Assessing how North Atlantic ocean overturning has varied over the last 50 years

Vassil Roussenov[1], Ric Williams[1], M. Susan Lozier [2] and Doug Smith[3]

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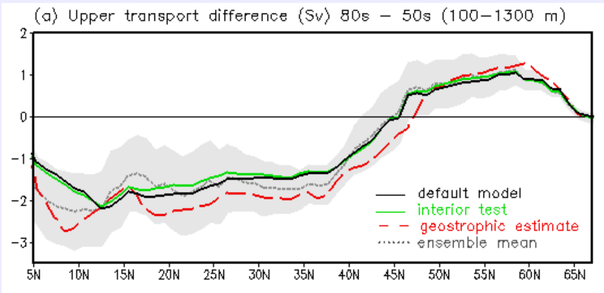

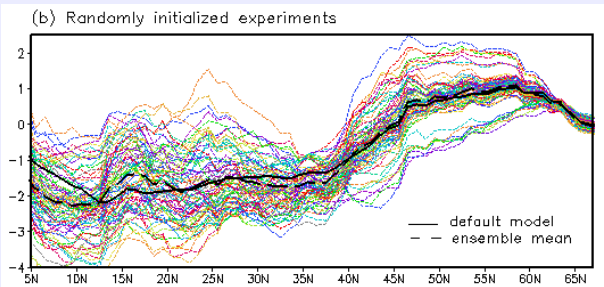

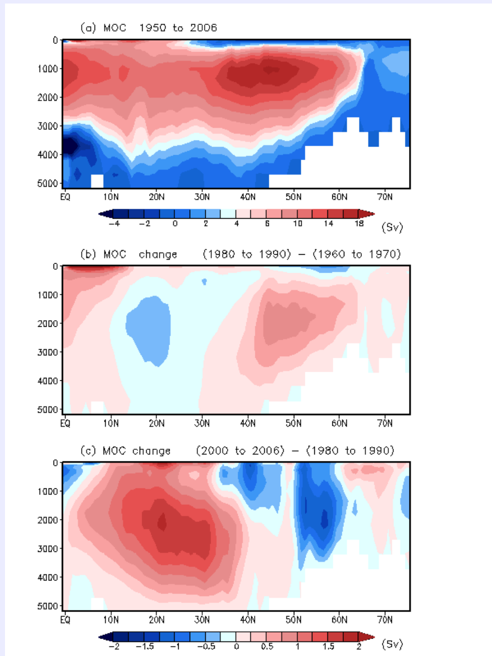

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Met Office

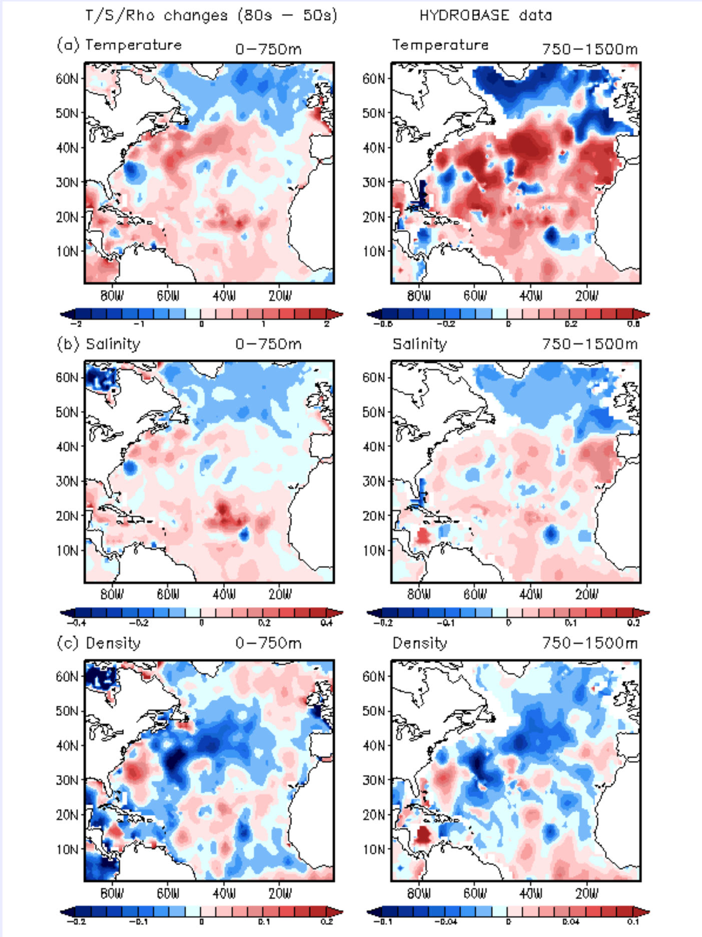
1. Long term property changes in the North Atlantic, WHOI-HYDROBASE data set
2. Model set-up and dynamical adjustment experiments
3. Model assessment of the North Atlantic MOC changes
4. MOC and property variability estimated from Met Office data set

