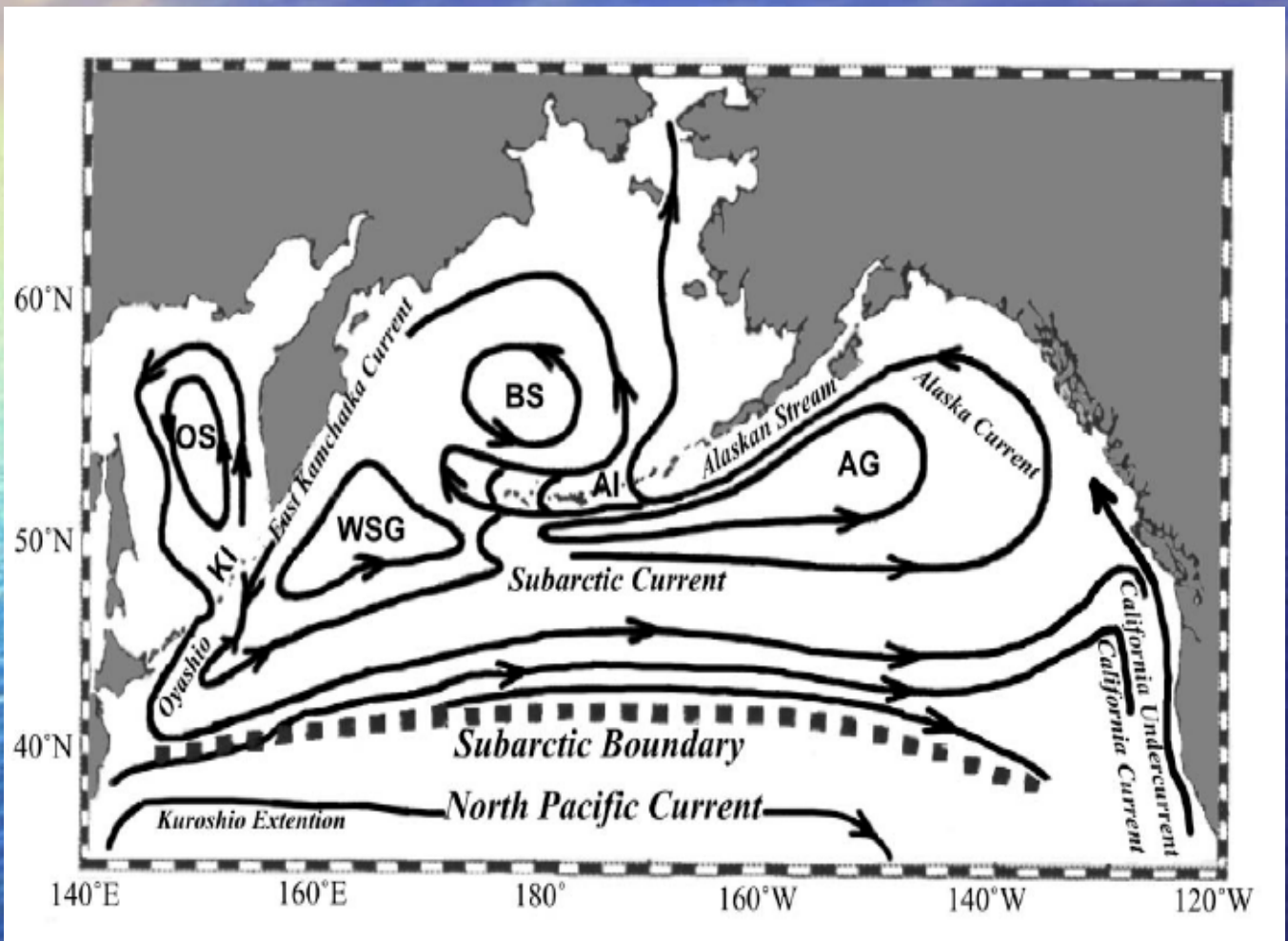
- **Impacts of the tides and atmospheric forcing variability on dissolved oxygen and salinity in the subarctic North Pacific**

- *Andreev A.G., V.I. Baturina*

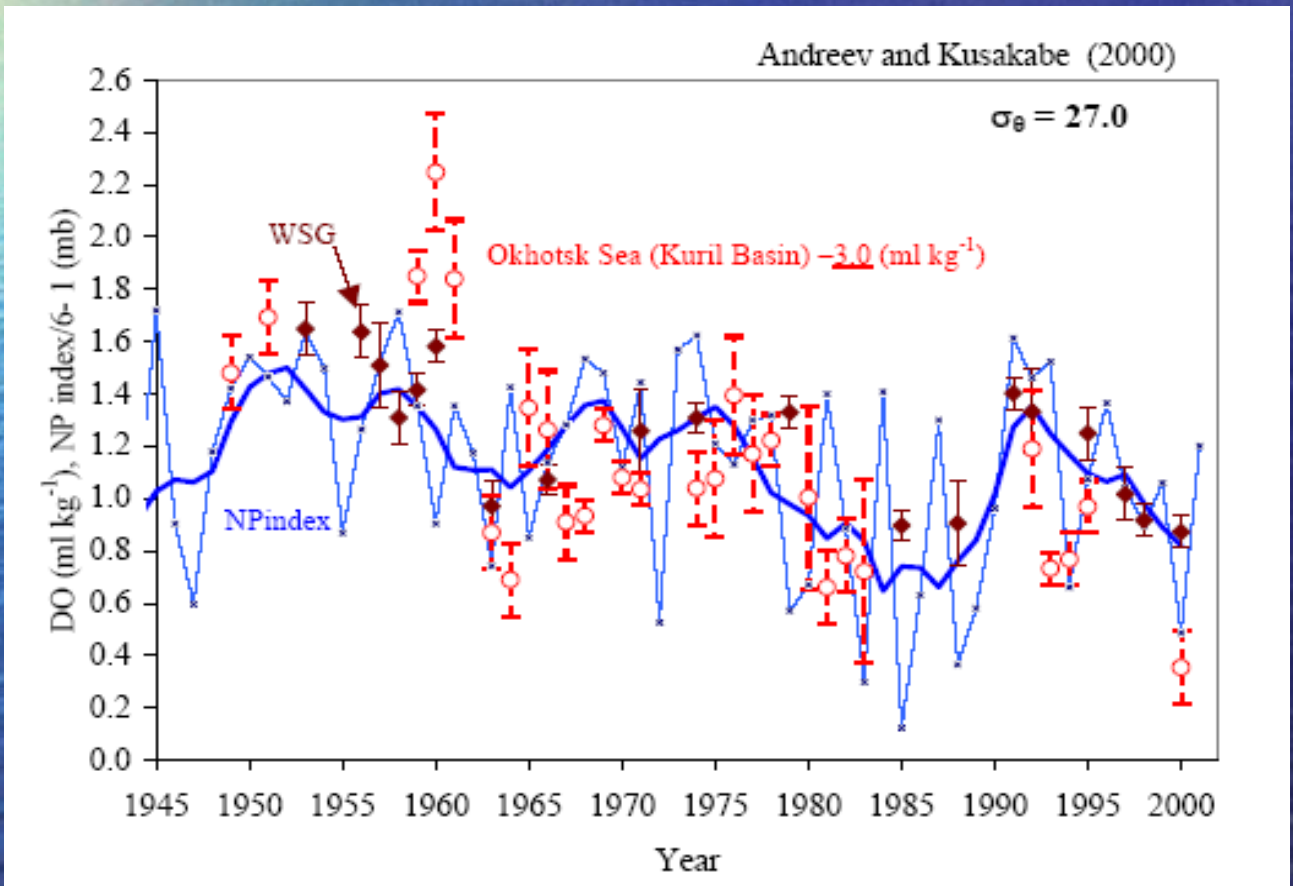
Abstracts

The impacts of the variation in the wind forcing and 18.6-year tide (K1) cycle on the concentration of the dissolved oxygen (DO) in the intermediate waters of the western and eastern parts of the subarctic North Pacific were analyzed. Our results demonstrate that the interannual changes of DO on isopycnal in the intermediate waters and the surface salinity in the western subarctic Pacific can be described very accurately by a linear combination of the intensity of the Aleutian Low pressure system (NPI index) and zonal momentum flux (45-52°N, 165°E-170°W) in winter, and an annually averaged cubic of tidal amplitude for the central Aleutian and northern Kuril regions. The residual signal shows a good correlation with the temporal variations of DO in the Alaskan Gyre.

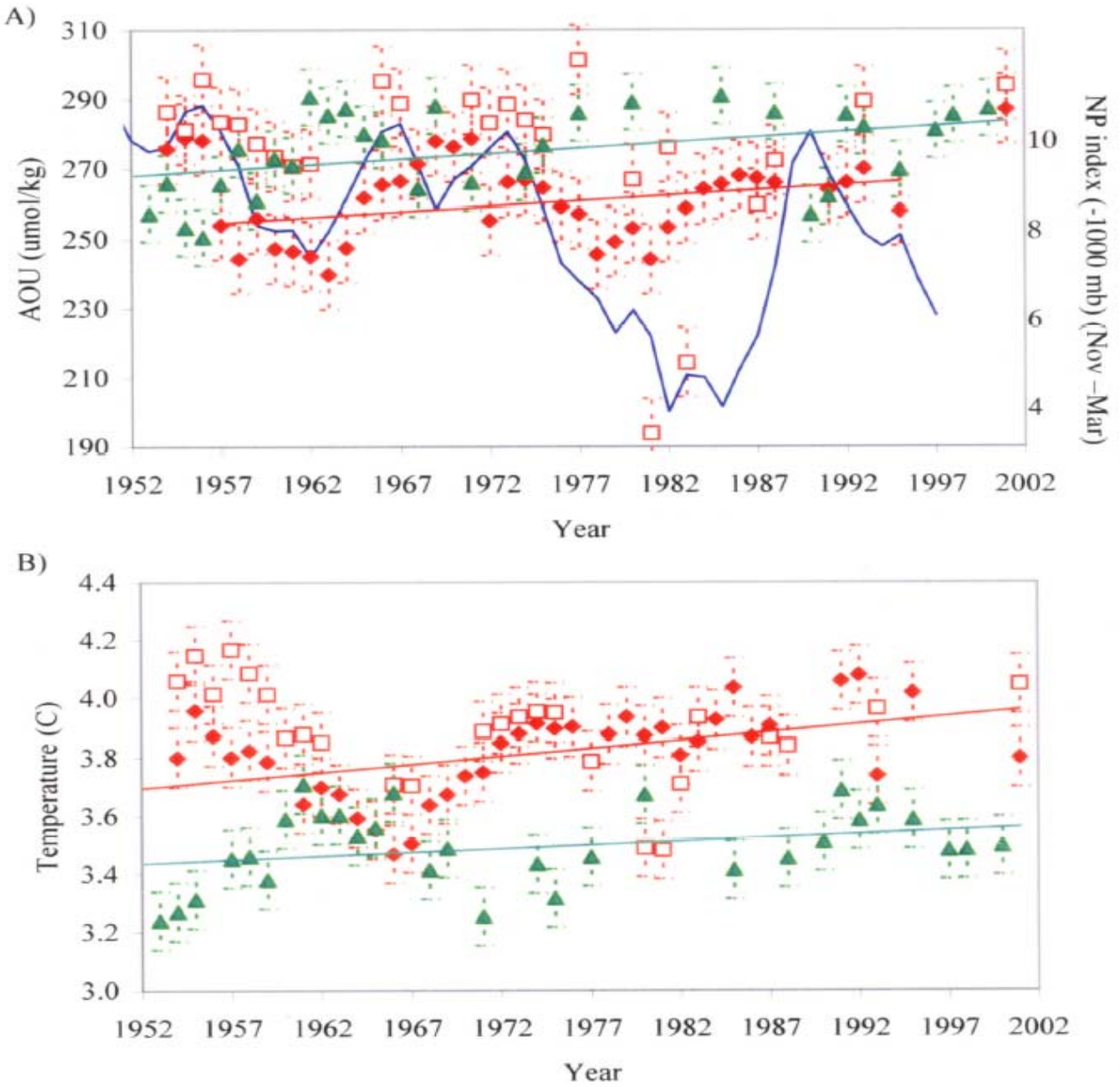
Schematic representation of the current and frontal system in the northern North Pacific (adapted from Favorite et al. [1976] and Ohtani [2001]).



Temporal variations in DO (μmol/kg) in the western (48-60°N, 160–170°E) subarctic Pacific and Okhotsk Sea at σθ = 27.0. DO data were grouped by year and then for each group an average and its 95% confidence intervals (error bars) were computed. The blue line [AB1]shows the temporal variation in the North Pacific index, smoothed with a 5-year running mean.



