Using sea surface height to track heat and salt content anomalies in the North Atlantic

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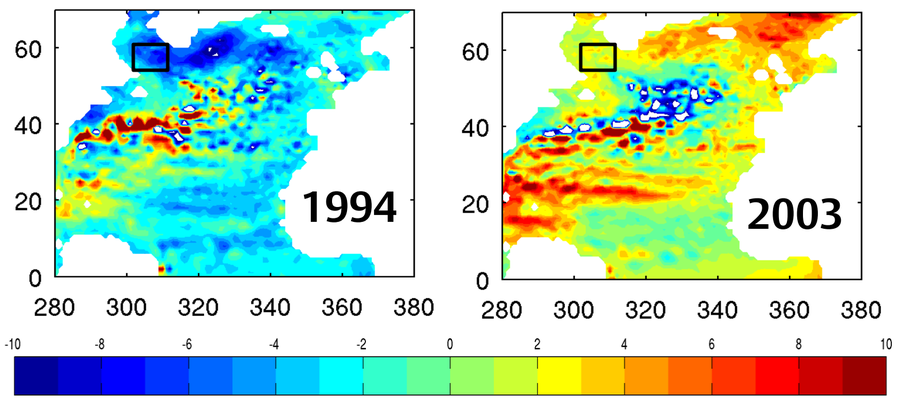
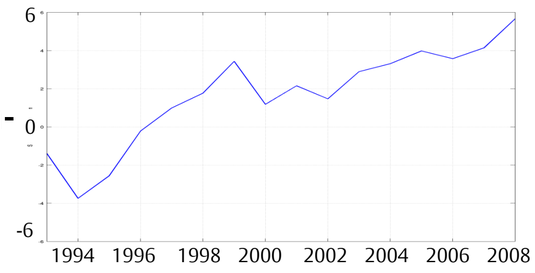
Introduction

Sea Level rise is used as an indicator of climate change. As the ocean warms sea level rises but the rate of warming is not a constant over the whole ocean. Salinity content changes also impact sea level and are important contributions in regions of dense water formation. If we are to fully exploit altimeter data to help make future climate predictions it is important to know the relative roles of salinity and temperature content anomalies in sea level variability.

Altimetry Data



Annual mean Sea level Anomaly for1994 and 2003 with respect to the 16 year average 1993-2008, (units cm). Topex/Poseidon data downloaded from AVISO.



The Labrador Sea is an important region of dense water formation linked to the strength of the Atlantic Meridional Overturning Circulation. This time-series shows the sea level anomaly (in cm) in the Labrador Sea (black box above). The rapid sea level change between '94 and '99 coincides with a rapid warming and weakening of the subpolar gyre (Hakkinen and Rhines, 2009).

However, sea level anomalies in this region can not be attributed to temperature anomalies alone. It has been found that halosteric anomalies counter thermosteric anomalies in the Labrador Sea. Observational coverage of salinity data across the North Atlantic is sparse temporally and geographically, although projects such as Argo will improve this situation in the future. To investigate the interactions of salinity and temperature variability in this region and their relative roles in driving sea level anomalies it is necessary to turn to models.

Steric Height Calculations

Changes in sea level are driven by changes in ocean mass (e.g. from melting ice caps) and Steric Height (SH). The latter is simply the integrated density, $\rho(S,T,p)$ of the water column relative to a reference density and depth, $\rho_0(S=35psu, T=0°C, p)$;

$$SH = -\int_H^0 \rho / \rho_0 \, dz$$

SH variability is driven by changes in the heat and/or salt content of the column. The contributions of S (or T) variability to the total SH variability can be isolated by using a climatology of T (or S), e.g. $\rho(S,\bar{T},p)$ or $\rho(\bar{S},T,p)$, where over-bar indicates climatology mean.