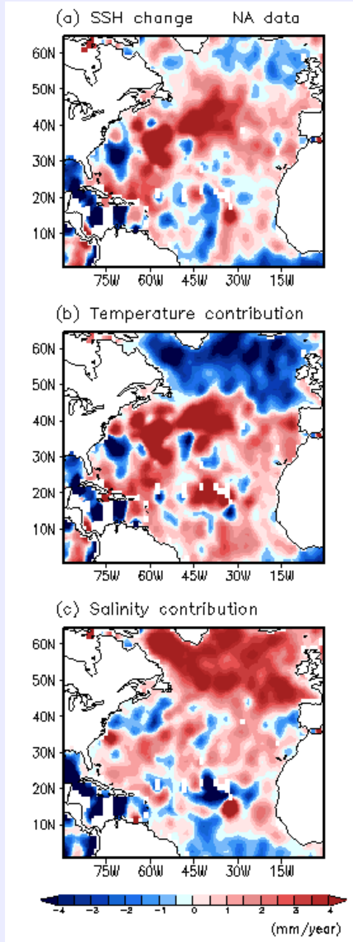
1. Long term property changes in the North Atlantic, data – model analysis

NERC RAPID, collaboration with S. Lozier, Duke University

Opposing decadal changes for the North Atlantic meridional overturning circulation.
M. Susan Lozier, Vassil Roussenov , Mark S. C. Reed and Richard G. Williams
Nature Geoscience, 2010, DOI: 10.1038/NGEO94

HYDROBASE Data set analysis:
hydrographic station data from NODC World Ocean Database 2005 binned into $1^o \times 1^o$ grid for the North Atlantic T/S and averaged over two 20 year periods: 1950-1970 and 1980-2000. Long term property changes: freshening and cooling in the subpolar gyre; warmer and saltier waters in the subtropigal gyre; density compensation of T and S changes reflected by reduced density changes. SSH changes comparable with reconstructions of sea level rise between 1950 and 2000 of typically 3 mm yr^{-1} along 40^o N (Church et al., 2004); opposing T/S contributions to the SSH change with partial compensation

