Dynamics of the deep-water overflow seasonality in the Luzon Strait

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Introduction

The Luzon Strait (LS) connects the Pacific Ocean and the largest marginal sea, the South China Sea (SCS). There is significant seasonal variability in the LS deep-water overflow, which is of great significance for understanding the meridional overturning circulation in the northwest Pacific and the layered circulation in the SCS.

The ocean bottom pressure (OBP) contains signals about the atmospheric pressure and the oceanic processes in the water column. Generally, the fluctuation of the bottom pressure gradient is the major driving force for bottom overflow variability. Our goal is to explore the contribution of barotropic and baroclinic processes to the OBP variability of the LS.

Methodology

Numerical model

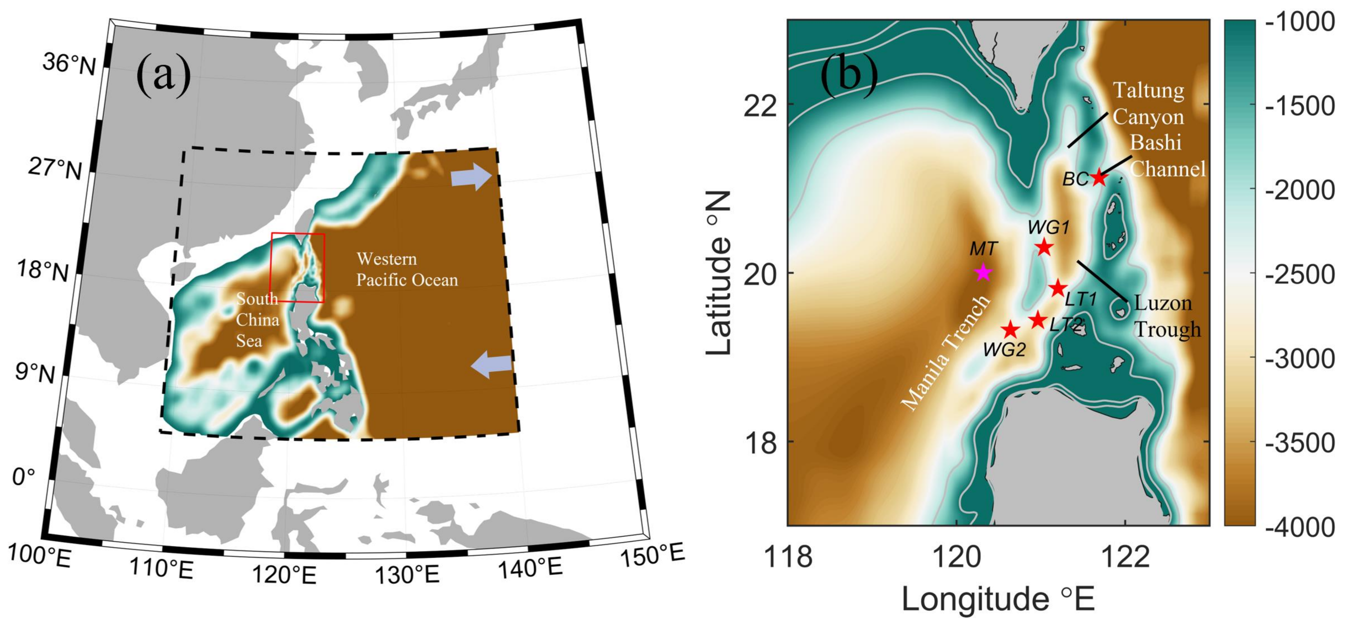


Figure 1. (a) Model domain and idealized topography (m) of the SCS and the western Pacific Ocean. The red box represents the LS. Arrows indicate the location of external volume flux. (b) Luzon Strait topography (m). The stars denote the mooring stations in the Bashi Channel (BC), Luzon Trough (LT1, LT2), Manila Trench (MT), and gaps on the Heng-Chun Ridge (WG1, WG2).

