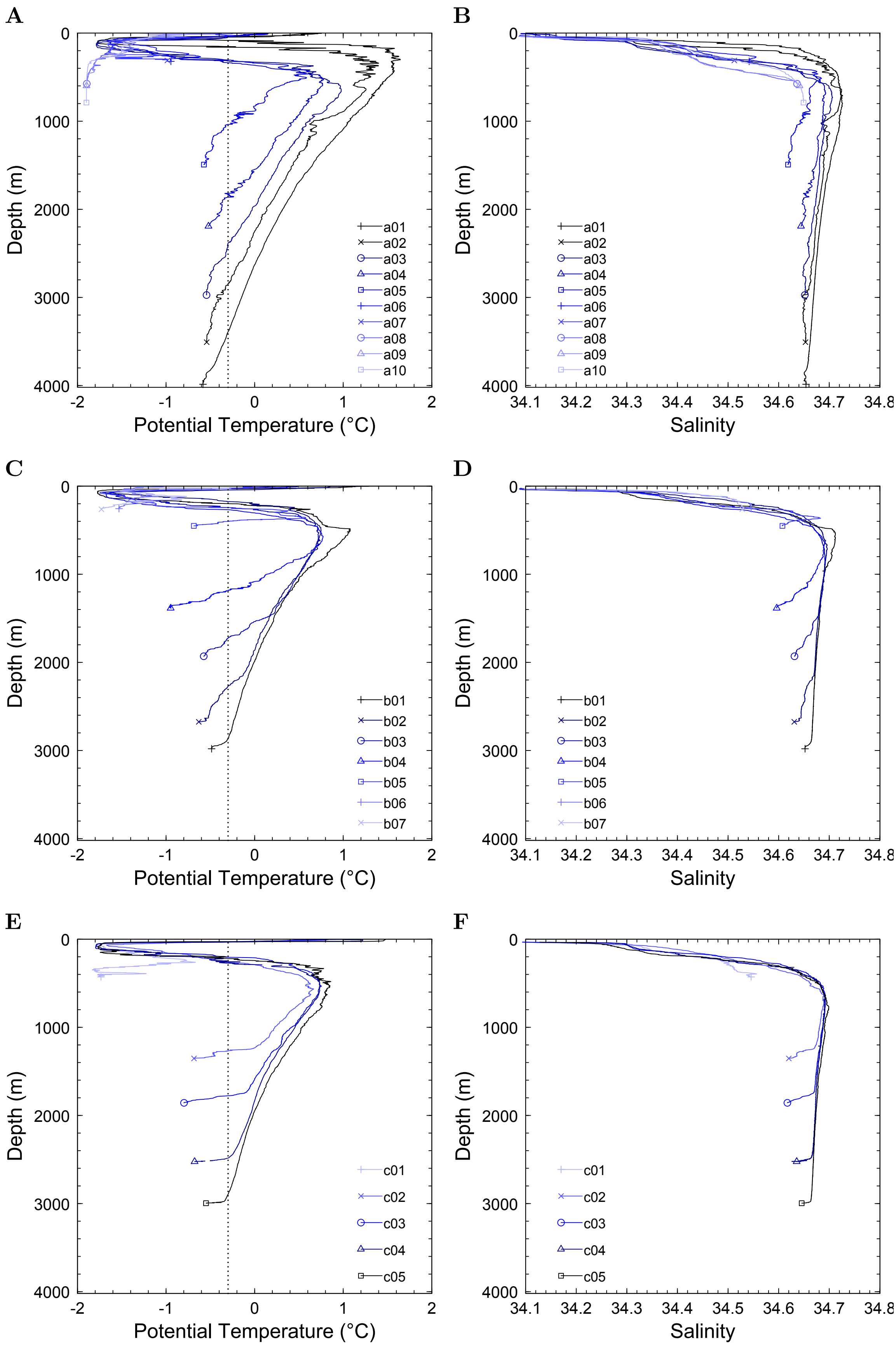
Supplementary Material

1 SUPPLEMENTARY TABLES AND FIGURES

Site	Period	Slope (°C)	Explained Variance
M1	P1	17.04	0.917
	P2	9.58	0.950
	P3	7.54	0.870
	P4	-21.03	0.697
M2	P1	9.51	0.991
	P2	9.90	0.950
	P3	21.30	0.891
	P4	9.60	0.852
M3	P1	8.18	0.993
	P2	11.25	0.968
	P3	10.63	0.645
	P4	13.22	0.839
M4	P1	9.33	0.996
	P2	9.07	0.993
	P3	10.47	0.888
	P4	17.16	0.931

Supplementary Table 1. The slope of the mixing line at moorings M1–M4 in periods P1–P4. The first, second, third, and fourth columns indicate mooring site, period, the slope of the mixing line, and the proportion of the variance explained by the first principal component, respectively.