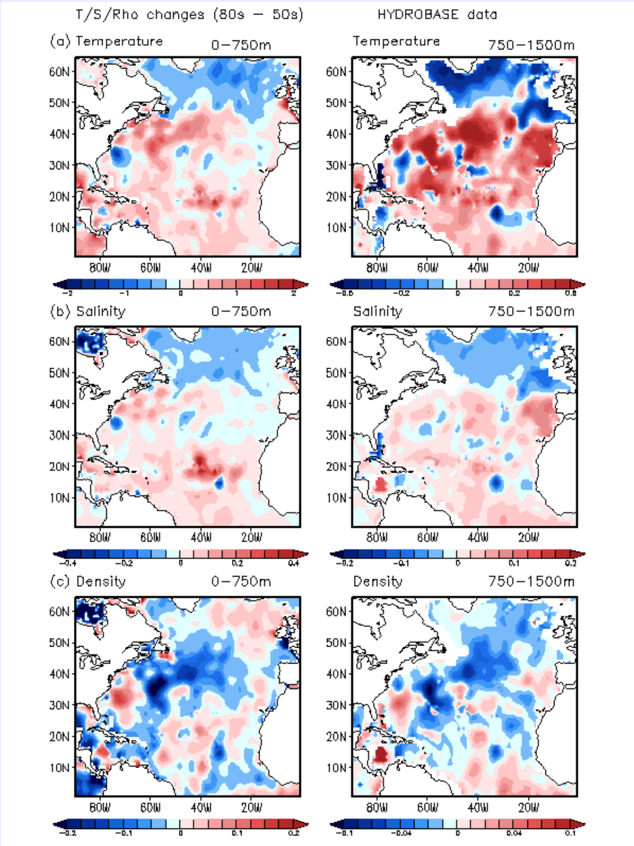




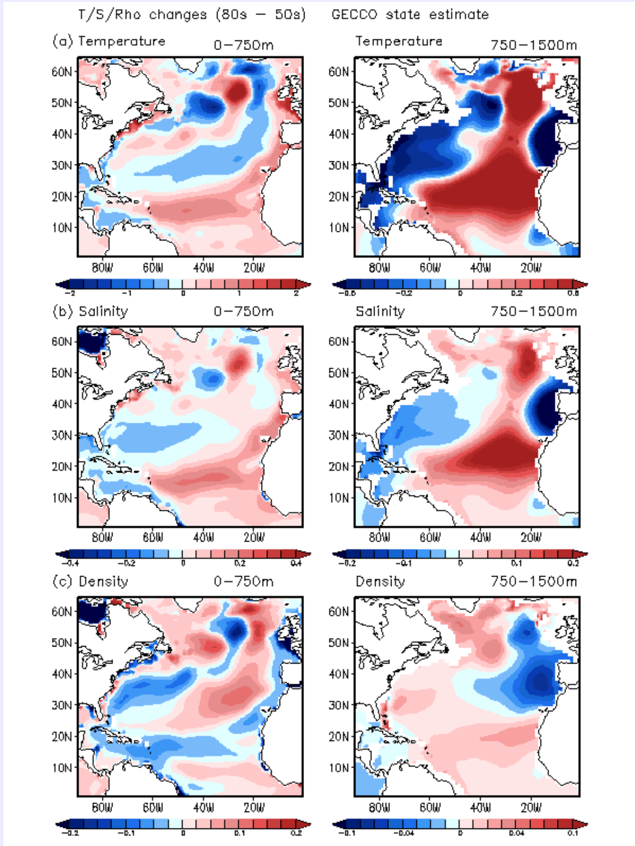
Hydrographic data assimilation

MOC can be reconstructed by data assimilated in the GCM, but results vary with the different assimilation procedures.
GECCO example: hydrographic data, similar to HYDROBASE data, assimilated with MITGCM and it's adjoint model for the period 1952 - 2001

