Variability in the hydrographic properties and the overturning over the last 50 years for the North Atlantic

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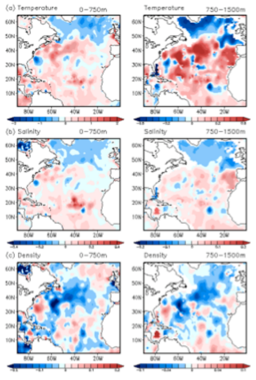
1. Historical data analysis

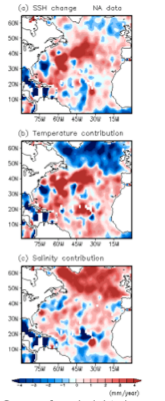
Two independent hydrographic data sets (WHOI-HYDROBASE and Met Office) have been used to assess the changes in the temperature, salinity and density over the last 50 years. HYDROBASE data set is based on hydrographic station data binned into 1°x1° grid for the North Atlantic T/S and averaged over two 20 year periods: 1950-1970 (50^s) and 1980-2000 (80^s), Lozier, et al., 2009. The Met Office data set is compiled by an advanced objective analysis of ocean temperature and salinity using covariances from a global climate model (Smith and Murphy, 2007). It covers the period 1950 to 2009 with monthly temporal resolution.



Salinity, temperature and density changes (80^s – 50^s)

The long term property changes show:

- 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 are not completely compensated leading to a decrease of density in 80^s
- T/S changes in the Met Office data set show similar gyre confined and opposing signals with slightly reduced amplitudes and smoother patterns



Sea-surface height change diagnosed from the data

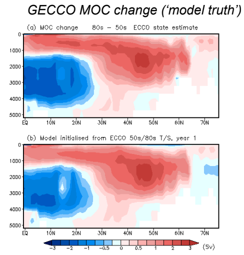
- SSH changes comparable with reconstructions of sea level rise between 1950 and 2000 of typically 3 mm yr^{-1} along 40° N (Church et al., 2004)
- opposing T/S contributions to the SSH change with partial compensation
- different response in the subtropical and subpolar gyres with sharp contrast along inter-gyre boundary

2. Model set-up and test experiments

MITGCM in a global 1°x1° set-up and 23 vertical levels has been used as dynamical adjustment tool. For each 20 year period, average T/S fields from GECCO state estimate (GECCO, Koehl et al., 2006) have been used to initialize the model and the model is 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. Internal 3D T/S relaxation towards initial fields has been used with 3 years restoring timescale. For the test case we use mean T/S from GECCO and compare the model MOC with the transports directly calculated from GECCO monthly velocities. Then we replace the North Atlantic GECCO T/S by our gridded data sets 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.

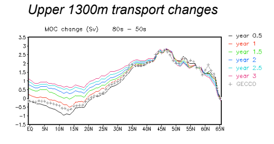
GECCO Test case

GECCO MOC change ('model truth')



Model MOC change (year 1)

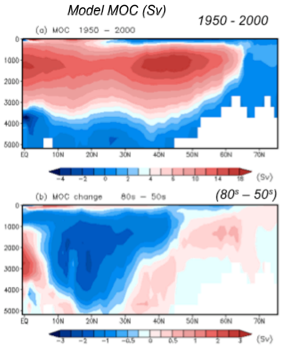
Upper 1300m transport changes



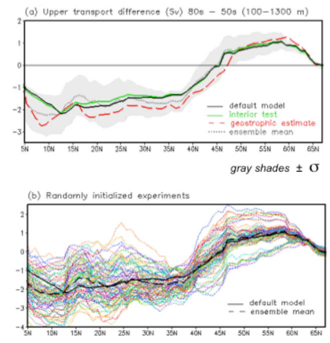
coloured lines - 12 month running mean transport difference;
++++ transport difference from GECCO velocity field

3. MOC changes

Model MOC (Sv)



Transport difference from randomly initialized experiments

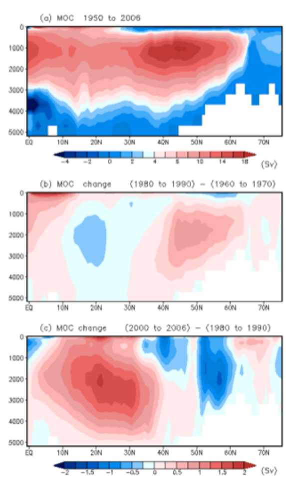


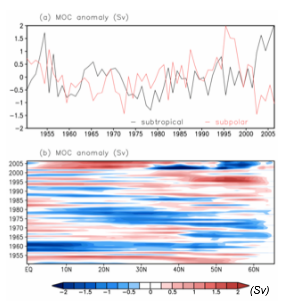
gray shades ± σ

Individual random members (coloured lines)

Uncertainties in the MOC changes have been assessed by Baysian-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 in the subtropical gyre is typically – 2 Sv (± 1 Sv) 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





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 2006) 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^s
- 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 2009. On the spatial pattern of meridional overturning changes in the North Atlantic, submitted.

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