- Resolution: horizontal 3 km, vertical 50 s levels
- Forcing: Wind stress (ERA5) Initialization: horizontally uniform profile (WOA)
- Vertical turbulence mixing coefficient from observation, intensified in SCS
- Idealized external volume flux, 25/20 Sv inflow/outflux

Data

- Deep sea mooring data
- Absolute dynamic topography (AVISO), OBP (GRACE), Temperature (EN4)

Features of the deep overflow

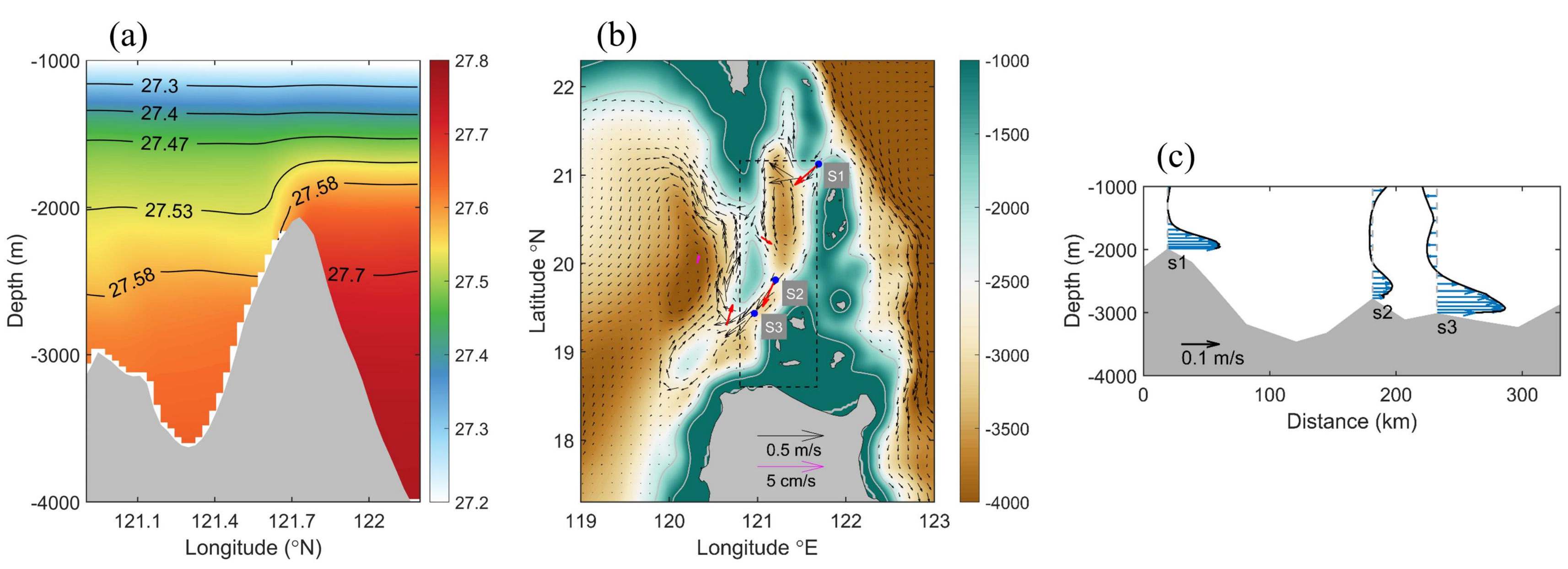
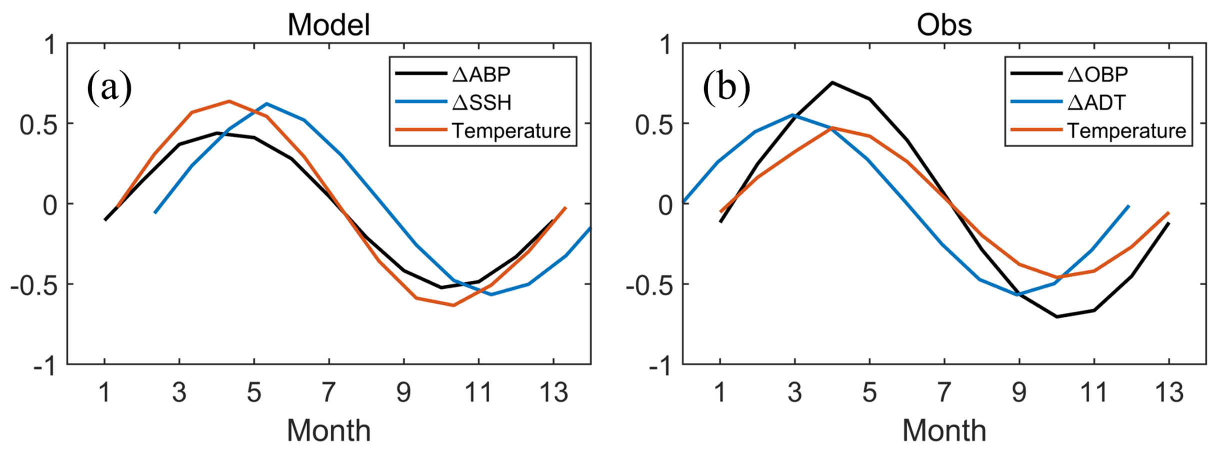


