E16

North Atlantic gyre-scale property changes and MOC variability over the last 60 years

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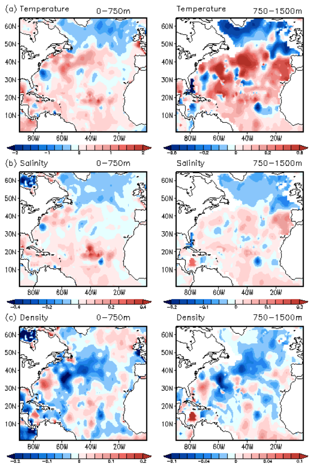
1. Historical data analysis

Two independent hydrographic data sets (HYDROBASE and Met Office) have been used to assess the changes in the temperature, salinity and density over the last 60 years. HYDROBASE is based on hydrographic station data binned into 1ºx1º grid for the North Atlantic T/S and averaged over two 20 year periods: 1950-1970 and 1980-2000, Lozier, et al., 2010. The Met Office data set is compiled by an advanced objective analysis of ocean T and S using covariances from a global climate model (Smith and Murphy, 2007). It covers the period 1950 to 2009 with monthly resolution.

The long term property changes show:

- freshening and cooling in the subpolar gyre; warmer and saltier waters in the subtropical gyre
- density compensated T and S changes reflected by reduced density changes
- T and S are not completely compensated leading to a decrease of density in 1980-2000



Salinity, temperature and density changes (1980-2000) minus (1950-1970)

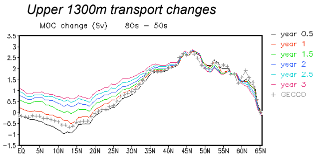
2. Model set-up and test experiments

The overturning is diagnosed using a dynamical adjustment in the MITGCM (global 1ºx1º set-up and 23 vertical levels). The model is initialised from gridded T/S data and integrated for few years to allow the density field to dynamically adjust and to spin-up the wind driven circulation. The model is forced by monthly NCEP winds averaged for each 20 year period. Weak internal 3D T/S relaxation towards initial fields has been applied.

- For the test case we use 20 year mean T/S from GECCO (GECCO, Koehl et al., 2006) and compare the model MOC with the transports directly calculated from GECCO monthly velocities.
- Then we replace the North Atlantic GECCO T/S by HYDROBASE data for the two 20 year periods, repeat the runs and use the model transports to diagnose the MOC change.
- Same procedure has been repeated with the Met Office global data on annual basis, using interannually and monthly varying NCEP winds.

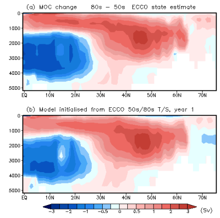
GECCO Test case

Upper 1300m transport changes



coloured lines - 12 month running mean transport difference;
++++ transport difference from GECCO velocity field

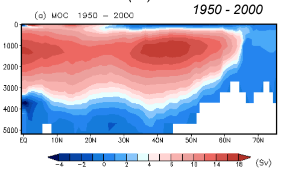
GECCO MOC change ('model truth')



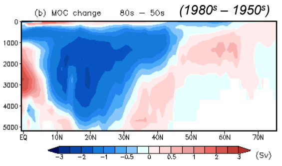
Model MOC change (year 1)

4. MOC changes

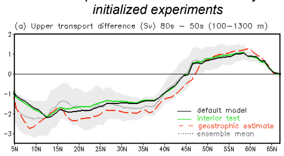
Model MOC (Sv) 1950 - 2000



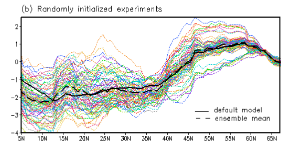
(1980s – 1950s)



Transport difference from randomly initialized experiments



gray shades ± σ



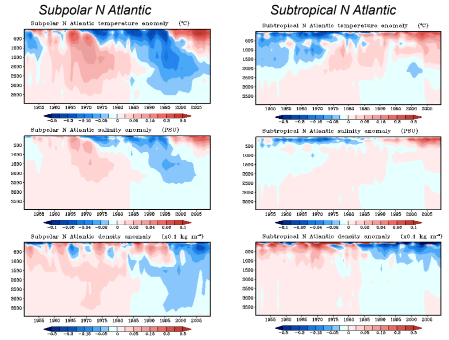
Individual random members (coloured lines)

