



OS41A-0145: Variability of North Pacific Tropical Water using MRI ocean data assimilation system (MOVE/MRI.COM-G) from 1993 to 2004



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1. Introduction

Background:

- # In order to clarify and understand variabilities of ocean interior related to climate change, salinity data are important, because salinity plays a role in deciding density and velocity fields, and variabilities of water properties (water mass).
- To understand the temporal variabilities of salinity, it is necessary to analyze long-term repeat hydrographic sections data or fixed point observation data (e.g., the 137E repeat hydrographic section by the Japan Meteorological Agency (JMA) and HOT (Hawaii Ocean Time-series) station ALOHA (ALOHA)).
- However we do not have enough salinity data to understand the spatial variations of salinity.
- # An ocean data assimilation system (MOVE/MRI.COM-G) has been developed in Meteorological Research Institute, and reanalysis experiments are implemented.
- A reanalysis dataset will provide useful information, in order to clarify and understand spatio-temporal variabilities of ocean interior related to climate change.

Objectives:

1. Confirmation of reproducibility of a reanalysis dataset.
 - We compared the reanalysis dataset with three different kinds of datasets of in situ observation.
2. Analysis of spatio-temporal variabilities associated with climate change.
 - We focus the subsurface salinity changed remarkably in the late 1990s.
 - Lukas (2001) reported the reversal of freshening in the subsurface at the HOT station ALOHA during 1997-1998.
 - North Pacific Tropical Water (NPTW) at the 137E repeat section by JMA changed remarkably (Fig. 1).

North Pacific Tropical Water (NPTW) is characterized by subsurface salinity maximum core over the subtropical gyre in the North Pacific. The NPTW is formed at the surface in the central North Pacific along the Tropic of Cancer, where evaporation is far higher than precipitation. The NPTW originates high salinity water in the Kuroshio region of the south of Japan. The variability of NPTW leads to the variability of North Pacific Subtropical Mode Water (NPSTMW) formed over the region of south of the Kuroshio Extension, and salinity minimum layer is formed into the just north region of the Kuroshio Extension.

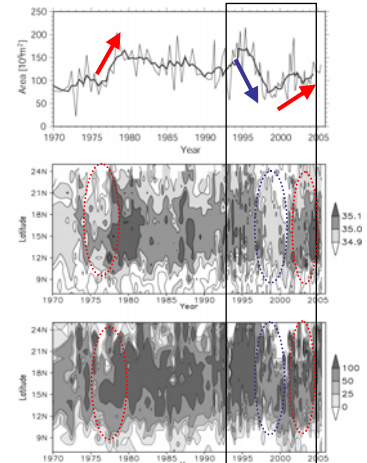


Fig. 1 Time-series of the NPTW core size (cross-sectional area with $S > 34.9$), salinity at $24.0 \sigma_\theta$ surface, and thickness of $S > 34.9$ at the 137E section.

2. Data and method

Outline of reanalysis dataset of MOVE/MRI.COM-G; hereafter MOVE-G

- Model: MRI community ocean model (MRI.COM; Ishikawa et al., 2005)
- region: Global (75S-75N)
- resolution: 1 (lon.) \times 0.3 (lat.; 6S-6N) and 1 (lon.) \times 1 (lat.; poleward of 15S and 15N) 50 vertical levels (24 levels in the upper 200m)

Data Assimilation method:

- MRI Multivariate Ocean Variational Estimation System (MOVE; Usui et al., 2006)
- 3DVAR with vertical coupled T-S EOF modes (Fujii and Kamachi, 2003)
- Incremental Analysis Update (IAU) technique

Reanalysis condition:

- period: Jan. 1993 to Dec. 2004
- observation data: in situ temperature and salinity data (ship, buoy, ARGO float) Altimeter data (TOPEX/Poseidon and Jason)
- forcing data: NCEP R-1

Definition of NPTW

- Temperature and salinity data are interpolated into every 1 m interval using the modified Akima method.
- Salinity (S) maximum is calculated in the density range $22.0 - 25.5 \sigma_\theta$, and in addition, depth, temperature and potential density at the depth of the salinity maximum are also calculated.
- Thickness of $S > 34.9$.

Atmospheric dataset

- NCEP/NCAR reanalysis dataset (wind stress curl, evaporation and precipitation): Jan. 1949 - Dec. 2005
- NOAA Climate Prediction Center Merged Analysis of Precipitation (CMAP; Xie and Arkin, 1997): Jan. 1979 - Sep. 2004

Sea surface height (SSH) reanalysis dataset (Kuragano and Kamachi, 2000)

- resolution: 0.5 (lon.) \times 0.5 (lat.)
- period: every 5 days from Jan. 1993 to Jun. 2002

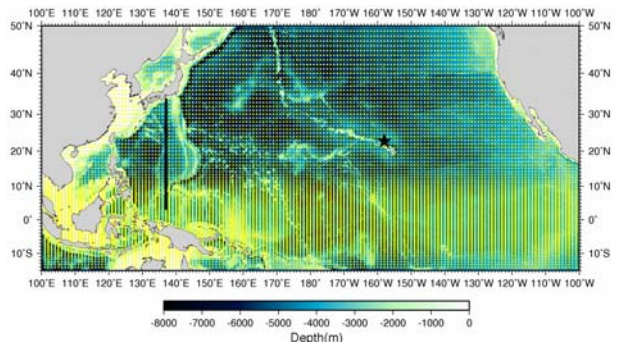


Fig. 2 Grid point of MOVE/MRI.COM-G in the North Pacific. Meridional line denotes the JMA 137E hydrographic repeat section and closed star indicates the HOT station ALOHA.