HYDROBASE data



GECCO data assimilation

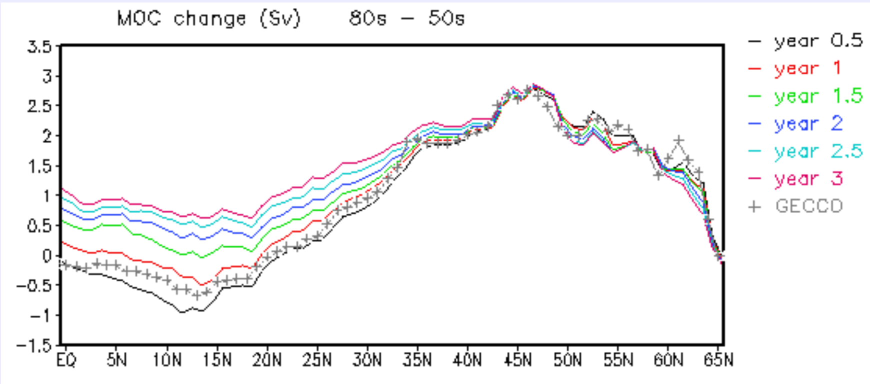


Model dynamics dominates and substantially modifies assimilated data

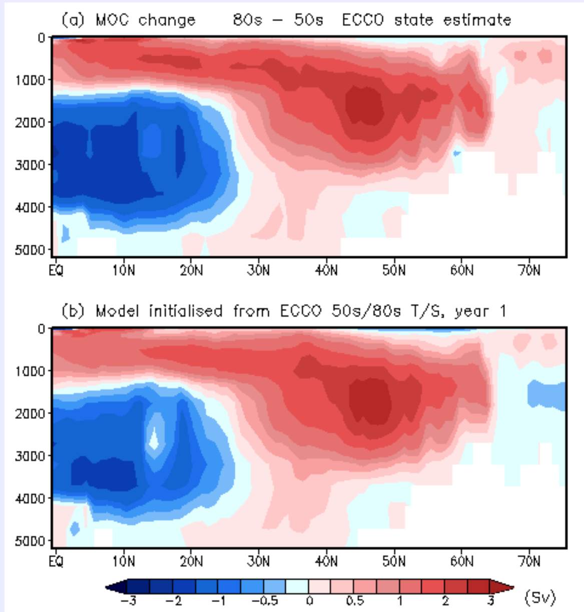
MITGCM MOC variability – GECCO test

‘Model truth’ - MOC change for the two 20 year periods based on GECCO monthly velocities
Form mean T/S data sets for each 20 year periods from GECCO monthly T/S

MITGCM in a global 1ºx1º set-up and 23 vertical levels is used as dynamical adjustment tool. For each 20 year period, T/S data sets 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 and a weak internal 3D T/S relaxation towards initial fields used



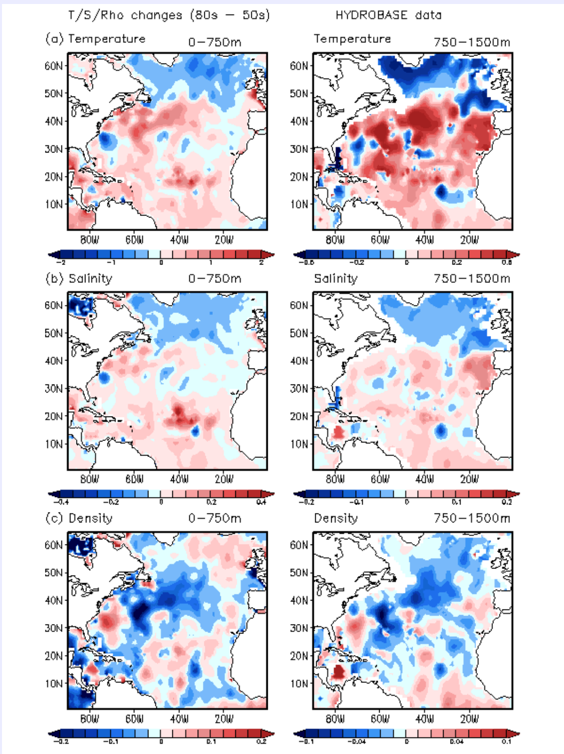
The model reproduces well the MOC changes during the first year of integration. Further integration modifies the model T/S and velocity field, leading to enhanced drift over the subtropical gyre.



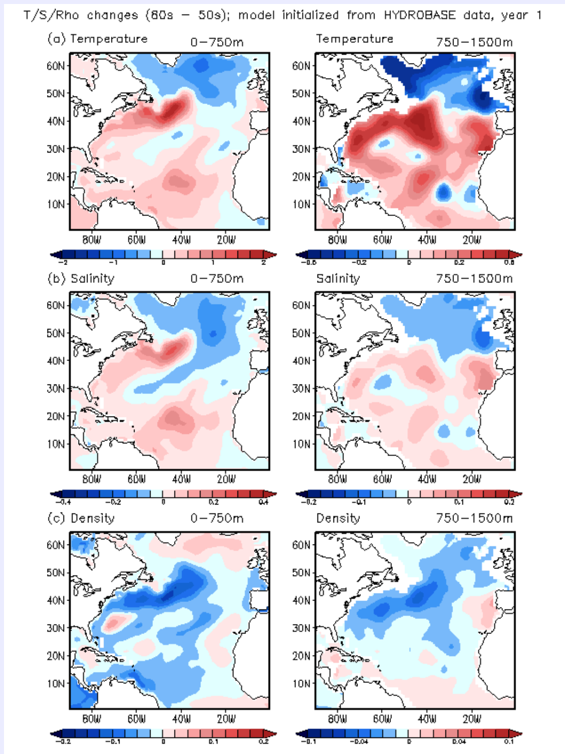
3. North Atlantic property changes , HYDROBASE data – model analysis

For each 20 year period, N Atlantic T/S replaced by HYDROBASE T/S and the test experiment repeated in order to dynamically adjust the density field and to spin-up the wind-driven circulation.