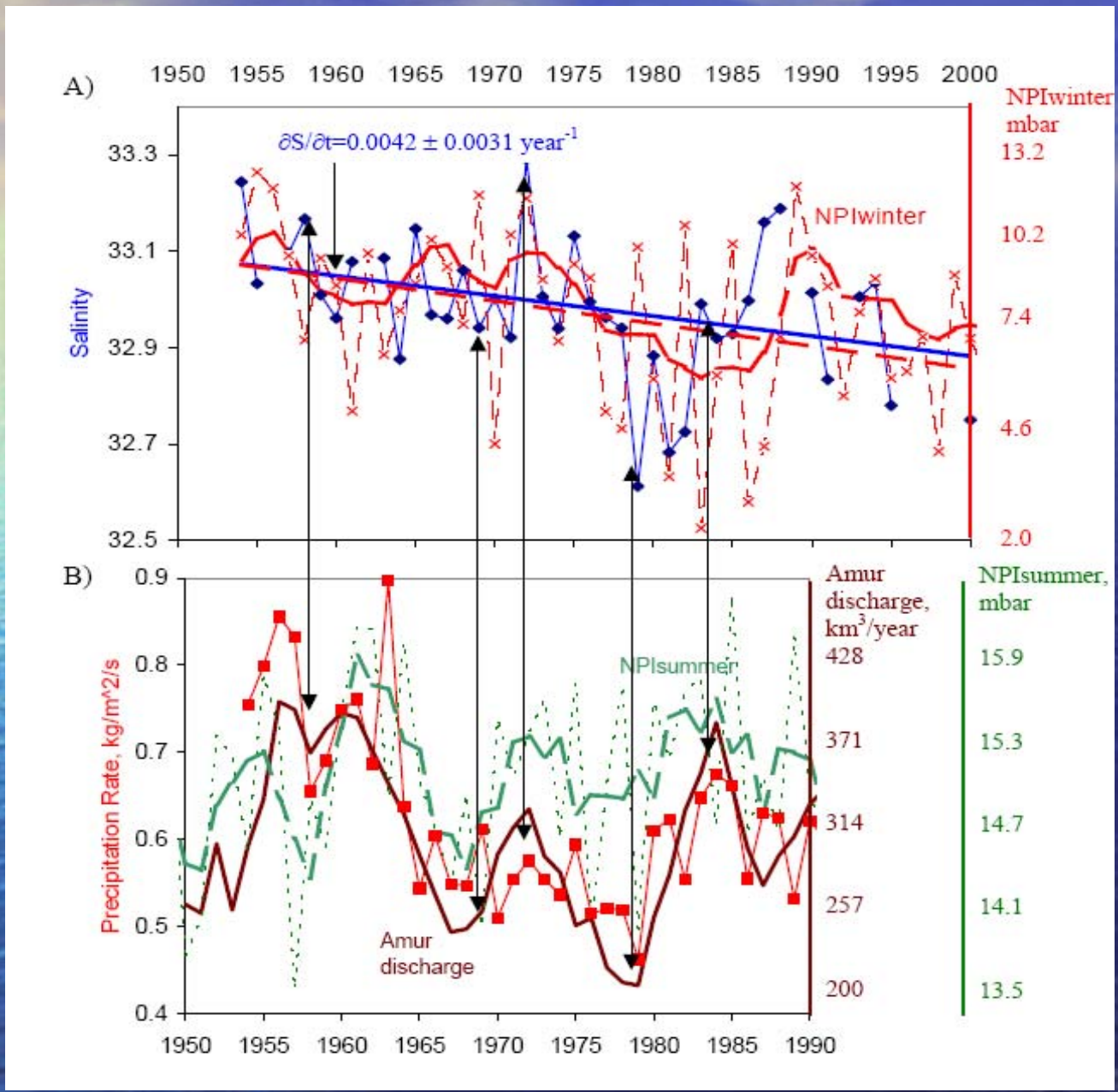
Andreev and Watanabe, 2002



▲ - Western Subarctic Gyre ,

◆ - Alaskan Gyre

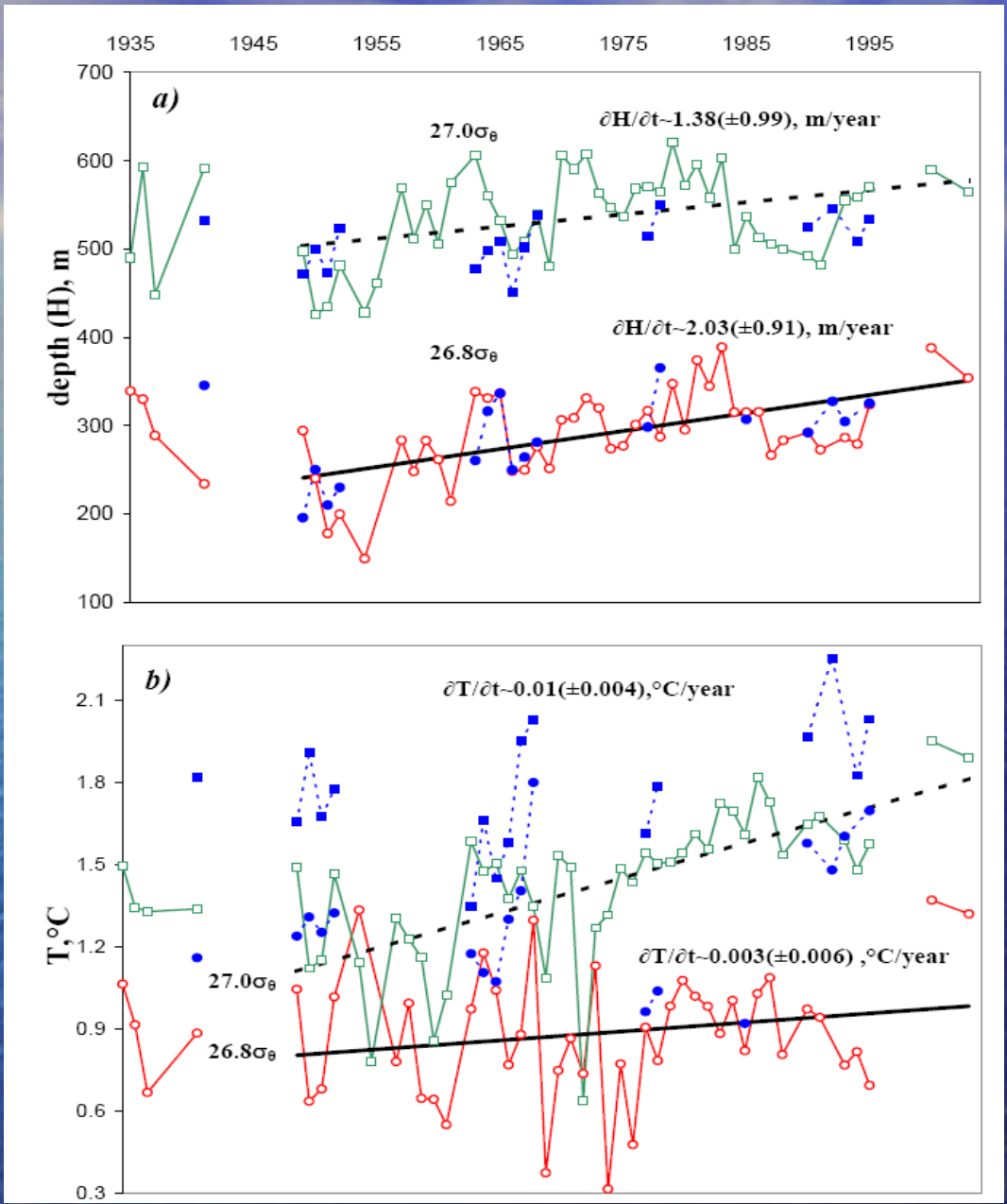
Kuril Basin of the Okhotsk Sea (Andreev and Baturina, 2005)



A. Temporal variations of surface (40 –60 m) salinity in the southern Okhotsk Sea, and the NP index in winter (December – March). Red solid line is the NP temporal variations, smoothed with a three – year running mean.

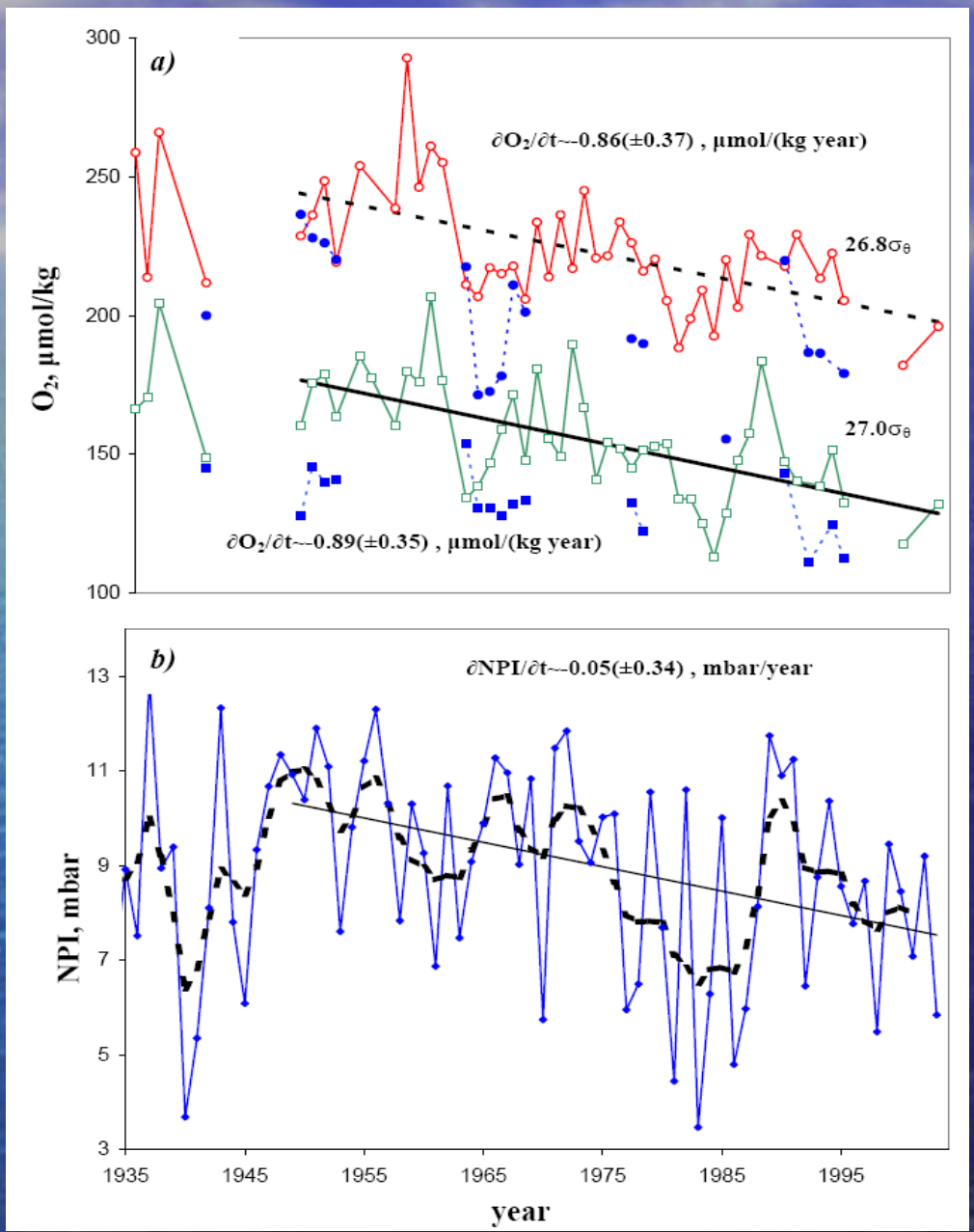
B. Temporal variations of the Amur River discharge, May- October Precipitation Rate (45-55 °N, 120- 135 °E), and the NP index in summer (May- October). Green solid line is the NP temporal variations, smoothed with a three – year running mean.

Kuril Basin of the Okhotsk Sea
(Andreev and Baturina, 2005)

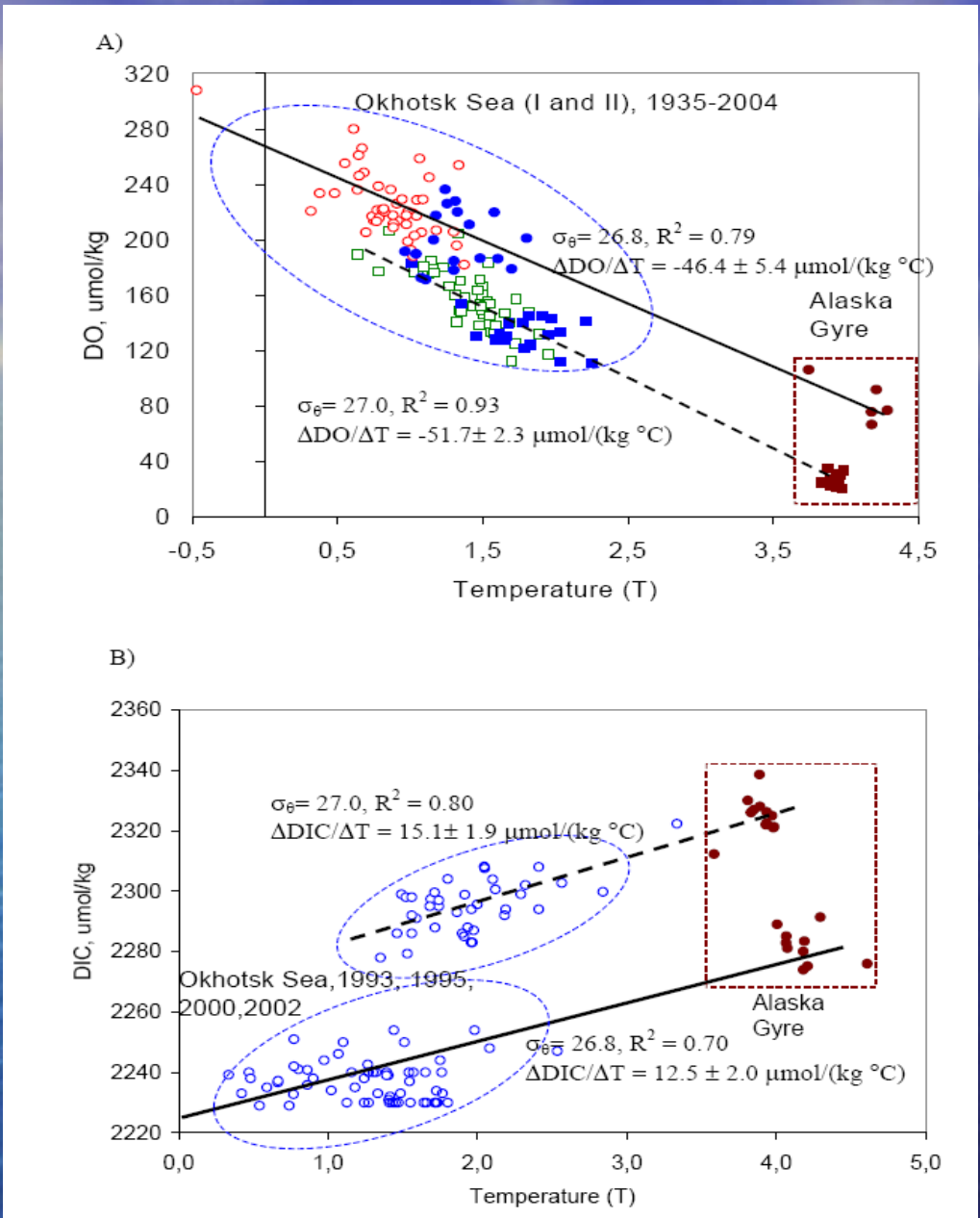


Temporal variations of the depth of isopycnal of 26.8σθ and 27.0σθ (a) and temperature (b) at 26.8σθ and 27.0σθ in the southern and central parts of the Okhotsk Sea.