3. Reproducibility of reanalysis dataset

Comparison between the reanalysis dataset and three different kinds of datasets

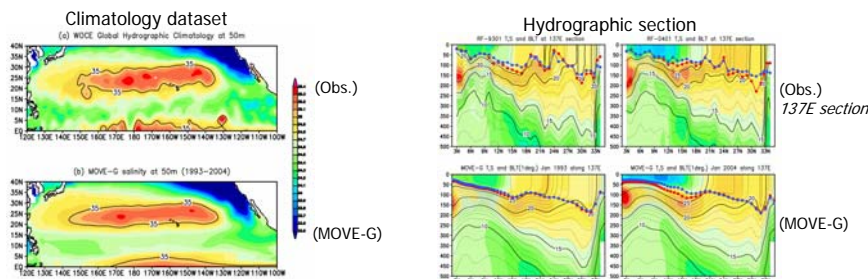


Fig. 3 Climatological map of salinity at 50 m depth. (a): WOCE Global hydrographic climatology (Gouretski and Koltermann, 2004), (b): MOVE-G.

Fig. 4 Vertical section of temperature, salinity, surface isopycnal depth (blue) and surface isothermal depth (red).

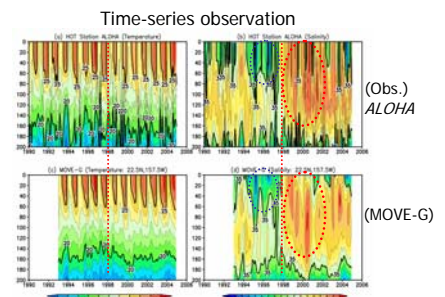
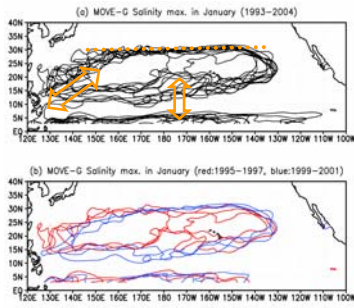


Fig. 5 Time-series of temperature and salinity at fixed point observation.

4. Spatio-temporal variabilities of NPTW



The position of northern end is stable. The variabilities of the positions of southern and western ends are very large.

Fig. 6 (a) Maps of $S=35.0$ contour line in the horizontal distribution of salinity maximum in every January from 1993 to 2004. (b) Maps of $S=35.0$ contour line in the horizontal distribution of salinity maximum in every January from 1995 to 1997 (red), and from 1999 to 2001 (blue).

《1995-1997》 The north-south width of the area surrounded by contour line of $S=35.0$ is narrow around the date line, and then divided into two portions. The distribution of salinity maximum parallel to longitude. The distribution of the thickness greater than 100 m spread into the Kuroshio recirculation region of the south of Japan.

《1999-2001》 The north-south width of the area surrounded by contour line of $S=35.0$ is not narrow around the date line, and the position of southern end shifts southward. The distribution of salinity maximum is inclined in the southwest-northeast direction. The salinity maximum of NPTW increased over the eastern formation area. The southern end of distribution of salinity maximum shifts southward.

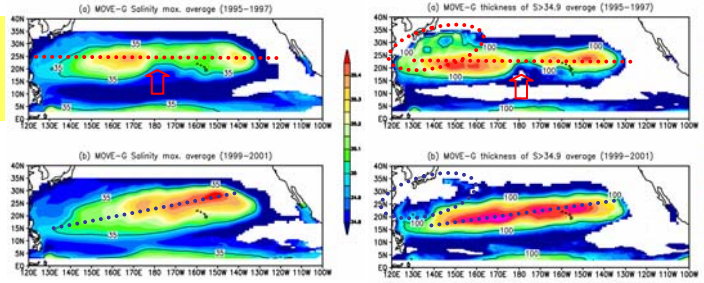


Fig. 7 Maps of mean salinity maximum averaged from 1995 to 1997 (a), and from 1999 to 2001 (b). Solid contour denotes $S=35.0$.

Fig. 8 Maps of mean thickness of $S>34.9$ averaged from 1995 to 1997 (a), and from 1999 to 2001 (b). Solid contour denotes thickness of 100 m.

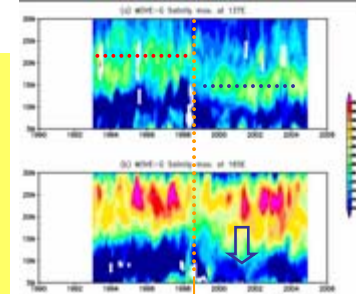


Fig. 9 Time-series of salinity maximum along (a) 137E, and (b) 165E.