Figure 2. (a) Meridional averaged density (kg m-3, black contour lines) crossing the Luzon Strait. (b) The horizontal pattern of mean deep overflow. The red and magenta arrows are the mooring data of the bottom flow. The magenta arrow is magnified 10 times. Three blue points represent the vertical velocity profile sites (S1-S3). (c) Vertical profiles of along-isobath velocity in different sites. The positive value means intrusion direction towards SCS.

Contrasting mixing intensities induce bottom-layer baroclinic flow

Magnitude and direction closely matched observations.



Synchrony with ADT and deep hydrology oscillations

Figure 3. (a) Bandpass filtered seasonal cycle of normalized along-isobath bottom pressure difference (ΔABP), SSH difference (ΔSSH), and temperature from model results. (b) Bandpass filtered mean cycle of normalized OBP difference (ΔOBP), absolute dynamic topography difference (ΔADT), and temperature from observations. The band-pass filtering extracts the seasonal variation signal within the period of 10-16 months.

Force balance of the deep overflow

Along-isobath pressure gradient force (PGF) and along-isobath velocity exhibit similar patterns

$PGF_{along} > COR_{along}$

bottom PGF_{along} propels deep water in the LS's narrow channel

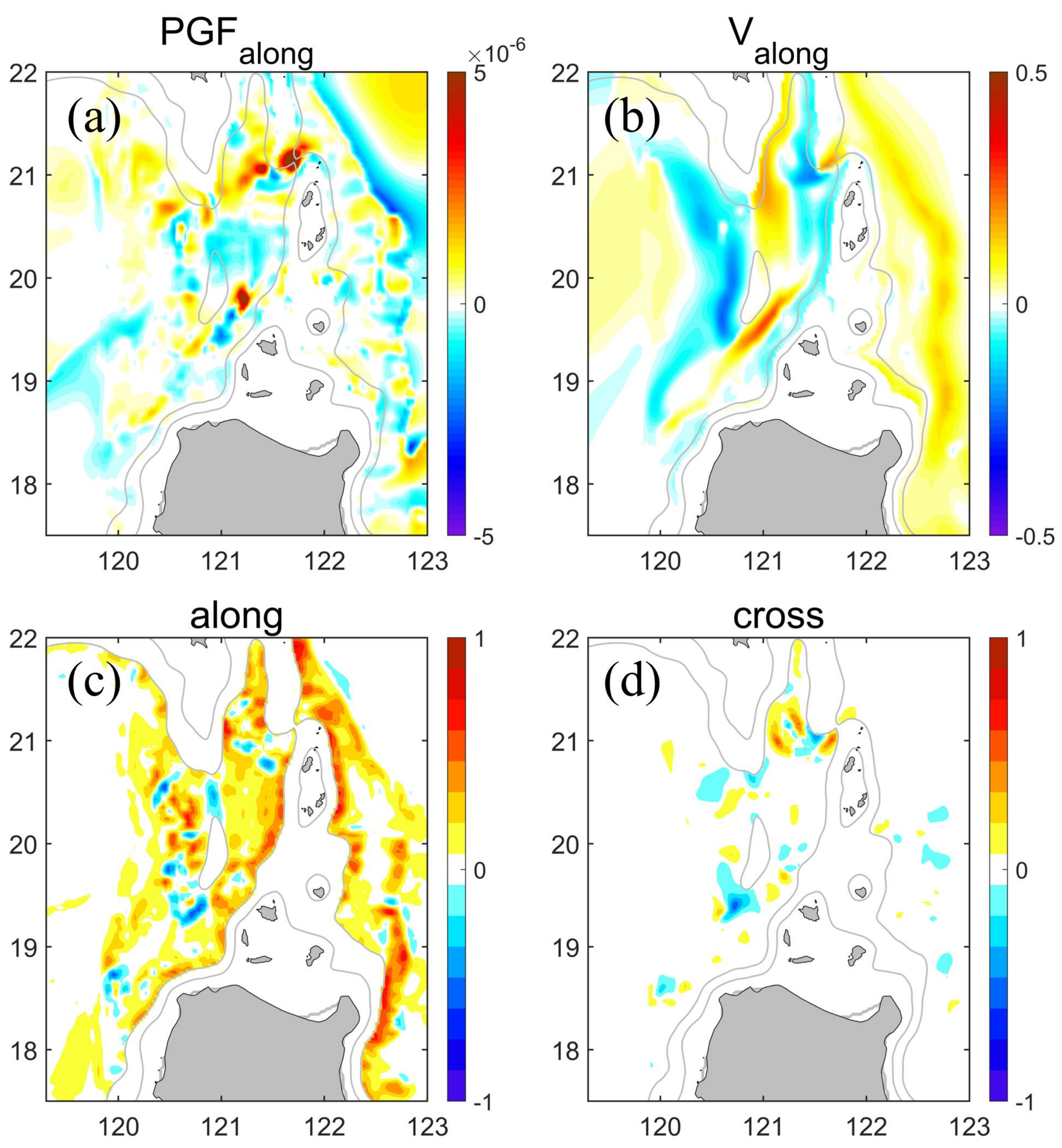


Figure 4. The horizontal pattern of the mean bottom layer (a) along-isobath PGF, (b) along-isobath velocity. The horizontal pattern of the mean bottom layer $\frac{AGE}{PGF}$ in (a) along-isobath and (b) cross-isobath direction. AGE is the sum of the Coriolis force (COR) and the pressure gradient force (PGF).

Seasonal variability of the bottom PGF

$$PGF = \underbrace{\frac{-\partial}{\rho_0 \partial x_*}\int_{-500}^{\eta} \rho g\, dz}_{\text{upper}} + \underbrace{\frac{-\partial}{\rho_0 \partial x_*}\int_{-2000}^{-500} \rho g\, dz}_{\text{middle}} + \underbrace{\frac{-\partial}{\rho_0 \partial x_*}\int_{\text{bottom}}^{-2000} \rho g\, dz}_{\text{deep}}$$

The entire LS, particularly the Bashi Channel area, exhibits consistent seasonal variation patterns across the upper, deep, and bottom layers