Kuril Basin of the Okhotsk Sea
(Andreev and Baturina, 2005)

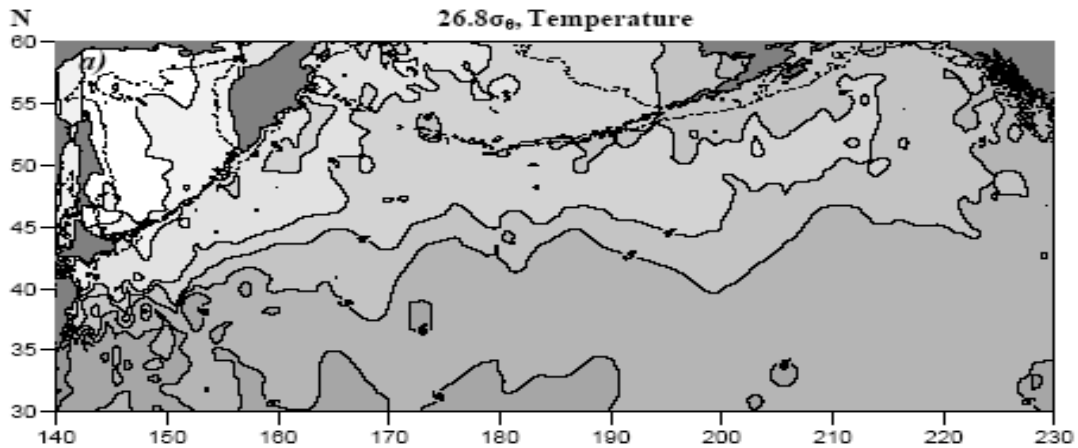


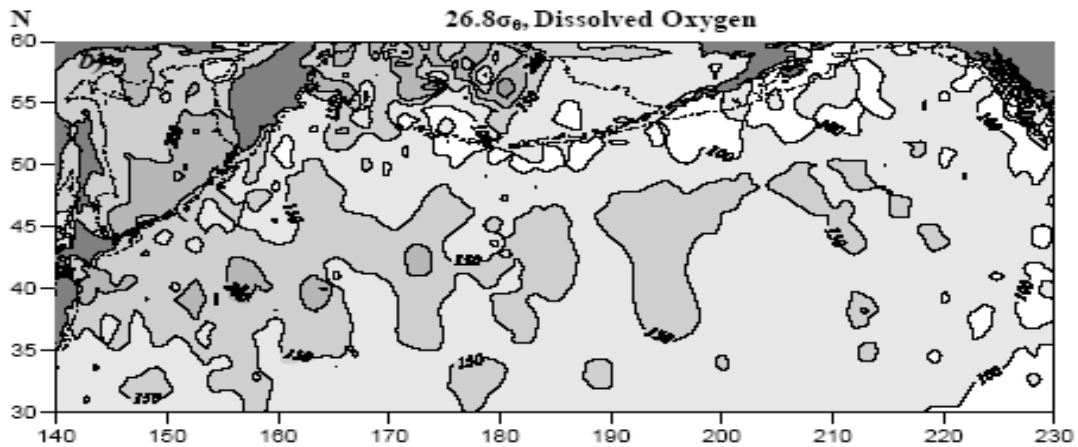
Temporal variations of the dissolved oxygen at 26.8σθ and 27.0σθ in the southern and central parts of the Okhotsk Sea (a), and the NPI in winter (b).

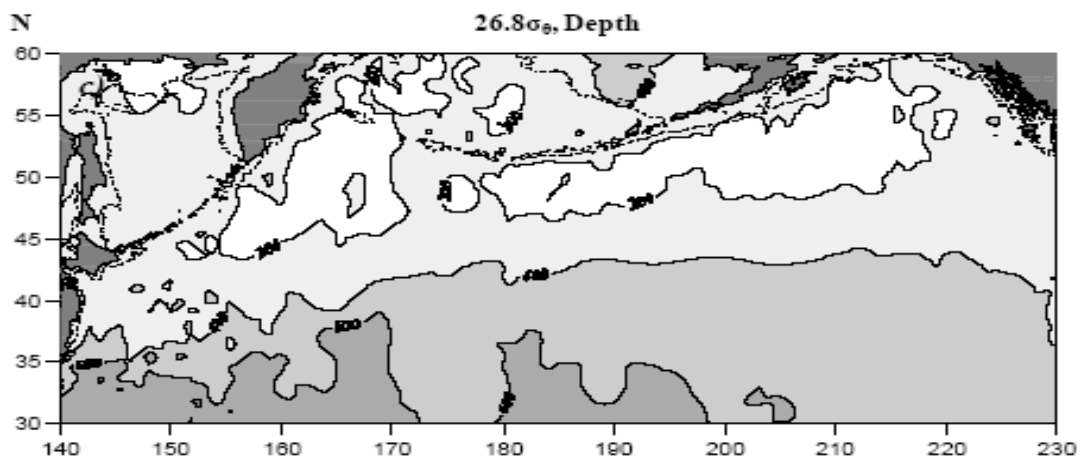


Dissolved oxygen (A) and dissolved inorganic carbon (B) versus temperature at σθ= 26.8 and σθ= 27.0.

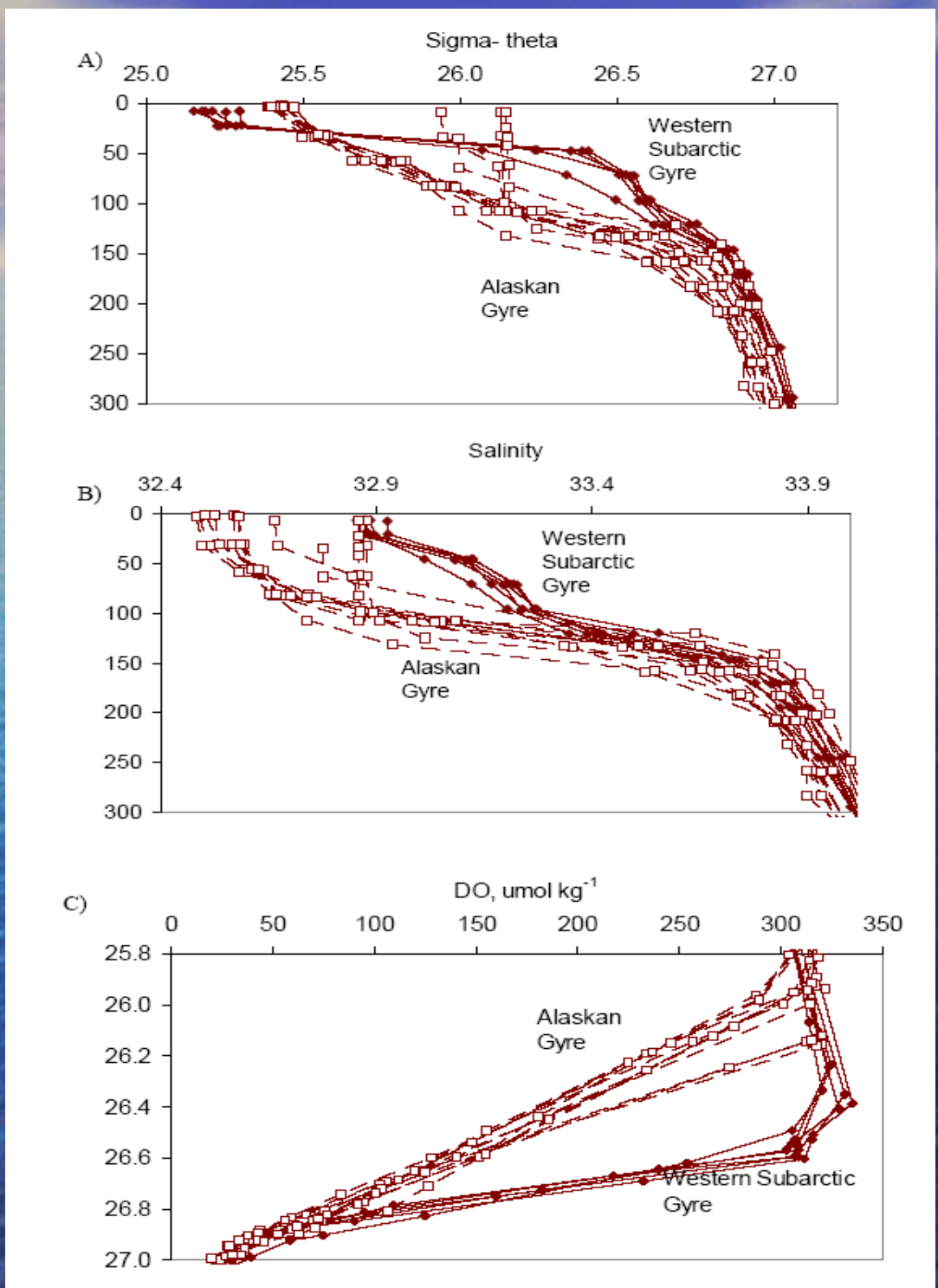
Composite maps of temperature and dissolved oxygen (umol/kg) distribution at 26.8 sigma- theta isopycnal surface, and the depth of 26.8 sigma- theta in the northern North Pacific in 1960- 1990.

