Barrier Layers in the Subtropical Gyres of the World’s Oceans

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Abstract

The barrier layers (BLs) in the subtropical gyres of the world's oceans are detected by analyzing all temperature and salinity profiles taken by Argo floats from January 2000 to June 2005. The synoptic BLs are thicker and occur more frequently during January-April (July-November) in the subtropical gyres in the Northern (Southern) Hemisphere with some differences in thickness and occurrence rates among the oceans. We suggest that the same mechanism of BLs as that in the North Pacific, i.e., the subduction of saline water at sharp salinity fronts on a small scale of about 100 km, is at work in the other subtropical gyres. Seasonal change of the mixed layer depth contributes to the seasonality of BL thickness and frequency in all subtropical gyres.

1. Introduction

1.1 A barrier layer (BL) is a layer between the bottoms of mixed layer depth (MLD) and isothermal layer depth (ILD), caused by the strong stratification of salinity without temperature stratification.

1.2 The relatively thick BLs distribute in the subtropical gyres of the world's oceans in the winter hemisphere, as well as the equatorial Pacific in the climatology.

1.3 The real feature of BLs in the North Pacific, which is not found in the climatological temperature stratification isothermal layer depth (ILD), caused by the strong stratification of salinity without temperature stratification.

1.4 Data

1.5 World Ocean Atlas 2001 (WOA01)

- seasonal data (1°×1°)
- vertical grid: 10 m (interpolated using Akima's spline)

1.6 Data and method

1.7 The measured depth nearest the surface is shallower than 10 dbar.

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2. Data and method

2.1 Argo profiling float data

- area: 30°S-30°N, 0°-360°
- period: 2000.1 - 2005.6 (43,402 profiles)
- quality check

(1) Quality flags of 1/6 data in all the measured levels are coded as ”1”.
(2) The measured depth nearest the surface is shallower than 10 dbar.
(3) The vertical sampling interval from surface to 100 dbar is less than 15 dbar.
(4) The vertical grid: 10 m (interpolated using Akima's spline)

2.2 World Ocean Atlas 2001 (WOA01)

- seasonal data (1°×1°)
- vertical grid: 10 m (interpolated using Akima's spline)

2.3 The definition of ILD, MLD, and BL thickness (BLT)

- according to Sprintall and Tomczak [1992] and Sato et al. [2004]

ILD: depth at T = T0 + ΔT
MLD: depth at ρ = ρ0 + Δρ

where T = T0 + ΔT so that

3. The BLs detected in the Argo data in the world's oceans

3.1 The BLs in the North Pacific (NP)

- thicker BLs
- more frequent

3.2 In the South Pacific (SP)

- thicker BLs
- more frequent

3.3 In the South Indian Ocean (SI)

- thicker BLs
- more frequent

3.4 In the Atlantic Ocean (AT)

- thicker BLs
- more frequent

4. The formation mechanism of the BLs

4.1 Distribution of BLs

4.2 The BLs are formed in the same way as in the subtropical gyre of the North Pacific. Assuming that the ILD after BL formation is not very different from the MLD before BL formation, we can define the BL thickness (BLT) in the following way:

BLT = MLD - ILD

where MLD = ρ0 + Δρ and ILD = T0 + ΔT.

4.3 Seasonal changes of the BL thickness in the subtropical North Pacific

- Maximum BLT of the year is greatest in the North Pacific and South Pacific.
- Total occurrence rate for the entire analysis period is highest in the North Pacific with smallest seasonal change in the occurrence rate.
- BLT is lowest in the South Atlantic because of relatively low frequency of BL in every month.
- The seasonal change of the relative frequency in the South Indian Ocean is clearest.

5. The factors controlling the seasonality of BL

5.1 The BLs can get thicker when ILDs are deeper.

- All ”ILD-”BLT” pairs are plotted when BLs are thicker than the synoptic BLs without significant ILDs simply mean MLS.

- The occurrence rate of BLs

ILD < 60 m
low, winter = summer
Most of summer ILD is populated.
ILD > 60 m
high
The majority of winter ILD is populated.
Assuming that the ILD after BL formation is not very different from the MLD before BL formation.

- MLS deeper than 60 m are more probable for BL formation than shallower MLSs.
- The higher occurrence rate of BLs in winter is associated with the higher occurrence rate of thicker MLSs.

- The same relationships between BLT and ILD are found in the other subtropical gyres.

5.2 The seasonal change of MLD contributes to that of thickness and occurrence rate of BLs in all subtropical gyres.

6. Summary

- The distribution of the BLs in the subtropical gyres detected by the Argo profiling float data is consistent with the BL in the climatological data.
- The thickness and relative frequency of the BLs in all subtropical gyres change seasonally in the fairly similar manner to those in the North Pacific.
- The slightly different features in the seasonal change of the thickness and relative frequency in each other region are recognized.
- The BLs are more frequent in the North Pacific.
- The seasonality of thickness and relative frequency of BLs in all subtropical gyres are attributable to seasonal change in the ML depth.

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