Uncertainties in the MOC changes have been assessed by Bayesian-type perturbation experiments carried out by randomly perturbing initial fields using the density standard errors for the historical data. The ensemble mean of 80 random members is close to the estimate from the default run with confidence limits based on the standard deviation of the ensemble. The transport change is typically – 2 Sv (± 1 Sv) in the subtropical gyre and + 1 Sv (± 0.5 Sv) for the subpolar gyre. In the case of removed data points along the topography (interior test, green line), the model communicates the interior T/S along the boundaries, recovering west east density contrast and leading to a transport change very close to the default case.

4. MOC variability estimated from Met Office data

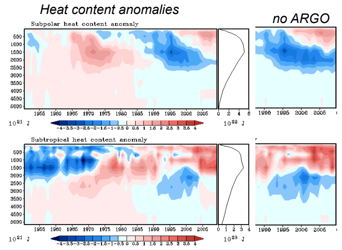
Met Office salinity, temperature and density anomalies

Subpolar N Atlantic — Subtropical N Atlantic



- property changes show gyre confined and opposing patterns similar to Hydrobase estimates
- increased T and S over the upper 2000m across the basin during the last decade
- T and S not completely compensated leading to a gradual decrease of density since 1995

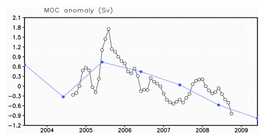
Heat content anomalies — no ARGO



The recent increase in the heat content of the upper 2000m is dominated by the subtropical warming, but extends across the entire basin. The warming likely to reflect a natural variation, not a bias due to ARGO

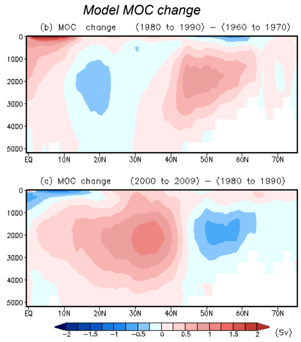
Model MOC change versus RAPID

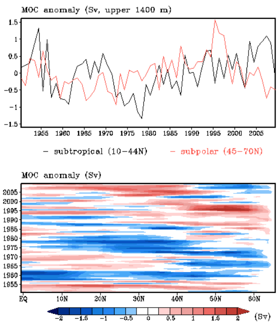
-- model -- RAPID



The model captures the trends in the RAPID array MOC variability with lower amplitudes due to the use of annual mean T/S

Model MOC change





The long term MOC changes estimated from the Met Office data are in accord with the previous results with opposing signals in subtropical and subpolar gyres. The changes in the later period (2000 to 2009) show the opposite pattern: increase in the subtropical and decrease in the subpolar gyres. MOC changes, estimated on annual basis, show more complicated structures with amplitudes of 1.5 - 2 SV superimposed on the long term decadal variations.

5. Conclusions

- data analysis shows different responses in the long term property changes in the subtropical/subpolar gyres: freshening and cooling in the subpolar gyre; warmer and saltier waters in the subtropical gyre
- density compensation of T and S changes reflected by reduced density changes
- T and S not completely compensated leading to a decrease of the density in 1980 to 2000
- model estimates of the long term MOC changes show weakening over the subtropical gyre by 2 Sv (± 1 SV) and slight increase over the subpolar gyre by 1 Sv (± 0.5 Sv)
- MOC variations estimated on annual basis from Met Office data set have similar amplitudes, but show more complicated patterns and opposing changes in the latest period

References:

Lozier, MS, V Roussenov, MSC Reed and RG Williams 2010. On the spatial pattern of meridional overturning changes in the North Atlantic, Nature Geoscience, , DOI: 10.1038/NGEO94.

Smith, DM and JM Murphy, 2007. An objective ocean temperature and salinity analysis using covariances from a global climate model. JGR, 112, C02022.