger tidal mixing.

MEM spectrum in climate indices in the 20th century



Peak at around 16-20-year period and troughs at 12 and 24-yr in JFM-NPI, -PDOI, -MOI, NAOI, -AOI
Peak at 14-year period in SOI.

Isopycnal depth at 26.7 and Thickness (26.7-27.2) variations in Oyashio