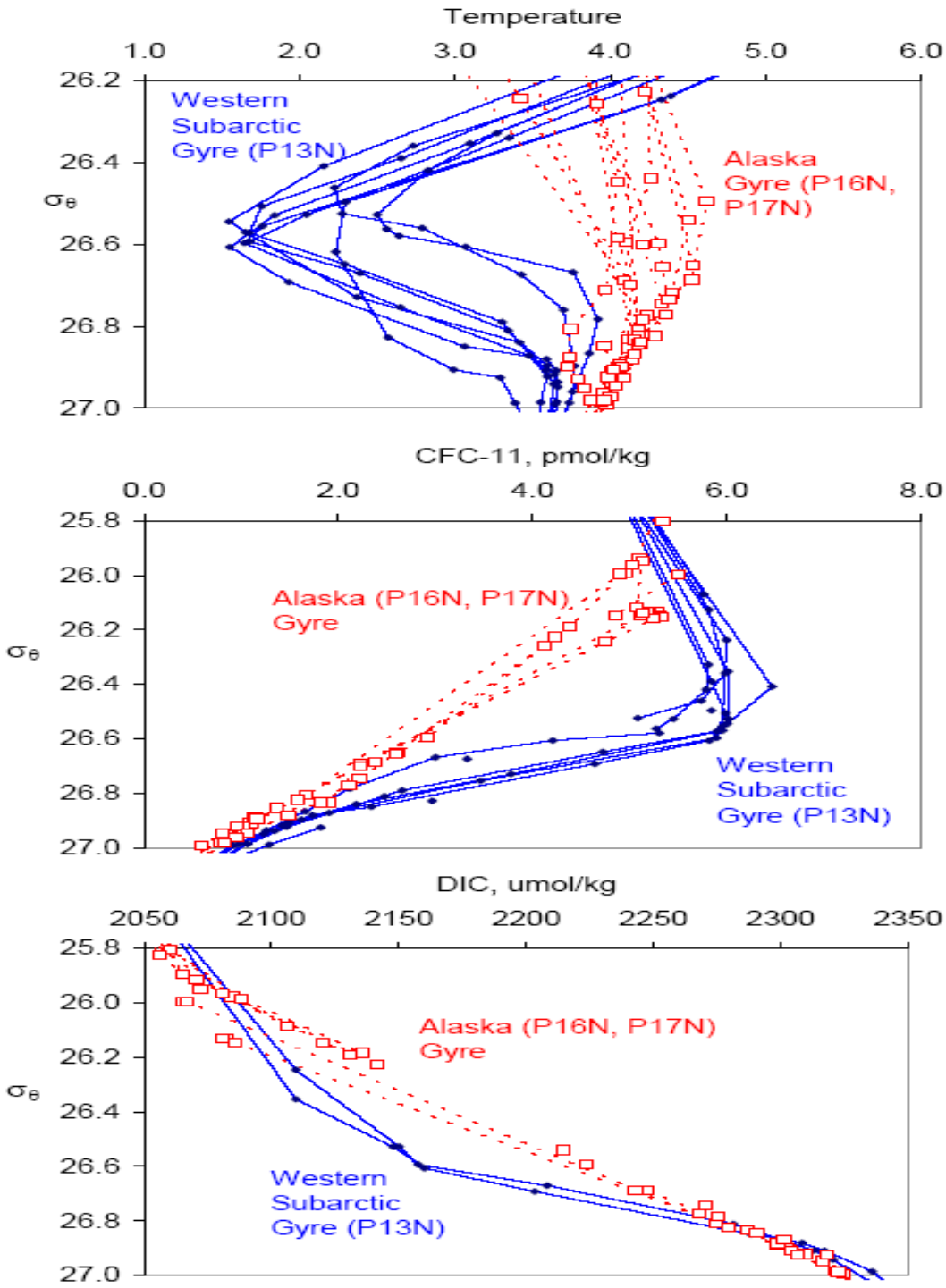


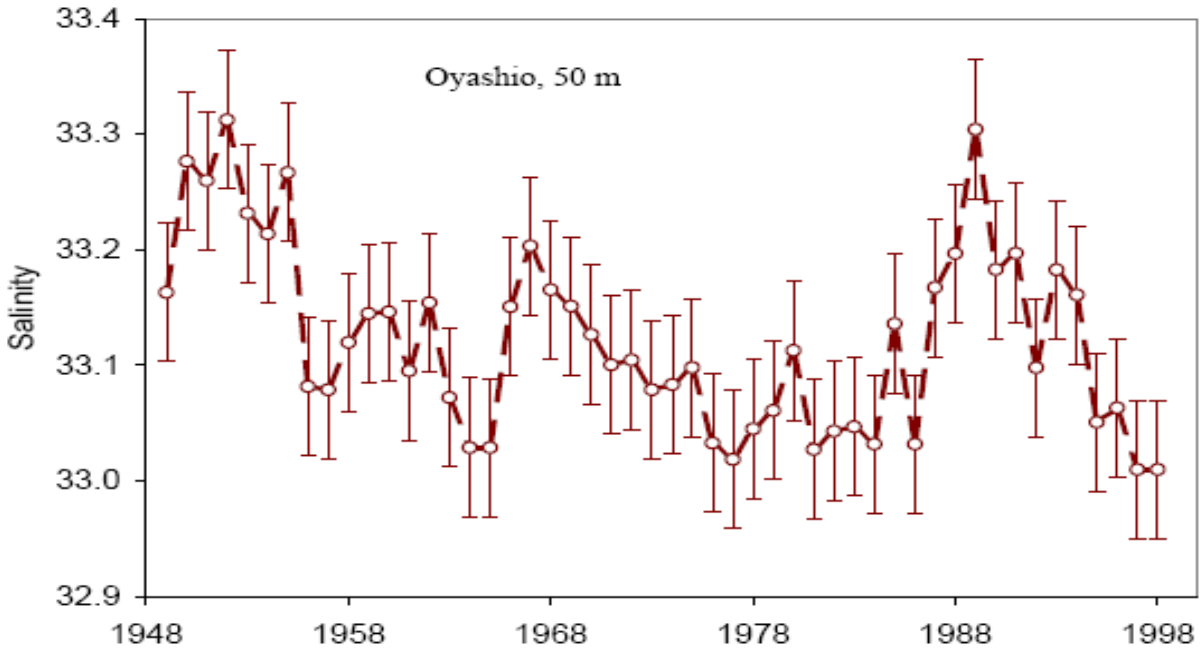


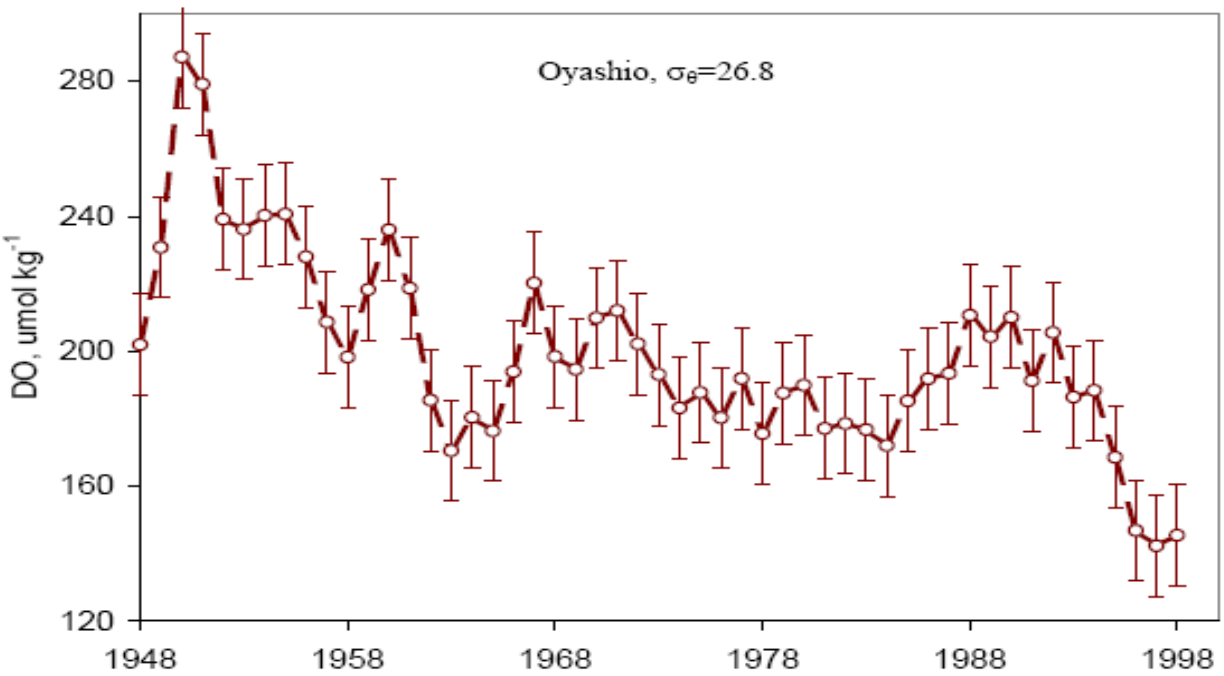


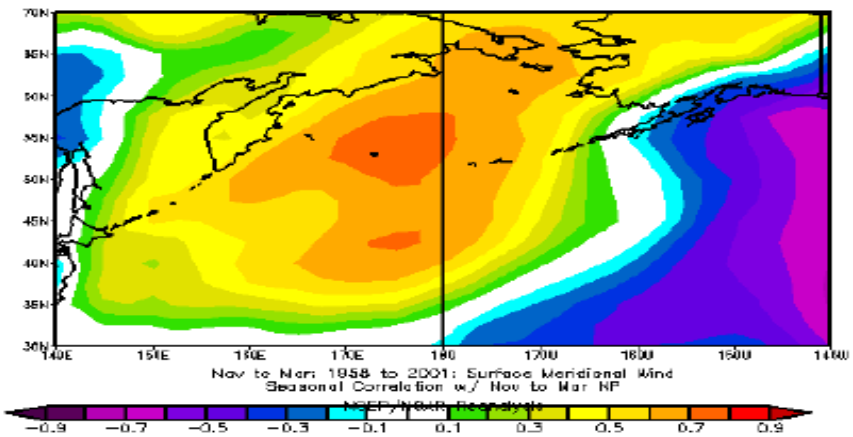
Vertical profiles of the potential density (A) and salinity (B), and dissolved oxygen versus potential density in the Alaska Gyre (WOCE data, P16N and P17N) and Western Subarctic Gyre (WOCE data, P13N).



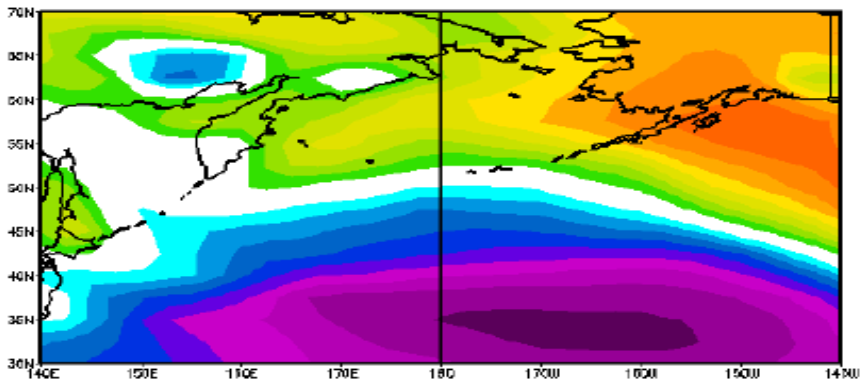

Temperature
1.0
2.0
3.0
4.0
5.0
6.0
26.2
26.4
26.6
26.8
27.0
σθ
Western
Subarctic
Gyre (P13N)
Alaska
Gyre (P16N,
P17N)
CFC-11, pmol/kg
0.0
2.0
4.0
6.0
8.0
25.8
26.0
26.2
26.4
26.6
26.8
27.0
σθ
Alaska (P16N, P17N)
Gyre
Western
Subarctic
Gyre (P13N)
DIC, umol/kg
2050
2100
2150
2200
2250
2300
2350
25.8
26.0
26.2
26.4
26.6
26.8
27.0
σθ
Alaska (P16N, P17N)
Gyre
Western
Subarctic
Gyre (P13N)


Oyashio, 50 m
Salinity
33.4
33.3
33.2
33.1
33.0
32.9
1948
1958
1968
1978
1988
1998

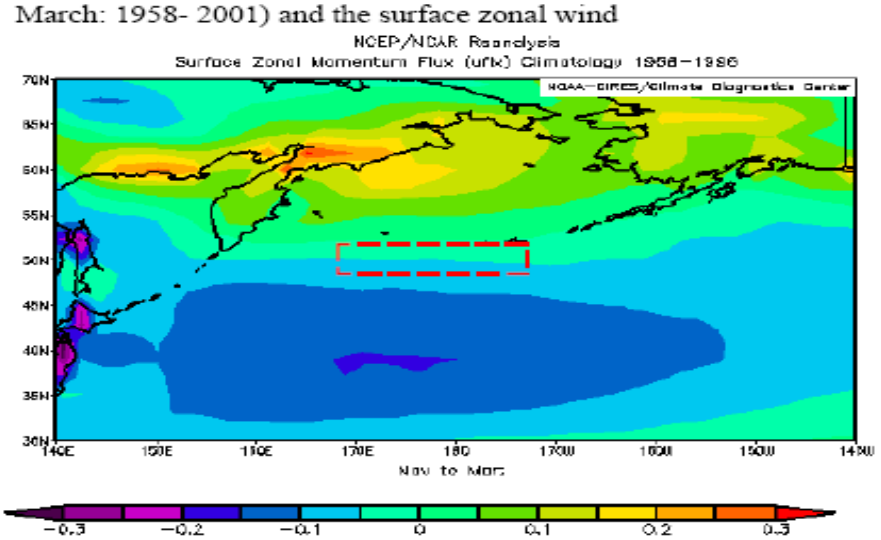

Oyashio, σθ=26.8
DO, umol kg-1
280
240
200
160
120
1948
1958
1968
1978
1988
1998



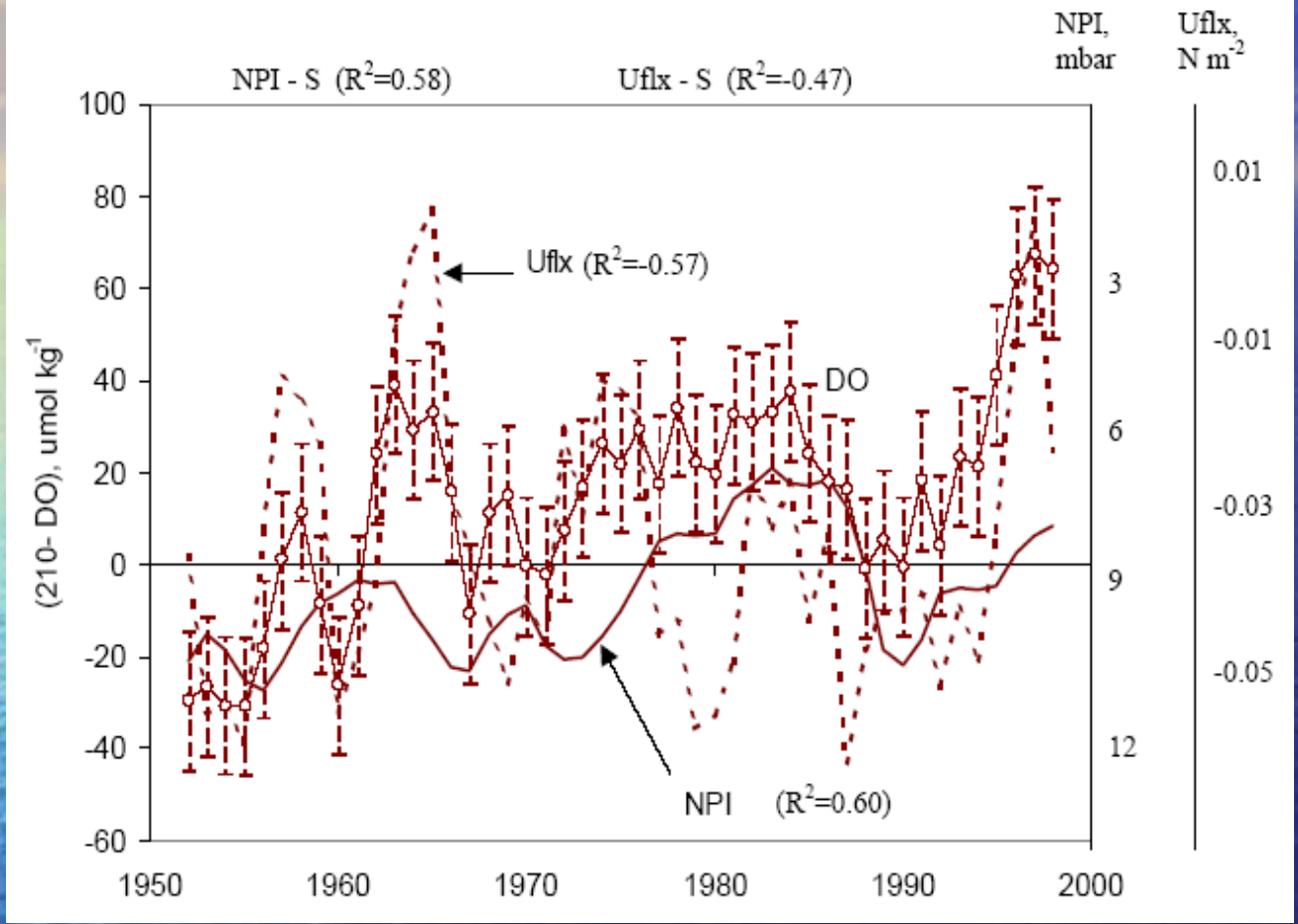
The correlation between the North Pacific Index (November to March: 1958- 2001) and the surface meridional wind