References

- Hakkinen and Rhines, JGR, April 2009, C04005

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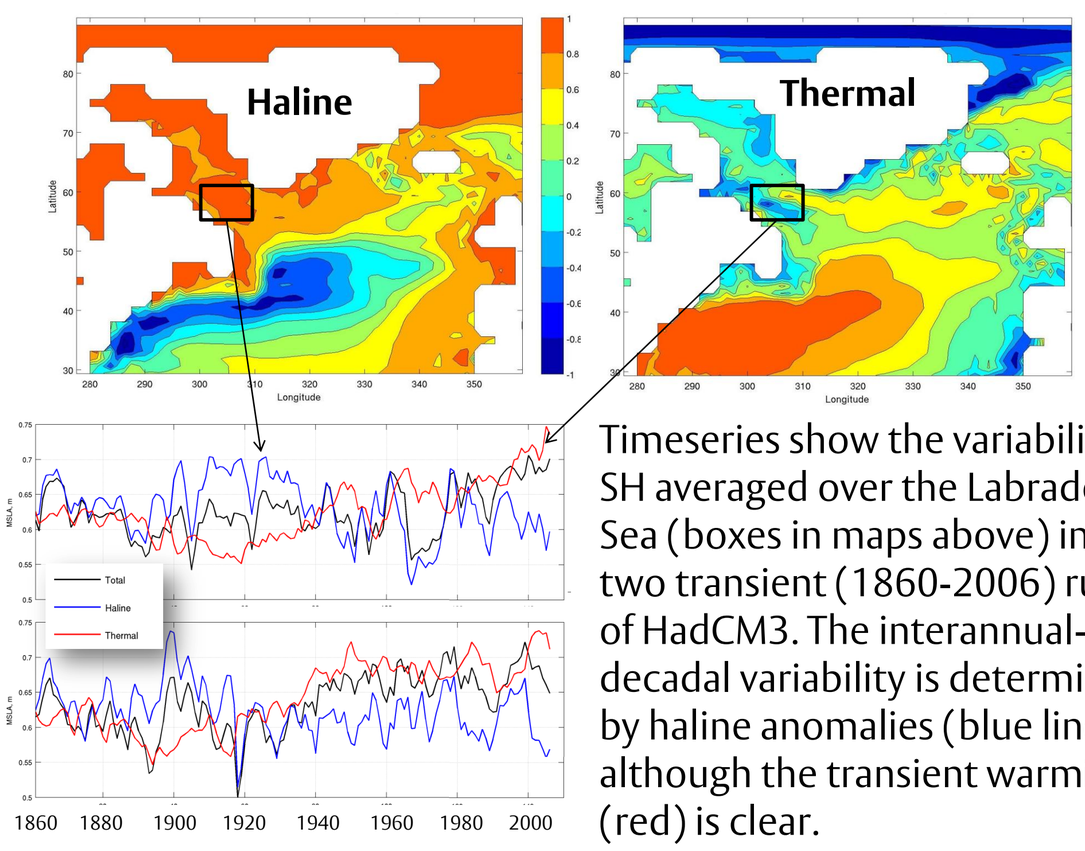
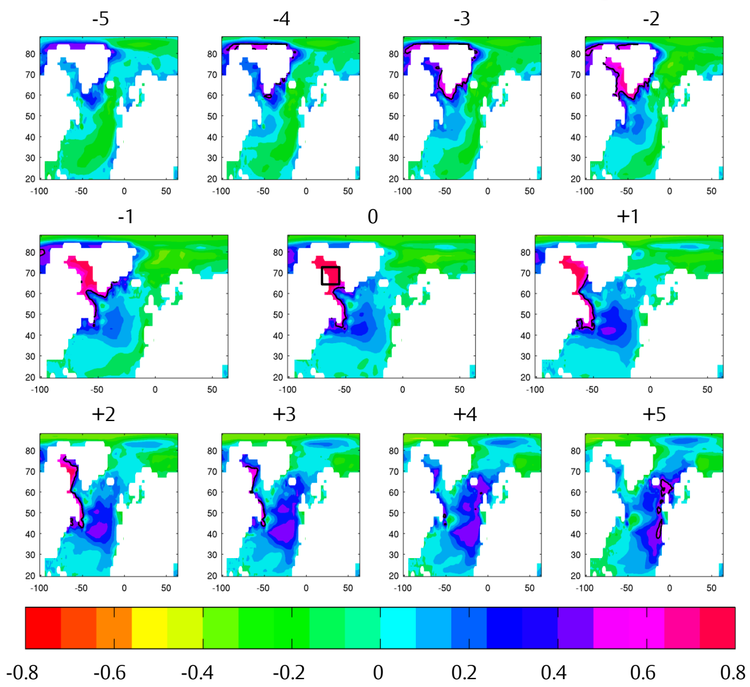
Salinity or Temperature?

The following figures show the correlations of total SH anomaly (relative to 1200m) of a 900 year control run of HadCM3 in the North Atlantic to SH driven by salinity (left) and temperature (right). The salinity anomalies dominate at high latitudes, especially in the Labrador Sea region. Temperature anomalies counter salinity in the Greenland Seas and Arctic Ocean. Note the "corridor" of low temperature correlations linking the salinity dominated regions of the Labrador Sea and Eastern Atlantic.



Timeseries show the variability in SH averaged over the Labrador Sea (boxes in maps above) in two transient (1860-2006) runs of HadCM3. The interannual-decadal variability is determined by haline anomalies (blue line) although the transient warming (red) is clear.

Labrador Sea Salinity



Lag correlations of salinity driven SH anomalies in the Labrador Sea (see box at zero lag) with the rest of the North Atlantic in the control run. Black contours show correlations greater than +0.5. Positive lag when Labrador Sea anomalies lead the rest of the North Atlantic.

The salinity anomalies in the Labrador Sea originate in the Greenland Seas. They spread southward along the Labrador Current, then move across the Atlantic with a positive correlation occurring in the Eastern Atlantic approx. 5 years after the anomaly in the Labrador Sea. The salinity anomalies appear in the regions identified above as those in which the total SH variability is driven by salinity.

Future Work

Given the relationship between salinity anomalies in the Labrador Sea and the patterns of salinity dominance of SH across the North Atlantic in HadCM3, we ask if similar relationships can be found in the real world (e.g. using Argo data) and in other coupled models, e.g. HadGEM.