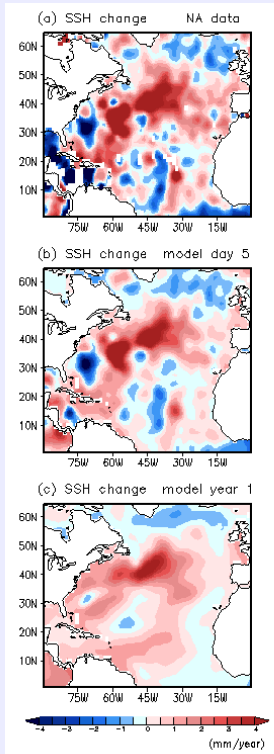
HYDROBASE data



Model year 1

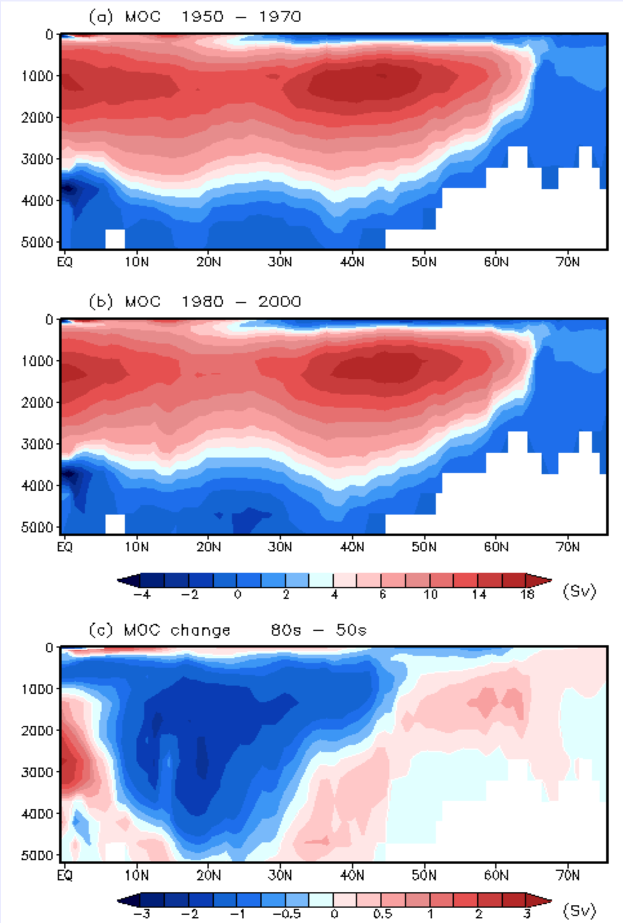


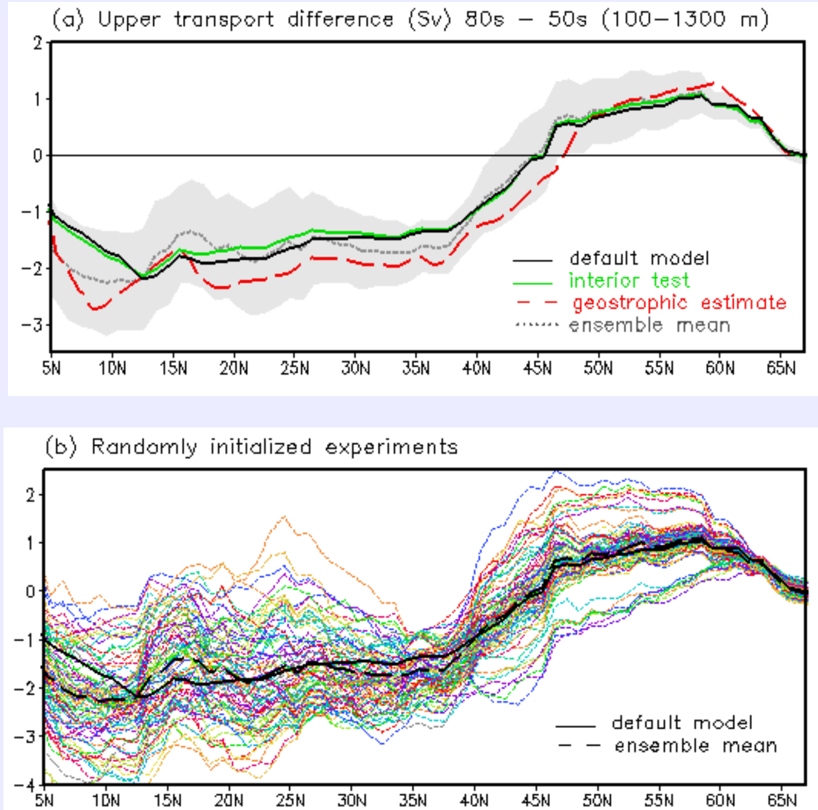
SSH



MOC changes

MOC changes diagnosed from the model velocity field for year 1 and the uncertainties estimated by randomly perturbing initial fields using the density standard errors for the historical data. 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.

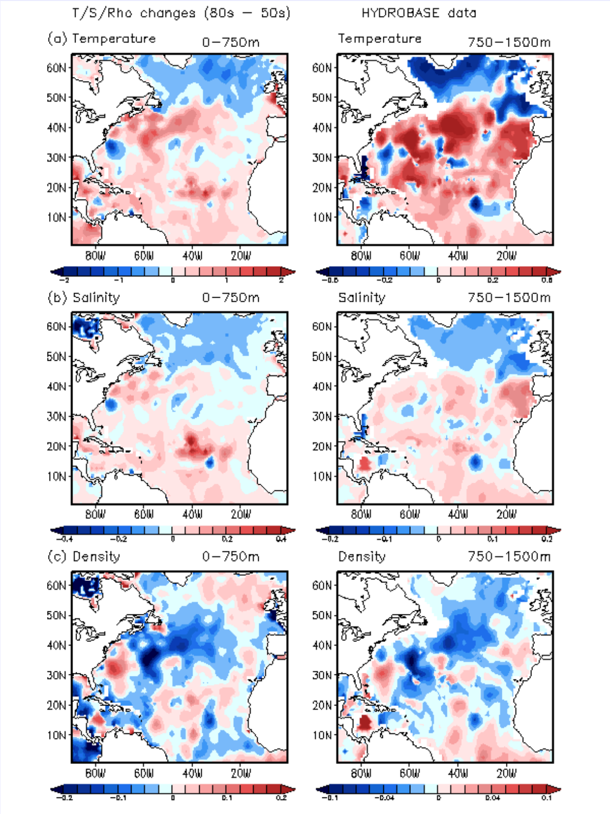
Met Office hydrographic data set