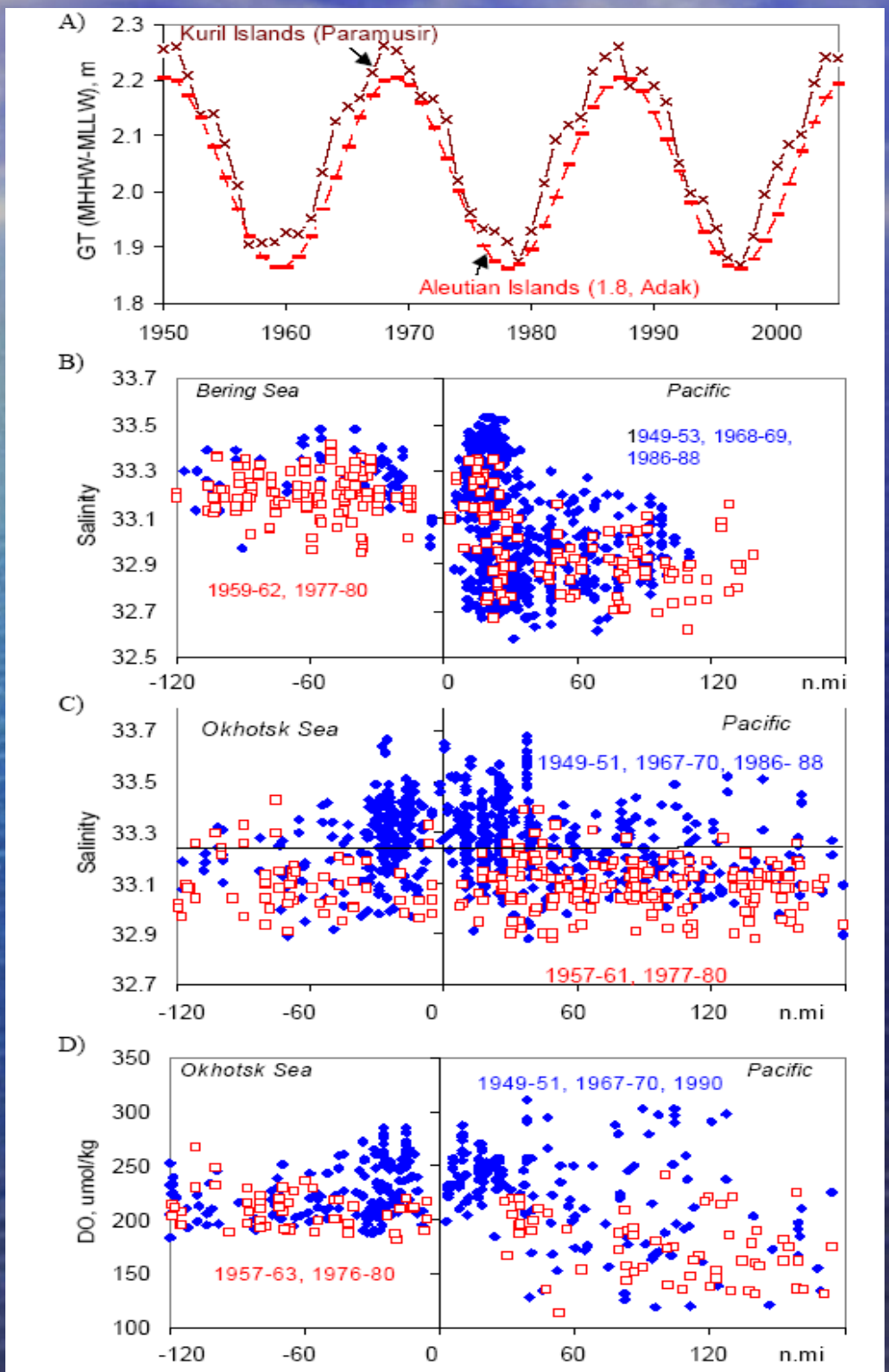
The correlation between the North Pacific Index (November to March: 1958- 2001) and the surface zonal wind

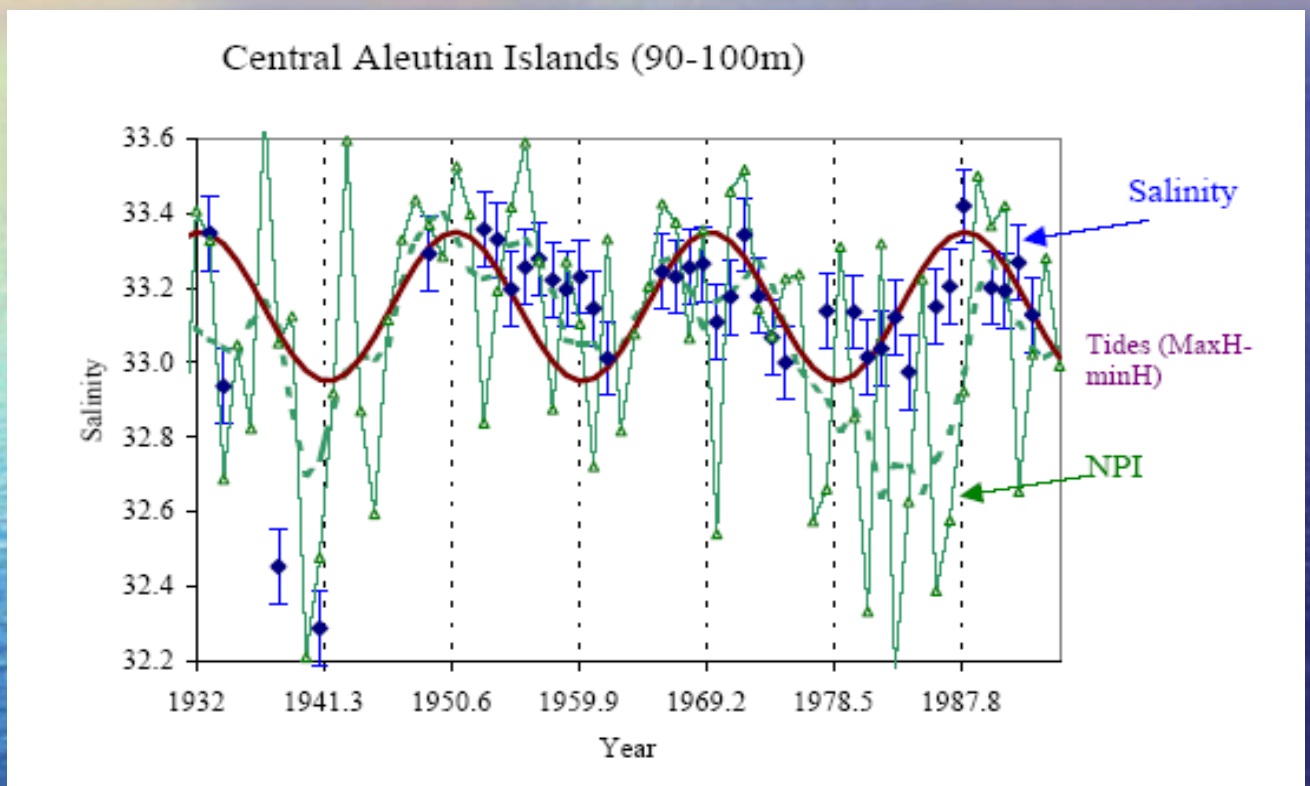


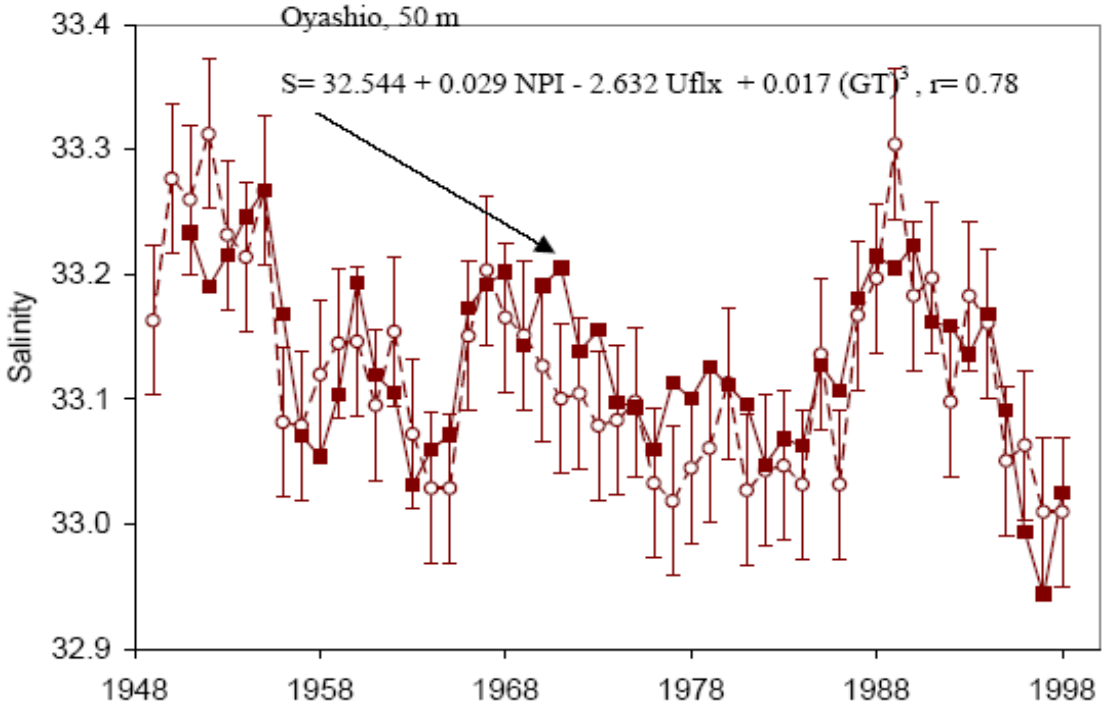
The surface zonal momentum flux composite mean (November to March: 1958- 2001)

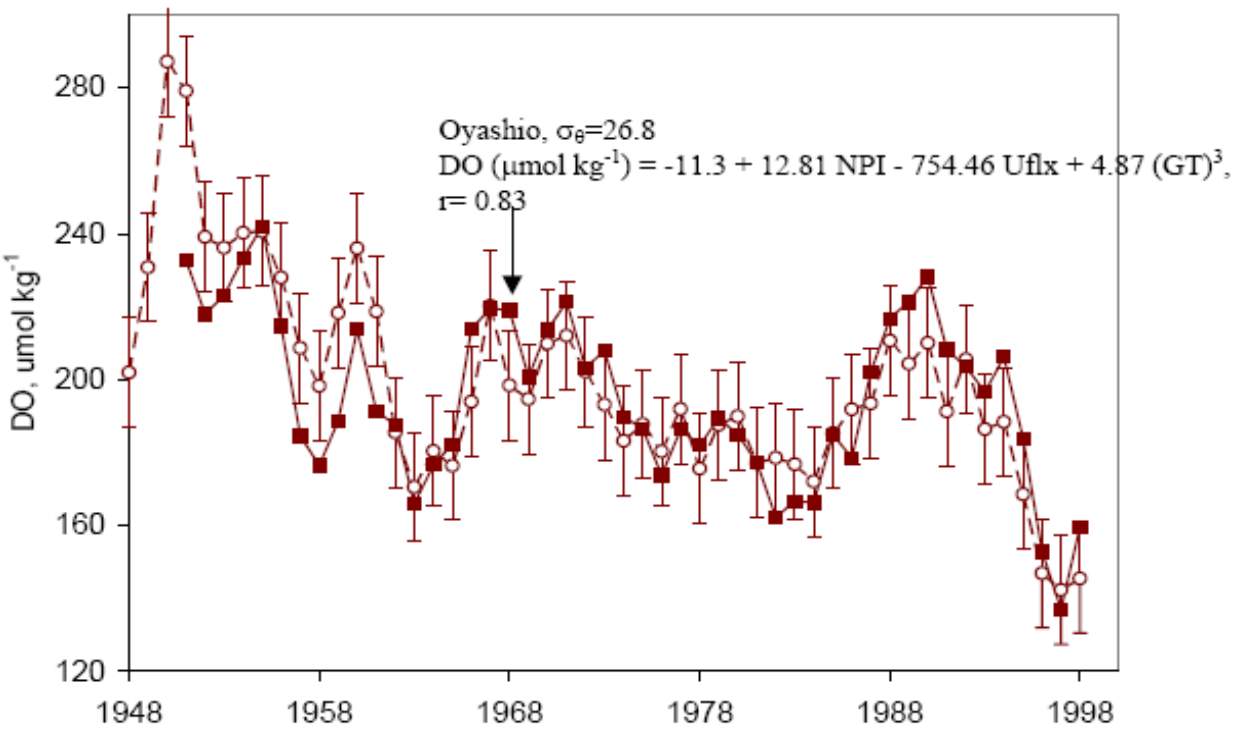

NPI - S (R2=0.58)
Uflx - S (R2=-0.47)
NPI, mbar
Uflx, N m-2
(210- DO), umol kg-1
Uflx (R2=-0.57)
DO
NPI (R2=0.60)
100
80
60
40
20
0
-20
-40
-60
3
6
9
12
0.01
-0.01
-0.03
-0.05
1950
1960
1970
1980
1990
2000

