A REVISIT TO CAUSES OF THE NORTH PACIFIC CENTRAL MODE WATER PROPERTY CHANGES ASSOCIATED WITH REGIME SHIFTS

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Abstract

Traditional interpretation of the changed in the North Pacific Central Mode Water (CMW) properties associated with climate regime shifts is re-examined based on eddy-resolving ocean general circulation model hindcast and Argo float data. We hypothesize that major causes of the CMW property changes are changes in northward transport of warm and salty water to the CMW formation region associated with the changes in the path and strength of the Kuroshio Extension rather than changes in heat and freshwater water fluxes at the sea surface.

1. Introduction

The North Pacific Central Mode Water (CMW) is known as a water mass in the lower part of the ventilated pycnocline in the North Pacific subtropical gyre. It was reported that CMW got warmer, saltier and lighter remarkably just after the regime shift at the end of 1980s (Fig. 1; [1]). This change was interpreted as a result of the decrease of heat and freshwater losses at the sea surface in the CMW formation region caused by weaker westerly wind. However, it was recently found using atmospheric reanalysis data that the changes in heat and freshwater losses were not large enough to explain the change of CMW properties. The purpose of this study is to present another plausible cause of the CMW properties change associated with the regime shift at the end of 1980s using a high-resolution OGCM and to examine this hypothesis using all available temperature and salinity profiles observed by Argo floats from 2000.

2. Why did CMW properties change associated with the regime shift?

We use the Modular Ocean Model version 3 (MOM3) OGCM [2] for The Earth Simulator (OFES; [3]). OFES covers a near-global domain extending 75°N-75°S, with a horizontal resolution of 0.1°. The model has 54 vertical levels. For horizontal mixing of momentum and tracers, we use scale-selective damping with a biharmonic operator [4]. The nonlocal K-profile parameterization (KPP) boundary layer mixing scheme [5] is employed for vertical mixing.

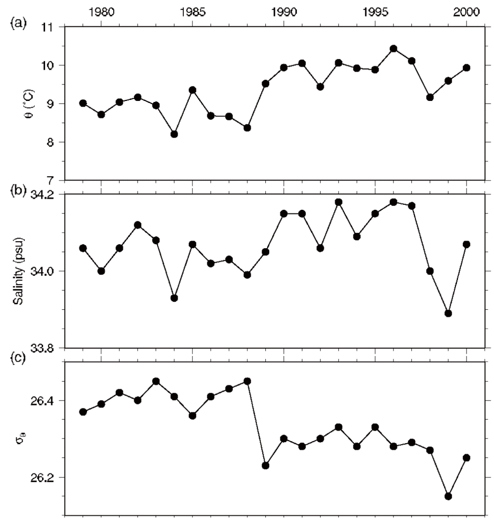

Figure 1. Time series of the potential temperature, salinity, and potential density of the CMW in the 180°section [1]

Surface heat flux and evaporation are calculated by bulk formulas with atmospheric variables based on the National Centers for Environment Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis data [6] and the simulated SST field. Freshwater fluxes are evaluated from evaporation fields and daily precipitation rate data, under the constraint that sea surface salinity (SSS) is restored to the observed monthly climatology at a time scale of 6 days. For details, see [3] and [7].

Following a 50-year integration with climatological monthly mean forcing from the annual-mean temperature and salinity climatological fields without motion, a 54-year hindcast integration with daily mean atmospheric fields of NCEP-NCAR reanalysis data from 1950 to 2003. This hindcast simulation successfully captures variability with intraseasonal-todecadal time scales [7].

At first, we focus the change of sea surface temperature (SST) and SSS in the formation region of CMW associated with the regime shift at the end of 1980s. SST and SSS there increased after the regime shift. These are equivalent to the observed temperature and salinity increases of CMW.

Next, we investigated the cause of SST and SSS increase in the CMW formation region. Downward heat flux there decreased after the regime shift. It means that heat flux was not a factor causing SST increase in the CMW formation region. On the other hand, the Kuroshio Extension (KE) moved northward and accelerated in the upstream (Fig. 2) after the 1980s' regime shift. This variation of location of KE and its strength is also shown in the satellite sea surface height (SSH) data [8]. Therefore, it is considered that the increase of SST and SSS in the CMW formation region at the end of 1980s is due to northward shift of KE and acceleration of the upstream KE jet rather than the atmospheric thermal and freshwater forcing in the CMW formation region. We hypothesize that the dynamic change of KE affects a northward supply of warm and saline water to the northern margin of the subtropical gyre and makes a change of the CMW properties.

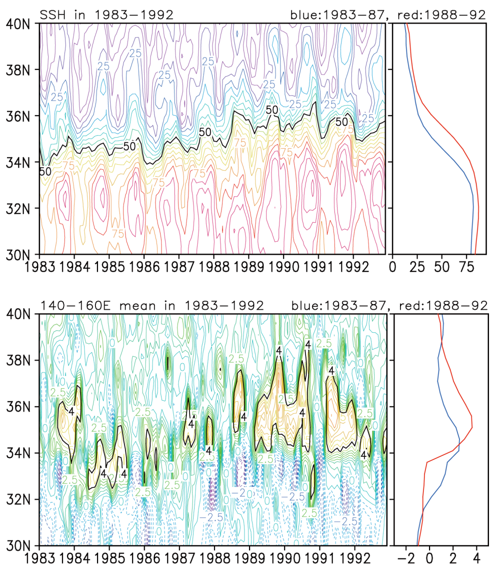

Figure 2. Time series of OFES SSH averaged in 140°E-180° (upper panel) and eastward velocity averaged in 140°-160°E (lower panel). Right panels show meridional profiles of the corresponding variables averaged for 1983-97 (blue curves) and 1988-92 (red curves).

3. Examination of our hypothesis using Argo data from 2000

To examine our hypothesis, we analyzed near-real time data of sea level anomalies (SLA) of a merged altimeter satellite product combining some satellites distributed by AVISO (http://www.aviso.oceanobs.com), NCEP-NCAR reanalysis data, and Argo data from 2000 to 2008.

The KE moved southward rapidly at the beginning of 2006, while the shift was small compared to that at the end of 1980s. Associated with this shift, SST and SSS decrease in the area north of the KE, including the CMW formation area, from January to March in 2006. Temperature and salinity at the core of CMW observed from May to September in 2006 also decreased compared to those in 2005 by 1°C and 0.1, respectively. Although heat and freshwater losses in the CMW formation region increased in winter of 2006, the changes in these factors were not large enough to explain those of CMW properties. Thus, the change in the CMW properties in 2006 supports our hypothesis presented above.

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