The Met Office data set is based on advanced objective analysis of hydrographic data, using HADCM correlation fields (Doug Smith and James Murphy, JGR,2007).
The data set consists of monthly T/S, global 3D fields on 1.25^{o}x1.25^{o} grid for the period 1950 – 2009.

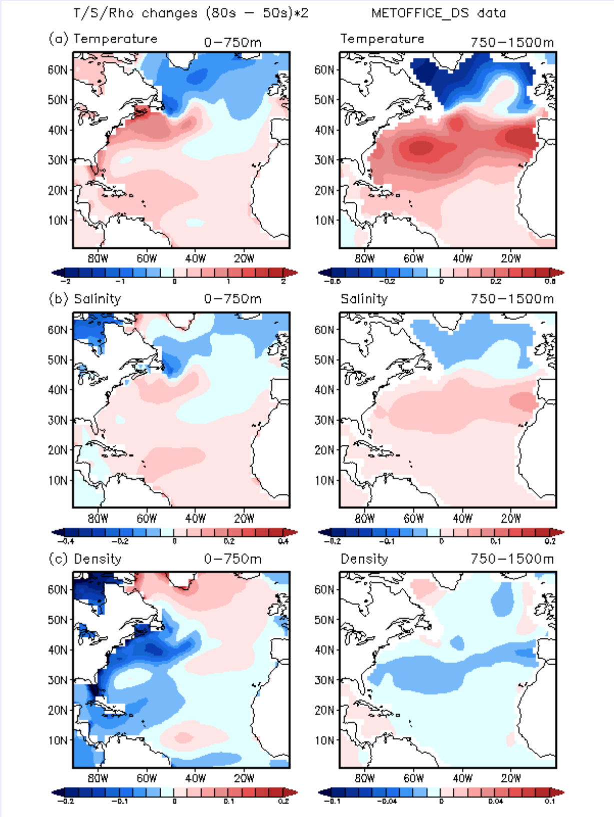
Annual mean T/S, interpolated into the MITGCM grid, have been used to initialize the model (similar procedure as for the HYDROBASE data) and diagnose the MOC, SSH, heat content etc. for each individual year.