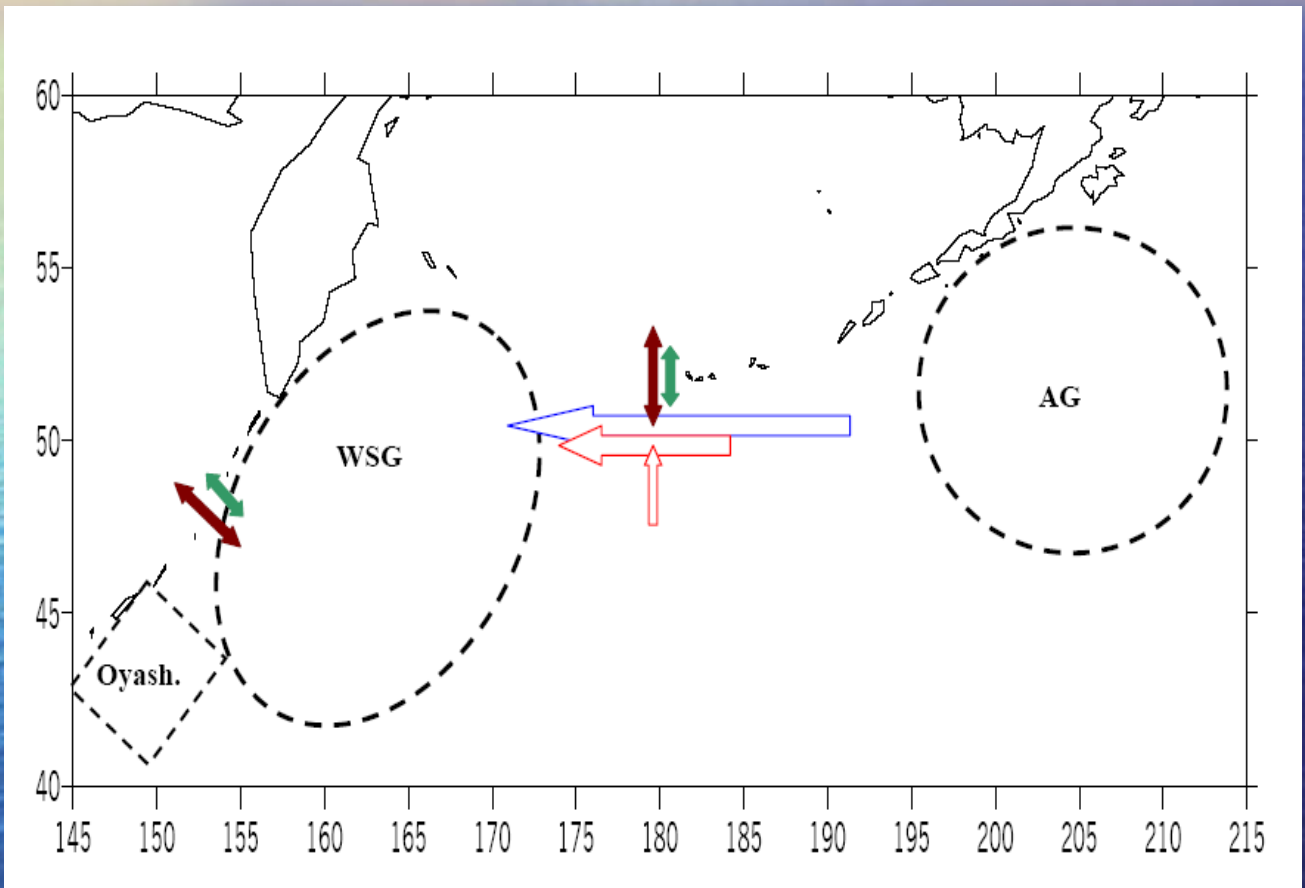
Temporal variation of the annually averaged difference (GT) between the Mean Higher- High Water and the Lower- Low Water in the Adak and Paramusir Islands (A) and the distributions of the surface (50m) salinity and dissolved oxygen at σθ=26.8 at the transections across the Aleutian (B) and Kuril Straits (C, D).

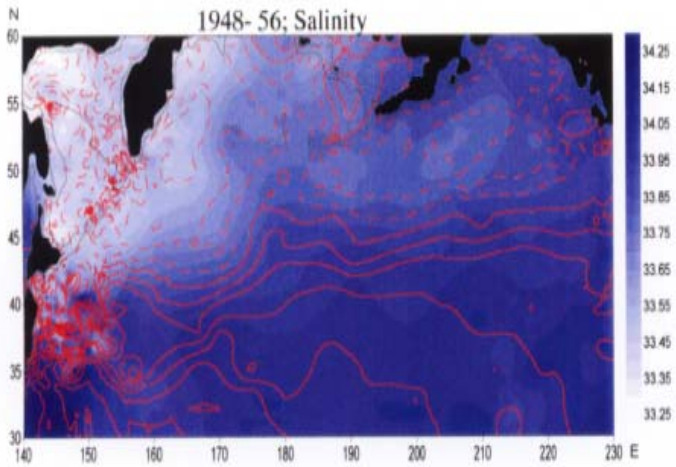


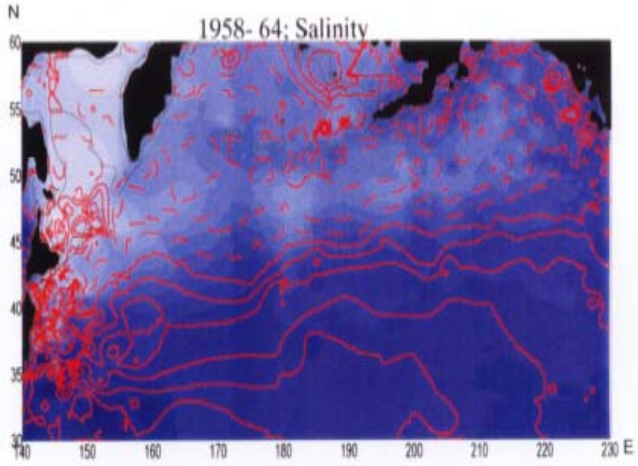

Central Aleutian Islands (90-100m)
Salinity
33.6
33.4
33.2
33.0
32.8
32.6
32.4
32.2
1932
1941.3
1950.6
1959.9
1969.2
1978.5
1987.8
Year
Salinity
Tides (MaxH-minH)
NPI

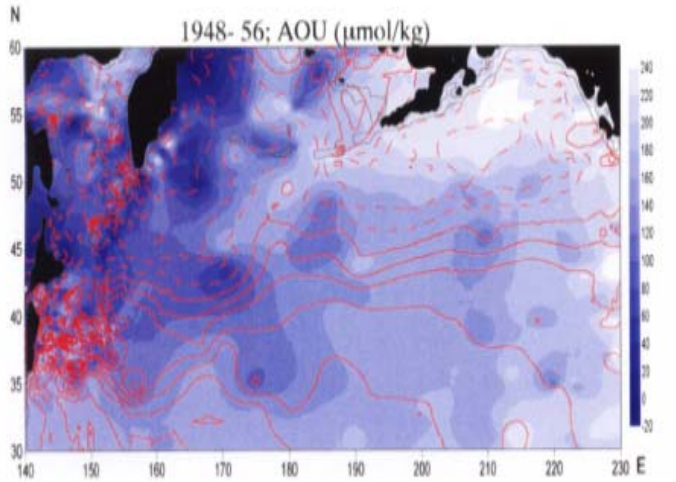

Oyashio, 50 m
S= 32.544 + 0.029 NPI - 2.632 Uflx + 0.017 (GT)^3 , r= 0.78
Salinity
33.4
33.3
33.2
33.1
33.0
32.9
1948
1958
1968
1978
1988
1998

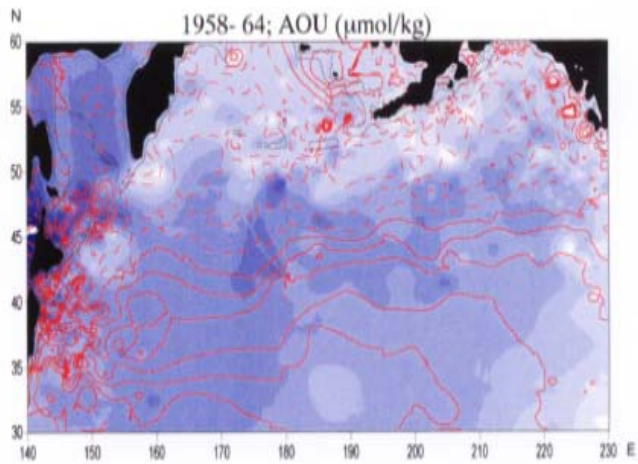

Oyashio, σ_θ=26.8
DO (μmol kg^{-1}) = -11.3 + 12.81 NPI - 754.46 Uflx + 4.87 (GT)^3,
r= 0.83
DO, umol kg^{-1}
280
240
200
160
120
1948
1958
1968
1978
1988
1998

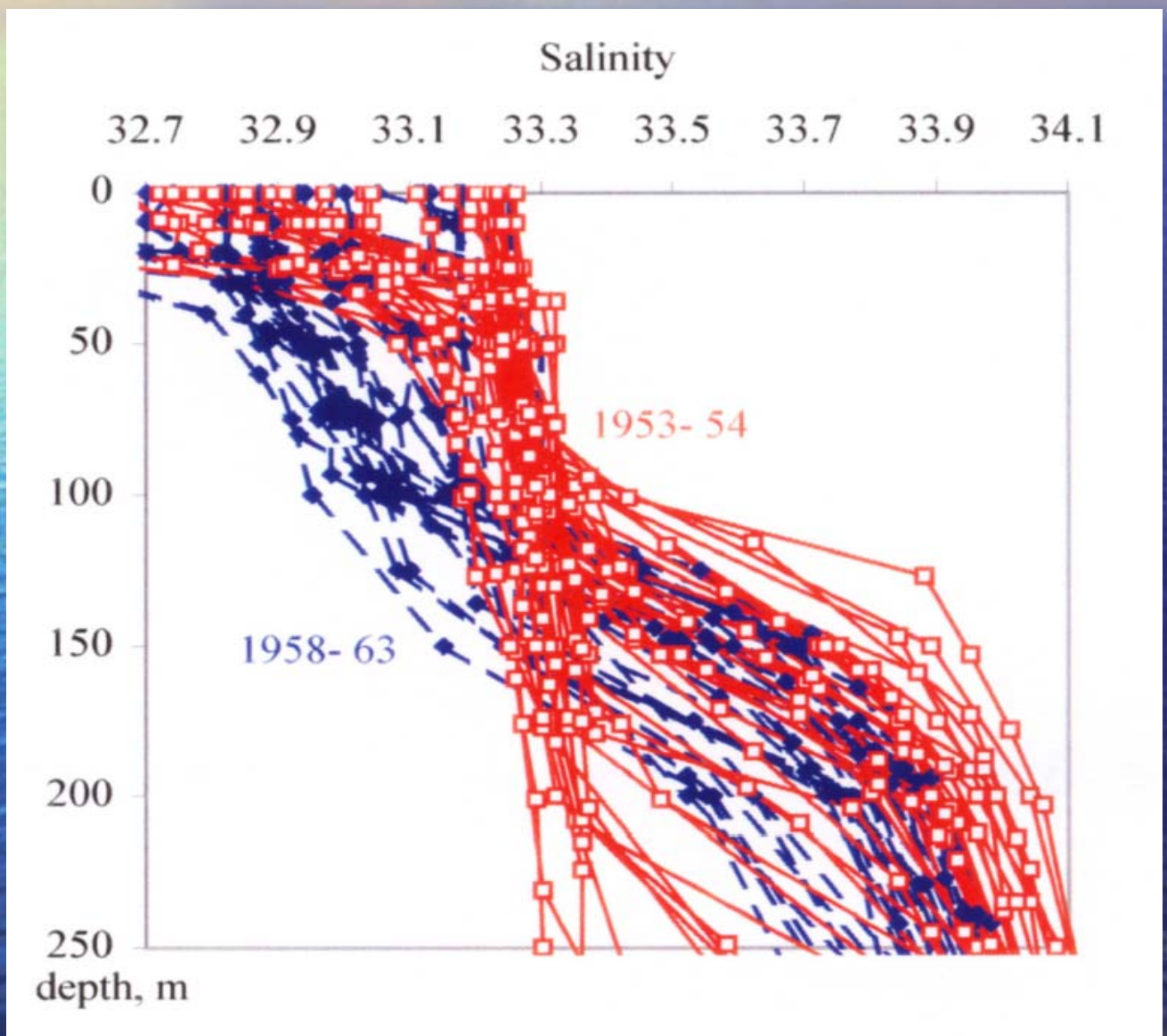

60
55
50
45
40
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
WSG
AG
Oyash.

