Estimates of mid-latitude AMOC heat transport from ARGO float data

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Introduction

The importance of the AMOC for global climate is largely related to its role in transporting net heat to the mid-high latitude Atlantic region. *Willis* [2010] shows that by combining data from the ARGO array with satellite sea surface height data, a continuous time-dependent estimate of the strength of the AMOC can be acquired.

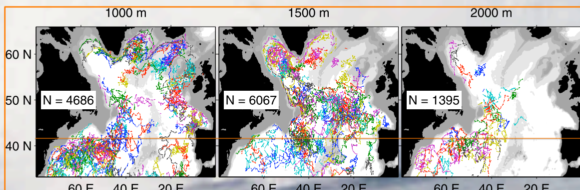
In this research a similar approach is used to make a time-dependent estimate of the AMOC's heat transport over the period of the ARGO data. A reliable time series of the AMOC's heat transport would have important implications for both monitoring climate change, and for analysis of the AMOC's influence on the global climate system

Method

The method of estimating transport using ARGO/SSH data is fully explained in the literature [*Willis & Fu,* 2008; *Willis*, 2010]. Briefly, hydrographic data from the ARGO profiles is used to estimate geostrophic shear, and ARGO drift displacements are used to estimate the 1000m velocity, these are combined to give a 4D estimates of the absolute dynamic height; SSH data is used to reduce sampling errors.

ARGO floats are restricted to regions where the ocean depth is greater than 2000m, hence the use of this data for transport estimates is restricted to regions with relatively small transport on the shallow continental shelf; this study uses the 41.5ºN latitude for this reason; the distribution of float-data in this region is shown below. Furthermore, certain assumptions must be made about the unobserved deep-ocean transport.

The volume balance of the basin is assumed to be closed, hence the total transport of the ocean below 2000m can be estimated from the sum of the ARGO-estimated geostrophic transport above 2000m and the Ekman transport (derived from the NCEP/NCAR reanalysis wind-stress data). As a first-pass, the sub-2000m ocean is assumed to be single isotropic water mass (i.e. with constant temperature, density and potential temperature). The sensitivity of the net heat transport to our constant -temperature assumption is assessed by using the highest and lowest potential temperatures in the sub-2000m ocean from climatology. This method is assessed using climatological data.



North Atlantic ARGO float displacements by drift depth; colors indicate each individual float's trajectory. The 41.5oN line used in this study is indicted by a line. *(reproduced by permission from Willis & Fu, 2008)*

Validation

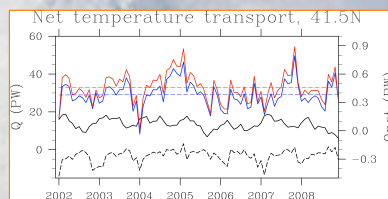
To test the proposed method, the volume and temperature transports were calculated for the section (i.e. 41.5ºN) for Levitus World Ocean Atlas (WOA09) and WOCE-WGHC climatologies of temperature and salinity, using the 1000m ARGO velocity as a reference velocity

The black profiles (right) show the transport using the climatology data throughout the depth of the section. (There was a net volume transport of 6.11/6.59 Sv for the WOA09/WGHC climatologies respectively; this was 'closed' by adding a correction velocity to the ARGO reference velocity). The net temperature transport is (including Ekman) shown in the first column below.

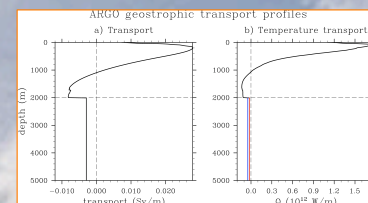
The magenta profiles are calculated using the method described for the ARGO data; the transport is calculated for the upper 2000m from the data, and below this level volume closure is applied for a constant density (1030 kgm^{-3}), heat capacity (3900 $J(kgK)^{-1}$) and high and low estimates of sub-2000m potential temperature (1.78 and 3.89 K); net values are shown in the table below.

The upper/lower estimates of net temperature transport are close to the net values calculated for the full-depth climatological data, indicating that the method is reasonable.

	net Q (PW)	lower estimate Q (PW)	upper estimate Q (PW)
WOA09	0.54	0.39	0.52
WOCE-WGHC	0.39	0.27	0.41



Temperature transport at 41.5ºN estimated from ARGO date. Black solid (dashed) lines show the super-2000m geostrophic (NCEP Ekman) temperature transport (left-hand y-axis). Red (blue) lines show the upper (lower) estimated net temperature transport (right-hand y-axis), with dashed lines showing the trends.



Profiles of time-mean 41.5ºN temperature and volume transport from ARGO data. Red (blue) lines indicate upper (lower) estimates of sub-2000m temperature transport.

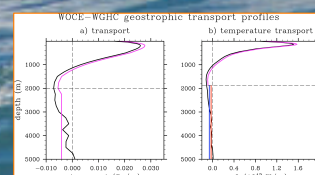
Results & Summary

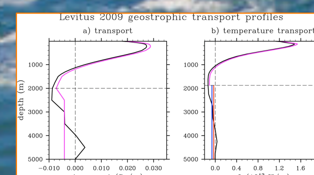
The time-mean net temperature transport estimate using the ARGO data and the closed-volume assumption is 0.38 – 0.46 PW, consistent with previous estimates of North Atlantic heat transport. A major source of uncertainty is the unobserved variability in sub-2000m temperature; the narrow range of the high/low temperature transport estimates suggest that the method is robust with respect to deep-ocean temperature.

No significant trend is observed over the relatively short period of observation. Comparison of the Ekman (dashed) and super-2000m heat transports suggest that although the Ekman component is relatively weak, it is an important contributor to the AMOC's heat transport.

Further work is required to validate the variability expressed by the heat transport estimates, for example by comparison with the RAPID array. Sources of uncertainty that have yet to be considered are the transport of heat on the shallow continental shelf, and the validity of the constant-volume assumption used to estimate sub-2000m transport.

Initial results are encouraging, and indicate that this method will provide robust estimates of heat transport for climate analysis.





Profiles of 41.5ºN temperature and volume transport for the Levitus (WOA09) and WOCE-WGHC climatologies. Black curves show the profiles calculated for the full-depth observations. Magenta curves are calculated using the estimated sub-2000m transport method (red/blue lines show the upper/lower estimated temperature transports)