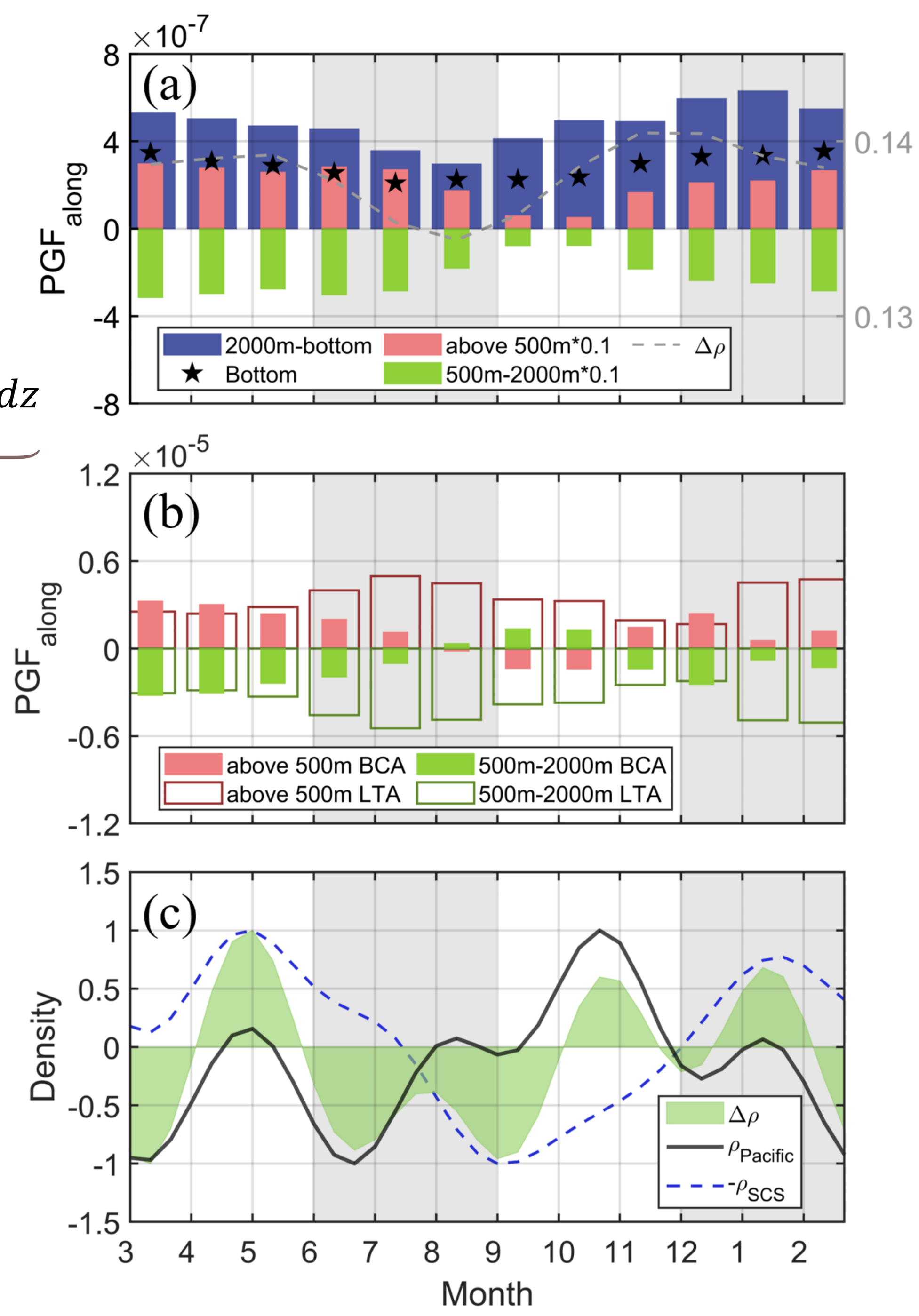


Figure 5. (a) Seasonal cycle of the bottom along-isobath PGF decomposition, 2,000 m to bottom (deep, blue bar), above 500 m (upper scaled-down 10 times, red bar), 500 m to 2,000 m (middle scaled-down 10 times, green bar), bottom (black star), and 2,000 m density difference between SCS and Pacific (gray dashed line). (b) Seasonal cycle of upper layer (red bar) and middle layer (green bar) contribution to the bottom PGF in Bashi Channel (BCA, filled bar) and Luzon Trough (LTA, hollow bar) area. (c) Seasonal cycle of normalized 2,000 m density gradient between SCS and Pacific (green shading), Pacific 2,000 m density (black solid line), and SCS 2,000 m density (blue dashed line).

Conclusion

- Barotropic signals and deep baroclinic signals collectively influence the seasonality of LS deep-water overflow.
- Deep baroclinic oscillations originate from oscillations in density differences between the Northwest Pacific Ocean and the SCS.
- Upper layer oscillations are related to seasonal changes in local wind and Kuroshio activity.
- The seasonal signal from the upper layer can propagate to the bottom layer through the Bashi Channel.