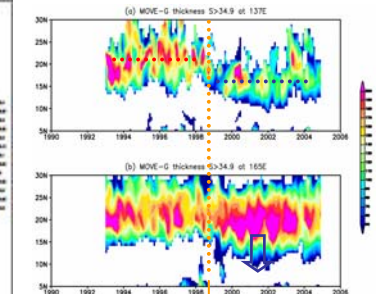


Fig. 10 Time-series of thickness of $S>34.9$ along (a) 137E, and (b) 165E.

5. Causes of variabilities of NPTW

Difference of the shape of the subtropical gyre

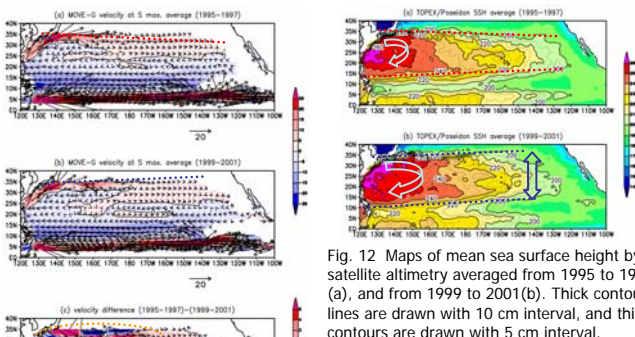


Fig. 11 Maps of mean velocity (color: u-component) at the salinity maximum depth averaged from 1995 to 1997 (a), from 1999 to 2001 (b), and its difference (c).

《1999-2001》 The Kuroshio extension shifts northward at the northern boundary, and the southern boundary of the subtropical gyre shifts southward.

《1995-1997》 The Kuroshio extension shifts southward and is weak (Qiu, 2002), the southern boundary of the subtropical gyre shifts northward as it goes to the east, and the spacing between northern and southern boundaries of the subtropical gyre is narrow as it goes to the east.

The salinity of NPTW changes in the formation region

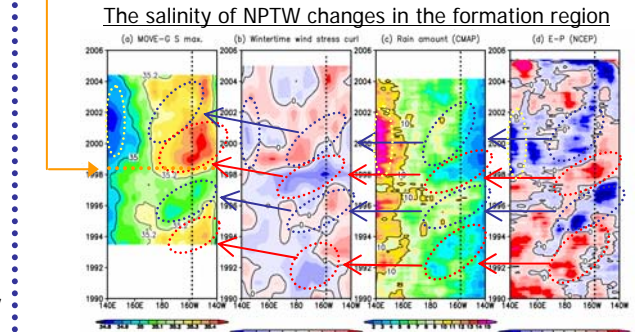


Fig. 12 Maps of mean sea surface height by satellite altimetry averaged from 1995 to 1997 (a), and from 1999 to 2001 (b). Thick contour lines are drawn with 10 cm interval, and thin contours are drawn with 5 cm interval.

Fig. 13 Time-series of (a) salinity maximum, (b) wintertime wind stress curl anomaly (10^7 N m^{-3}), (c) rain amount (cm month^{-1}), and (d) evaporation-precipitation anomaly ($10^5 \text{ kg m}^{-2} \text{ sec}^{-1}$) averaged 25N-30N. The data of (a), (c) and (d) are smoothed with 13 months running mean. Dotted line denotes the longitude of ALOHA.

- When the rainfall region of the central North Pacific extends to the east near the Hawaii Islands, the salinity reveals freshening at ALOHA.
- When the rainfall region is limited in the west of the date line, the salinity reveals reversal freshening at ALOHA.
- The variability of salinity follows the above variabilities with about 1 year time lag.

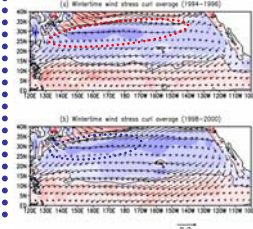


Fig. 14 Maps of mean wind stress curl (10^7 N m^{-3} ; color) and wind stress (10^7 N m^{-2} ; arrow) averaged from 1994 to 1996 (a), and from 1998 to 2000 (b).

6. Conclusion

《Reproducibility of a reanalysis dataset》

The distribution and time-series of temperature and salinity in the reanalysis dataset agree well with the climatological distribution, instantaneous meridional distribution and time change at a fixed point observation.

《The causes of the variability of NPTW in the late 1990s》

We suggest that the causes of the variability in the late 1990s associated with the variability of the shape of the subtropical gyre and the rainfall region related to wind stress curl field. The salinity maximum of NPTW is controlled by freshwater flux (evaporation-precipitation) associated with variability of the distribution of rainfall over the formation area of NPTW, and the distribution of NPTW is controlled by the variability of the shape of the subtropical gyre.

- We suggest that analysis results explain a cause of the variabilities of NPTW at the 137E repeat hydrographic section by JMA.
- The results of this study also suggest the availability of reanalysis dataset of MOVE-G.

《Future work》

We would like to go on to carry out sensitivity experiments using the MRI.COM, in order to investigate each contribution ratio of variabilities of freshwater flux over the formation region of NPTW and of the subtropical gyre.