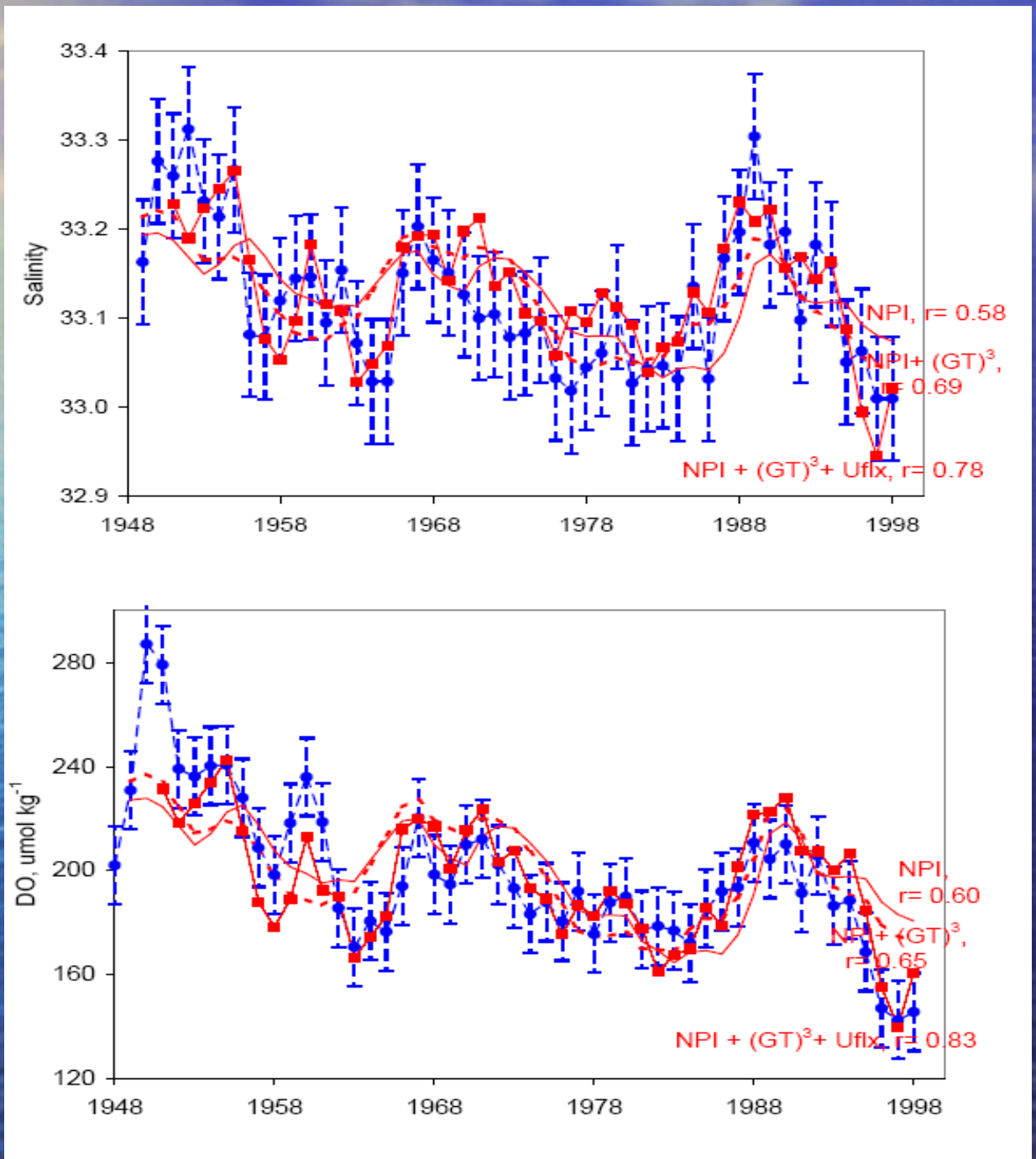

1948- 56; Salinity
N
60
55
50
45
40
35
30
140
150
160
170
180
190
200
210
220
230
E
34.25
34.15
34.05
33.95
33.85
33.75
33.65
33.55
33.45
33.35
33.25

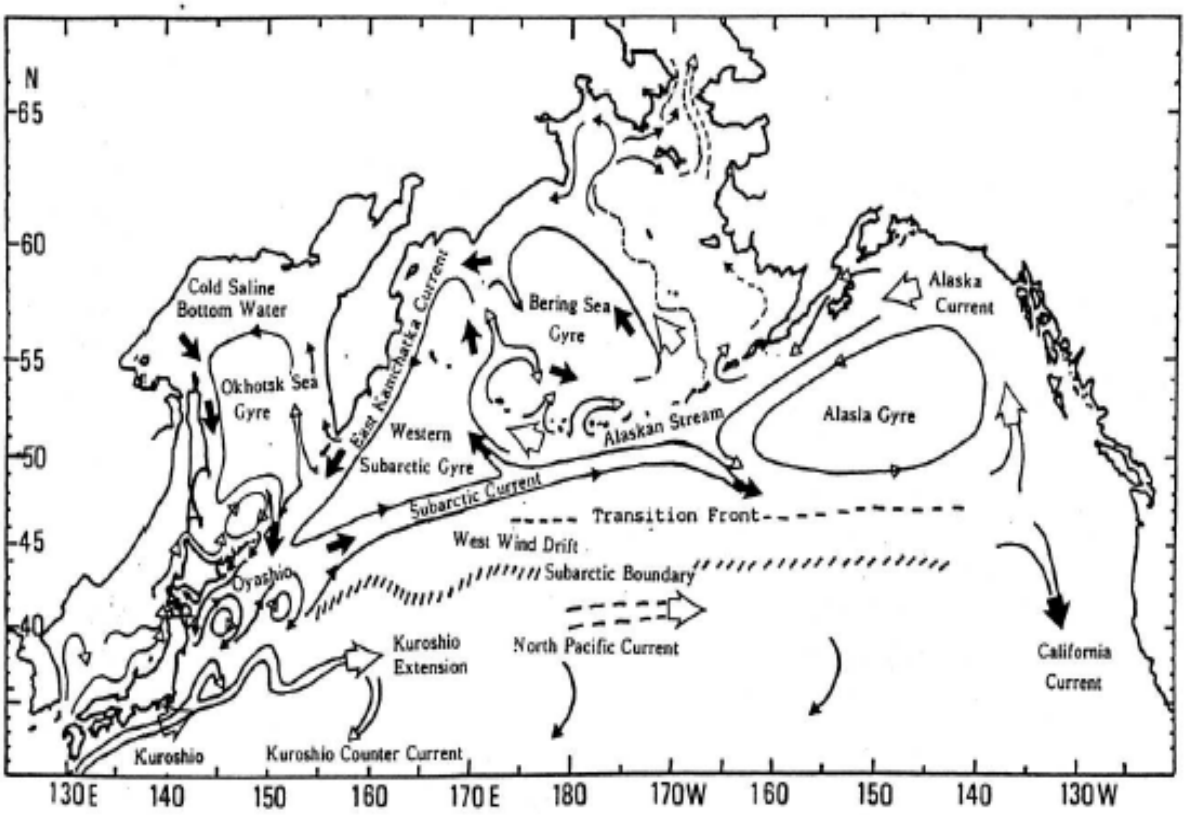

1958- 64; Salinity
N
60
55
50
45
40
35
30
140
150
160
170
180
190
200
210
220
230
E


1948- 56; AOU (µmol/kg)
N
60
55
50
45
40
35
30
140
150
160
170
180
190
200
210
220
230
E


1958- 64; AOU (µmol/kg)
N
60
55
50
45
40
35
30
140
150
160
170
180
190
200
210
220
230
E

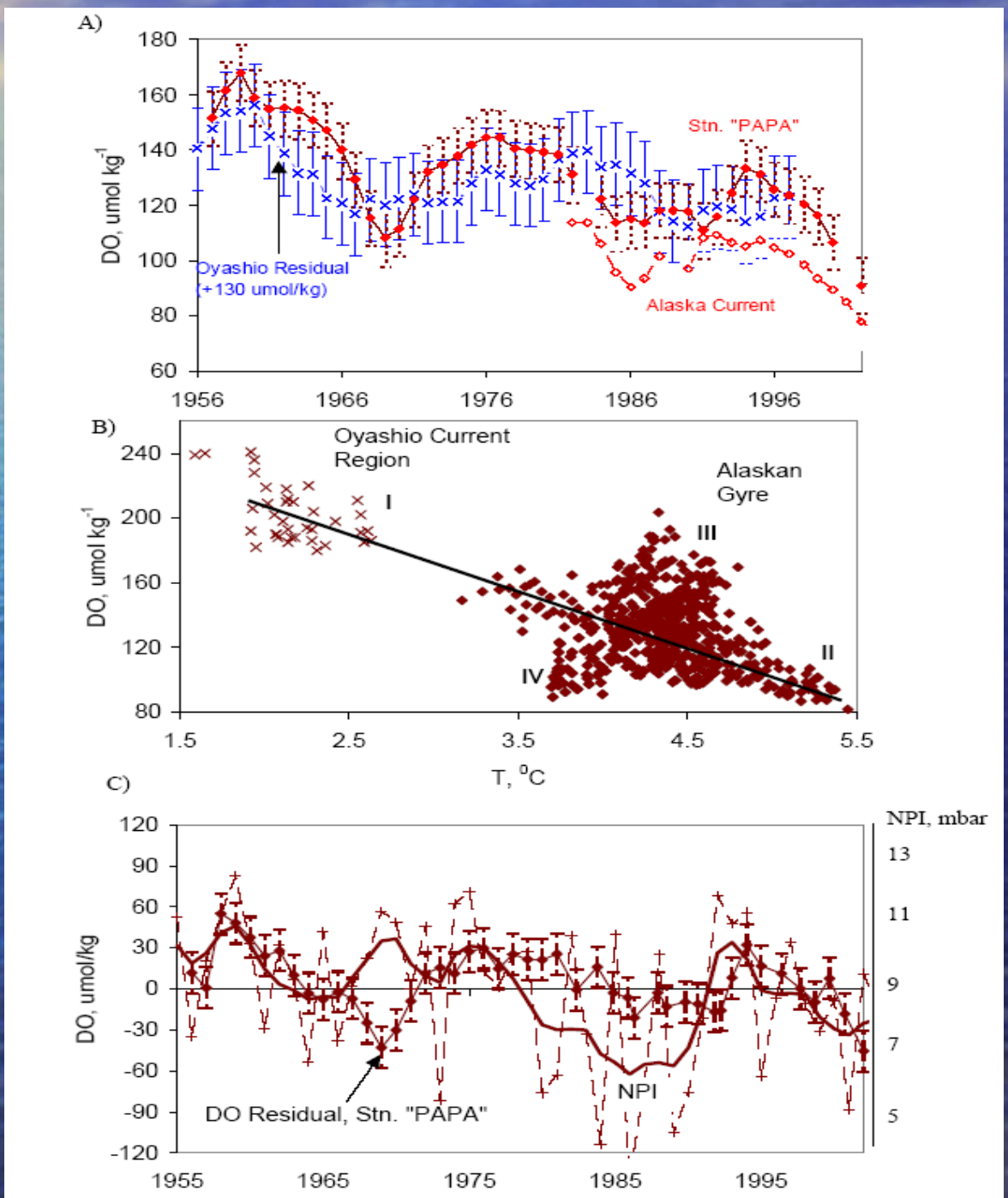

Salinity
32.7
32.9
33.1
33.3
33.5
33.7
33.9
34.1
0
50
100
150
200
250
depth, m
1953- 54
1958- 63


33.4
33.3
33.2
33.1
33.0
32.9
Salinity
1948
1958
1968
1978
1988
1998
NPI, r= 0.58
NPI+ (GT)3, r= 0.69
NPI + (GT)3+ Uflx, r= 0.78
280
240
200
160
120
DO, umol kg-1
1948
1958
1968
1978
1988
1998
NPI, r= 0.60
NPI + (GT)3, r= 0.65
NPI + (GT)3+ Uflx, r= 0.83

