INTERANNUAL VARIABILITY OF SUBTROPICAL MODE WATER IN THE NORTH ATLANTIC

Master of Science In Oceanography Physics and Applications

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Plan

1. Introduction
2. Data and method
3. Result and discussion
4. Conclusion and perspectives
Mode Waters

- are upper ocean water masses with nearly uniform temperature and salinity over a thickness of hundreds of meters which is found over a relatively large geographical area.
- usually occur between the permanent pycnocline and seasonal pycnocline.
Location and types of Mode Water?

- subtropical mode waters (STMWs), type I, Gulf Stream, Kuroshio, aiguillas current.
- the eastern type of subtropical mode waters type II, Madeira Mode Water
- subtropical and subpolar mode waters, type III.

**Figure 1:** Mode water distributions in the world's oceans, after Talley (1999a).
How and When are formed Mode Waters?

1. During the winter cold and dry air outbreaks from the nearby continents move toward NA Subtropical Gyre
2. Large surface heat loss on the warmer side of GS front
3. Convective mixing and generation of STMW.

Figure 2: Process of Mode Water formation.
Study of Variability NASTMW

1. program Clivar/Climode
2. considerable importance in climatic point of view
3. Oceanic uptake and decadal variability of atmospheric CO2 is modulated by the STMW reservoir
NASTMW Studying fields

- first observed over 130 yr ago by Thomson (1877)
- Subtropical Mode Water were first introduced by Worthington (1959)
- since then a large number of studies have investigated STMW
- Talley (1982) studied Eighteen Degree Water variability in Western North Atlantic.
- Kwon and Riser (2004) investigated the seasonal variability of North Atlantic Subtropical Mode Water
- Forget (2011) Estimated seasonal cycle of north atlantic eighteen degree water volume
All the studies of variability of mode water in the north Atlantic were based either on mapped or interpolation method. Here, we have used a new metric based probability computation which is simple and direct.

**Objective**

Our work aims to explore the interannual variability of North Atlantic Subtropical Mode water using this metric.
Problem

1. How does EDW volume vary while we are applying this statistical method on the data profiles?

2. How does the EDW thickness vary?

3. Which of the parameters, thickness, surface of the study area or the combination of the both is the Volume depended of?
Argo data

argo floats within the Program Argo

- 2000-2013, temporal: all resolution 10 days
- Argo website: http://www.argo.net/
- 3000 floats

Figure 4: Argo system.
**EDW criteria**

- Selected temperature profiles must be in the range of EDW, i.e. between 17 and 19 degree celsius
- Profiles thickness which is the difference of the depth corresponding to these two temperatures 17 and 19, must be greater than 20 m.

\[ H = \text{depth}(17) - \text{depth}(19) > 20 \text{ m} \]
Volume index

Method

\[ V = \frac{1}{H} \sum_{k=1}^{N_z} p(t, k) dz(k) \]  
(1)

\[ p(t, k) = \frac{1}{N_P^k} \sum_{p=1}^{N_P^k} \delta(k, p) \]  
(2)

\[ e(t, k) = \frac{\sigma^k}{\sqrt{N_P^k}} \]  
(3)

Figure 6: Layers structure.
200 m - near surface, temperature decreases rapidly with depth.

Seasonal thermocline

Figure 7: Eighteen Degree Water temperature profiles from the period 2000-2013 with thick greater than 20m over the study area (18°N- 42°N; 84°W- 35°W).
200 m - 600 m temperature is almost constant round 18 degree, forming nearly isothermal layer or thermostad (Seitz, 1967). 

**Figure 8:** Eighteen Degree Water temperature profiles from the period 2000-2013 with thick greater than 20m over the study area (18°N- 42°N ; 84°W- 35°W).
600 m - 1200 m temperature decreases less rapidly with depth, this is permanent thermocline.

1200 m - 200 m temperature is almost stable.

Figure 9: Eighteen Degree Water temperature profiles from the period 2000-2013 with thick greater than 20m over the study area (18°N- 42°N; 84°W- 35°W).
Figure 10: EDW thickness and geographical position from 20922 profiles during the period 2000-2013.

Figure 11: Annual mean net surface heat flux, it is balance heat flux over the ocean surface noted $q_{net}$ in Wm$^{-2}$, Negative values (blue) corresponds to upward fluxes, ie ocean is losing heat toward the atmosphere.
Figure 12: EDW thickness histogram distribution of the temperature profiles from 2000 to 2013.

Figure 13: Depth with Eighteen Degree Water temperature.

Figure 14: salinity with Eighteen Degree Water
EDW thickness variability

Figure 15: Monthly mean timeseries of profile numbers (red line), monthly mean of EDW thickness (blue line) and initial profiles (black scatter plot).

Figure 16: Timeseries of Monthly mean error bar.

Relative_error = \frac{Err \times 100}{\text{abs}(X)}
Volume index variability

\[ V' = (S \ast H)' = S' \ast H + S \ast H' + S' \ast H'. \]

Figure 17: Monthly timeseries of EDW volume index (no unit) for the period 2000-2013.

Figure 18: Timeseries of volume index error.
Volume index variability

Figure 19: Monthly timeseries of EDW probability profiles (no unit).
Volume index variability

\[ V(t) = V_{sc}(t) + V_{bf}(t) + V'(t). \]

**Figure 22:** Low frequency signal (interannual) of EDW volume index.
Objective
explore the interannual variability of North Atlantic Subtropical Mode water from Argo data profiles

Conclusion
• variability of the EDW volume reflects mainly this of the EDW thickness
Perspectives

- interannual variability contribution of atmospheric forcing?
- contribution of heat flux?
- vertical mixing?
- Ekman advection on this variability?
THANK YOU FOR YOUR KIND ATTENTION
Annexe

Figure 22: Low frequency signal (interannual) of EDW volume index.