Supplementary Figure 1. The vertical distribution of potential temperature and salinity at CTD stations a01–a10 (**A, B**), b01–b07 (**C, D**), and c01–c05 (**E, F**). The vertical dotted lines in **(A)**, **(C)**, and **(E)** indicates $\theta = -0.3$ °C.

2 APPENDIX

2.1 Three-layer quasi-geostrophic model

We consider a perturbation in a uniform zonal flow, using a quasi-geostrophic three-layer model on the f-plane. The perturbation streamfunction, ψ_m $(m = 1, 2, 3)$, can be expressed in the form of a wave,

$$\psi_m = \phi_m e^{ik(x-ct)} \cos ly \,, \tag{A1}$$

where t is time; c is the phase speed; x and y are the zonal and meridional coordinates, respectively; k is the zonal wavenumber; and l^{-1} is the meridional scale of the basic flow and perturbation. The growth rate and the angular frequency of the unstable mode are kc_i and kc_r, respectively, where c_r and c_i are the real and imaginary parts of c.

The quasi-geostrophic potential-vorticity equations of the perturbation are

$$(c - U_1)\left[K\phi_1 + F_1(\phi_1 - \phi_2)\right] + F_1(U_1 - U_2)\phi_1 = 0 \tag{A2}$$

$$(c - U_2)\left[K\phi_2 + F_{2-}(\phi_2 - \phi_1) + F_{2+}(\phi_2 - \phi_3)\right] + \left[F_{2-}(U_2 - U_1) + F_{2+}(U_2 - U_3)\right]\phi_2 = 0 \tag{A3}$$

$$(c - U_3)\left[K\phi_3 + F_3(\phi_3 - \phi_2)\right] + \left[F_3(U_3 - U_2) + \frac{f_0\alpha}{H_3}\right]\phi_3 = 0 \,, \tag{A4}$$

where U_m is the basic flow, H_m is the layer thickness, α is the bottom slope, f_0 is the Coriolis parameter, ρ_0 is the Boussinesq density,

$$K = k^2 + l^2 \,, \tag{A5}$$

$$F_1 = \frac{\rho_0 f_0^2}{g\Delta\rho_1 H_1} \,, \qquad F_{2-} = \frac{\rho_0 f_0^2}{g\Delta\rho_1 H_2} \,, \qquad F_{2+} = \frac{\rho_0 f_0^2}{g\Delta\rho_2 H_2} \,, \qquad F_3 = \frac{\rho_0 f_0^2}{g\Delta\rho_2 H_3} \,, \tag{A6}$$

and $\Delta\rho_1$ and $\Delta\rho_2$ are the density difference between the first and second and the second and third layers, respectively.

We can rewrite Equations A2–A4 in the form of a generalized eigenvalue problem of matrices,

$$A\mathbf{p} = cL\mathbf{p} \,, \tag{A7}$$

where

$$\mathbf{p} = \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix} \,, \tag{A8}$$

$$L = \begin{pmatrix} K + F_1 & -F_1 & 0 \\ -F_{2-} & K + F_{2-} + F_{2+} & -F_{2+} \\ 0 & -F_3 & K + F_3 \end{pmatrix} \,, \tag{A9}$$

and

$$A = \begin{pmatrix} KU_1 + F_1U_2 & -F_1U_1 & 0 \\ -F_{2-}U_2 & KU_2 + F_{2-}U_1 + F_{2+}U_3 & -F_{2+}U_2 \\ 0 & -F_3U_3 & KU_2 + F_3U_2 \end{pmatrix} \,. \tag{A10}$$

Using Equation A7, we can numerically calculate the eigenvalue, c, and eigenvector, ϕ_m. When we calculate the unstable mode induced by CDBW, we assume that $U_1 = U_2 = 0$. If we set $U_1 = U_2$, Equation

A2 yields

$$c = U_1 \quad \text{or} \quad (K + F_1)\phi_1 = F_1\phi_2 \,. \tag{A11}$$

In this case, one of the three modes is neutral, and the character of the other two modes is similar to that of the modes obtained in a two-layer model, because ϕ_1 is proportional to ϕ_2 (Pedlosky 1987).

REFERENCES

Pedlosky, J. (1987). *Geophysical Fluid Dynamics.* Springer-Verlag, New York.