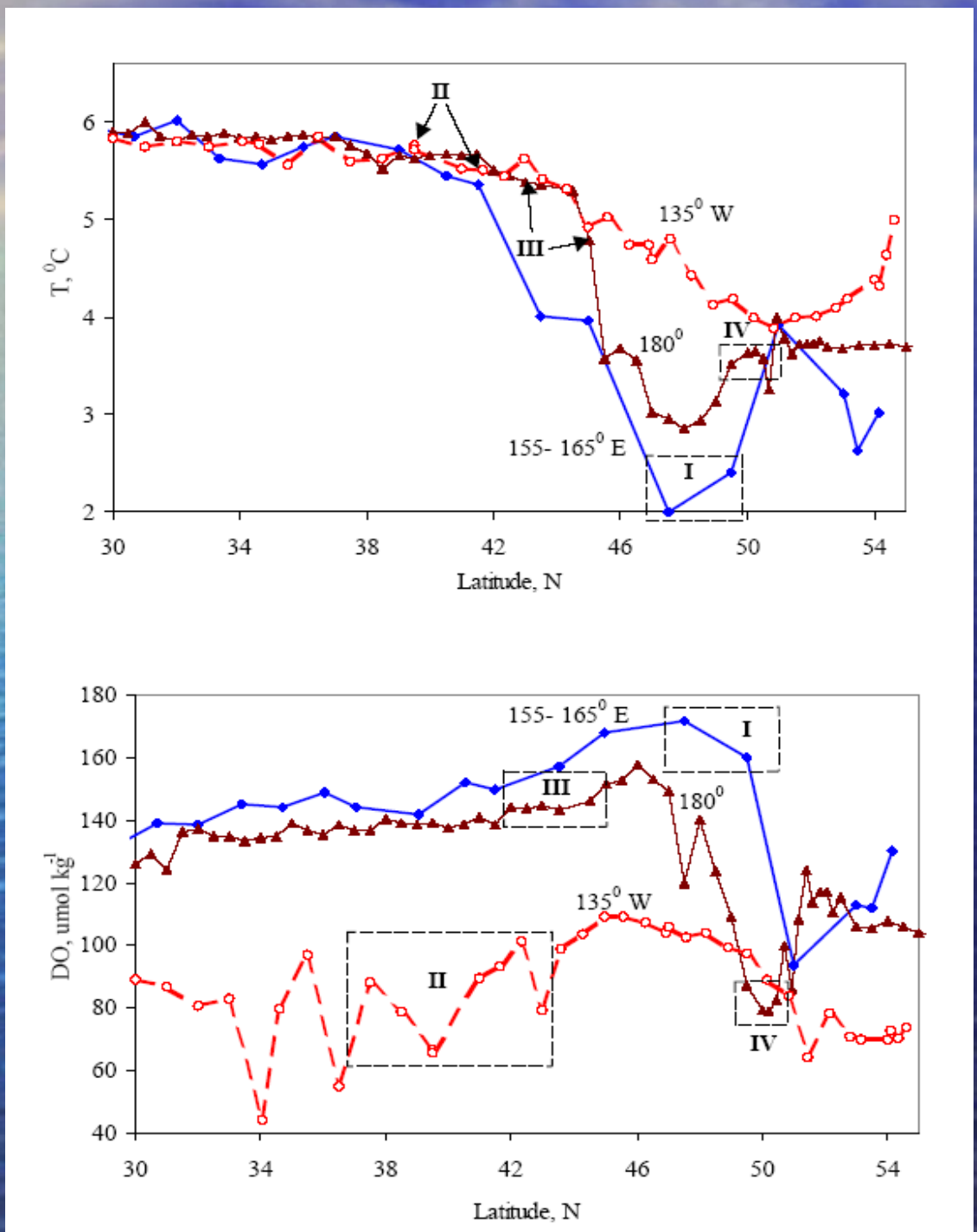


General surface circulation in the subarctic North Pacific Ocean. (after Dodimead et al., 1963; Favorite et al., 1976; as revised by Ohtani, 1991)

A) Temporal variations of dissolved oxygen at σθ = 26.8 in the Alaska Current region and at Stn."PAPA", and residual DO (the difference between the measured and calculated by Eq. (1) the concentration of dissolved oxygen) in the Oyashio Current region; B) Dissolved oxygen versus temperature at σθ = 26.8 in the Alaska Gyre region. Mixing occurs along solid line; C) Temporal variations of the residual DO at σθ = 26.8 at Stn."PAPA" (the difference between the measured and calculated by Eq. (3) the concentration of dissolved oxygen), and NP index with 3 year time lag. Thick solid line is the NP, smoothed with three –year running mean.



Distributions of the temperature and dissolved oxygen at σθ = 26.8 on sections in the North Pacific. WOCE data: P13 (165° E, 1992), P14 (180°, 1995), and P17N (135° W, 2001).



Aud G., J.P. Kenett, and A.J. Miller (2003), North Pacific Intermediate Water response to a modern climate warning shift. *J. of Geophys. Res.*, *108*, NO. C11, 3349, doi: 10.1029/2003JC001987.

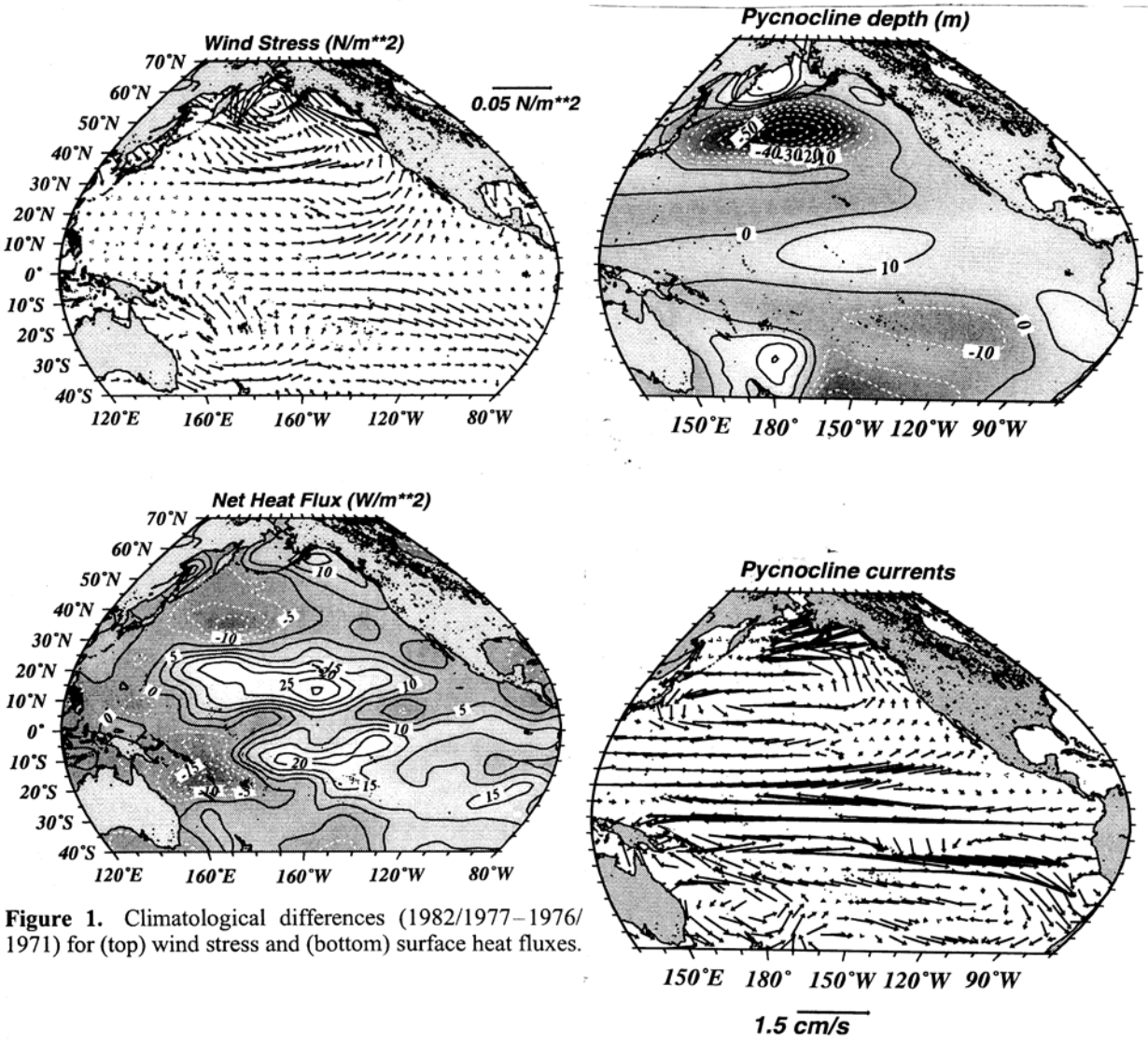


Figure 1. Climatological differences (1982/1977–1976/1971) for (top) wind stress and (bottom) surface heat fluxes.

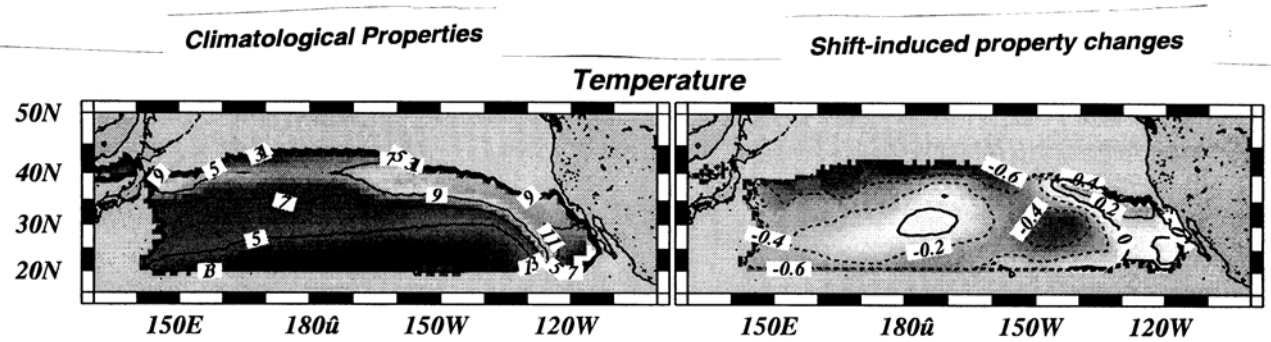
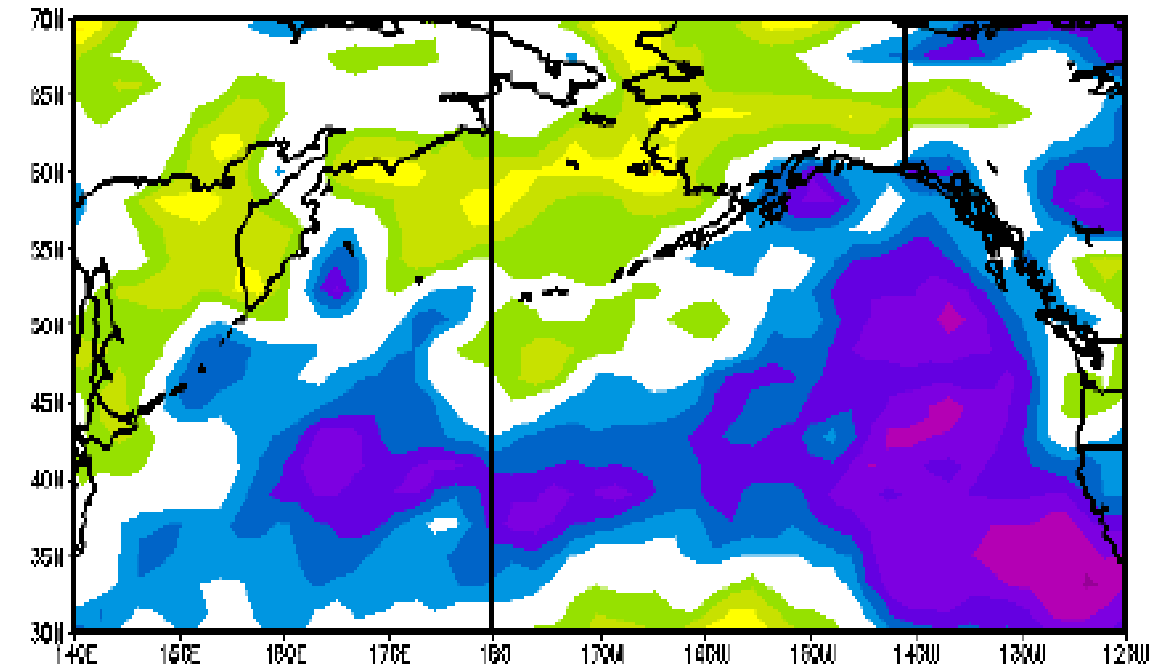


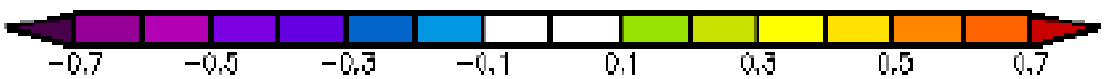
Figure 3. Mean properties (salinity, depth, and temperature) (left) for the annual mean of the model NPIW and (right) for the climatological change in those conditions after the sudden 1976–1977 climate shift. Differences were computed identically as in Figures 1 and 2.

Correlation between Surface Precipitation Rate and NPI.



Jan to Dec 1958 to 2001: Surface Precipitation Rate
Seasonal Correlation w/ Jan to Dec NPI

NCEP/NCAR Reanalysis



NOAA-CIRES/Climate Diagnostics Center

- **Conclusions**
- Our results demonstrate that to offer a reasonable description of the processes that make up the interannual variations in the physical and chemical parameters of the surface and intermediate waters of the subarctic North Pacific, a model with the subtidal/tidal dynamic and the atmospheric forcing by observed climatology should be applied. In addition, the model should account the changes in the density of the outcropping of isopycnal surfaces caused by the changes in the salinity stratification of the subarctic North Pacific.
- http://www.pmel.noaa.gov/co2/NP/JGR/