Interannual variability of the Subpolar Mode Water in the North Atlantic

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1. Introduction

Mode waters are key elements in the air-sea exchanges that occur in the subpolar gyre and in the water-mass transformation process that takes place in that area :

- ➢ Warm water from the subtropical gyre are cooled and transformed in mode waters and deep waters that return southward ⇒ MOC (Fig. 1).
- ➢ Mode water properties are related to air-sea forcing, warm water initial properties, general circulation and mixing.
- ➢ Mode water are one of the ocean indices monitored in the OVIDE project (www.ifremer.fr/lpo/ovide).

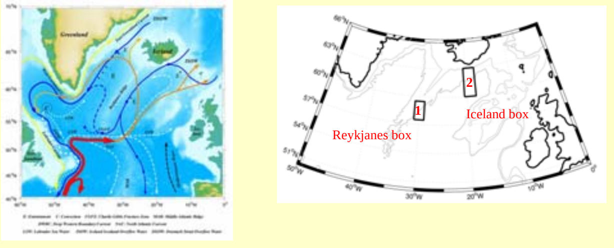

Fig 1: (Left) Pathway of the warm water flowing northward in the subpolar gyre and of the return flow at depth (after www.ifm-geomar.de). (Right) Locations of the two boxes where we investigate the mode water properties and variability.

The aim of this study is to document mode waters properties and variability in the Iceland basin and more particularly in two boxes located on the eastern flank of the Reykjanes Ridge and south of Iceland (fig.1).

3. Interannual variability

Mode water have become saltier, warmer and lighter since the end of the eighties. A trend toward colder and fresher mode water is observed from 1990 to 1995. South of Iceland, the data reveal the presence of oscillations: mode water were also in a warm and salty state in the 1960s and early 1970s.

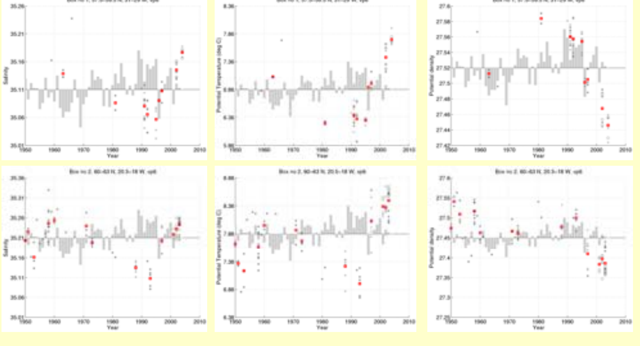

Fig 3: Properties of the subpolar mode water in the Reykjanes Box (upper panels) and in the Iceland box (lower panels). The gray bars represent the NAO index (Hurrel 1995). Stars and crosses are historical data. ***Argo data (circles) are consistent with CLIVAR data (crosses). The ARGO array has become the most important data provider since 2002.***

5. Conclusion

- ➢ The abrupt changes in the NAO index that occurred in 1996 induced a shift in the position of the subpolar front that may partly explain the changes in the mode water properties observed after 1996.
- ➢ From the mid-1960s to the mid-1990s, mode water in the Iceland box have become colder and fresher. This trend is consistent with the variability of the E-P forcing field observed during that period.
- ➢ The trend toward warmer and saltier water that begins in 1996 is observed until 2004 but the E-P forcing field is not consistent with the salty anomaly observed after 2000.
- ➢ Modification in the properties of the water mass sources, in relation with the gyre index, may have an influence on the mode waters properties, but the mean circulation pattern has to be clarified, especially south of Iceland.
- ➢ High-frequency variability (such as GSA) may superimpose to long-term signals.

2. Datasets and mode water identification

The mode water properties are determined from **historical CTD data**, including WOCE and CLIVAR data, and **from ARGO data**. We have retained profiles containing both temperature and salinity measurements, collected between beginning of June and end of September, and over the period 1950-2005.

In each profile, the subpolar mode water (SPMW) are identified as follow: potential vorticity q less than 6 x 10^{-11} m^{-1} s^{-1} ; potential density comprised between 26.85 and 27.65 (we do not consider Labrador Sea Water); depth range between the base of the mixed layer and 900 db; thickness greater than 100 db;

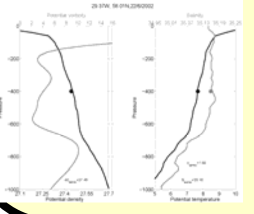

Fig. 2: Example of profile containing SPMW. Mode water are defined as the mean water mass properties in the layer where the potential vorticity is lower than the threshold values previously defined.

4. What can cause this variability ?

1. Changes in local air-sea forcing

➢ According to Josey and Marsh 2005, E-P variability explains the observed freshening of the Sea Surface Salinity along 60°N from the mid-1970s to the end of the 1990s (Reverdin et al. 2002) ➢ **but does not explain the salty anomaly observed since 2000.**

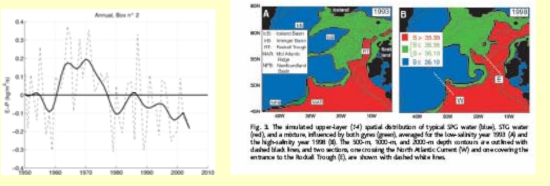

Fig 4: (Left) Time series of the E-P anomaly in the Iceland forcing box. (Right) Simulated upper layer salinity in the northeast Atlantic in 1993 and 1998 corresponding to high and low values of the gyre index, respectively (after Hàtun et al. 2005).

2. Mean circulation

➢ abrupt change in the NAO index (Hurrel 1995) in 1996 from positive to negative values (Fig. 3) ⇒ contraction of the subpolar gyre (Flatau et al. 2002) ⇒ warm and salty water from the subtropical gyre shifted toward the north-west ⇒ modifications of the water mass properties in the Iceland Basin consistent with the changes observed in the mode waters properties in the late 1990s (Bersch 2002, Johnson and Gruber 2006).

➢ **the NAO index returned to positive or near zero values since 1996 which cannot fully explain the trend observed since 1996** (Fig. 3)**.**

3. Modifications in the water mass source, advection of T and S anomaly

➢ the gyre index (Häkkinen and Rhines 2004, Hàtun et al 2005) reveals a decline of the subpolar gyre circulation from 1992 to 2005. A weak gyre circulation (low gyre index) is correlated with an increased salinity in the northeastern Atlantic due to a diminution of the influence of the relatively fresh North Atlantic Current (Hàtun et al 2005) (Fig. 4).

➢this anomaly may have an influence on the mode waters properties in the Reykjanes and Iceland boxes

➢ the GSA 1990s (Belkin 2004) reaches the Iceland basin in 92-95 (Fig. 5) ⇒ could have reinforced the fresh anomaly observed in 1995 in the Reykjanes box

Both processes implies a mean cyclonic circulation in the western Iceland Basin.

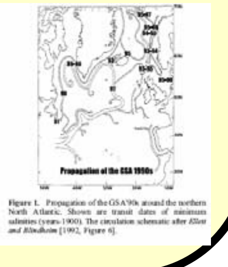

Fig. 5: Propagation of the GSA'90s around the Northern North-Atlantic (after Belkin 2004)

6. References

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