Met Office data set, property changes

HYDROBASE data

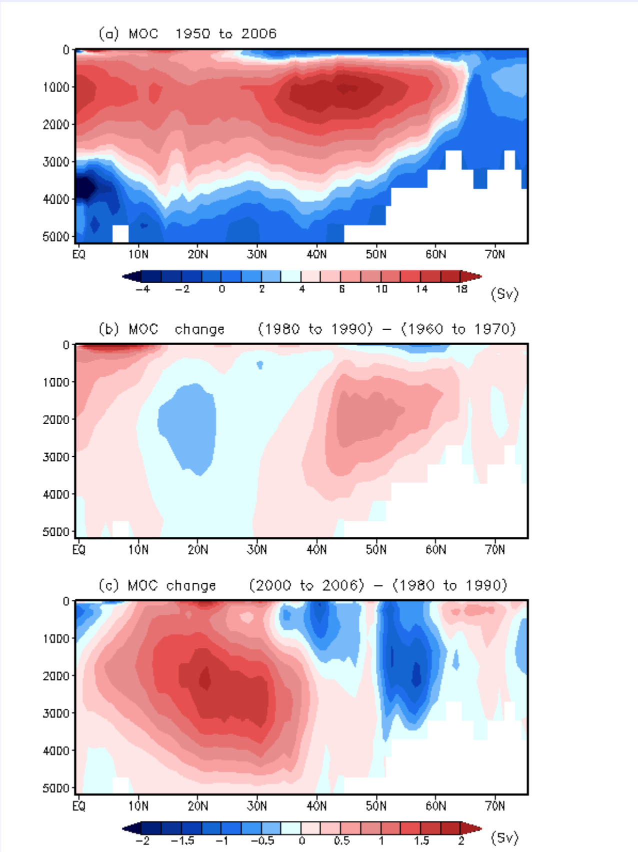


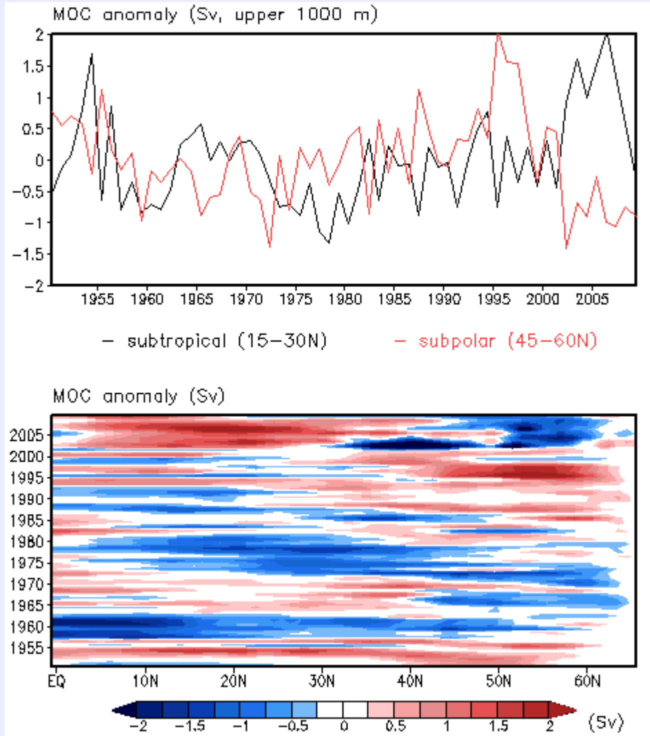
Met Office data



MOC variability estimated from the Met Office data

MITGCM initialized with Met Office data for each individual year 1950 – 2009. MOC changes diagnosed from the model annual mean velocity field for year one.





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 annual amplitudes of 1.5 - 2 SV superimposed on the long term decadal variations.

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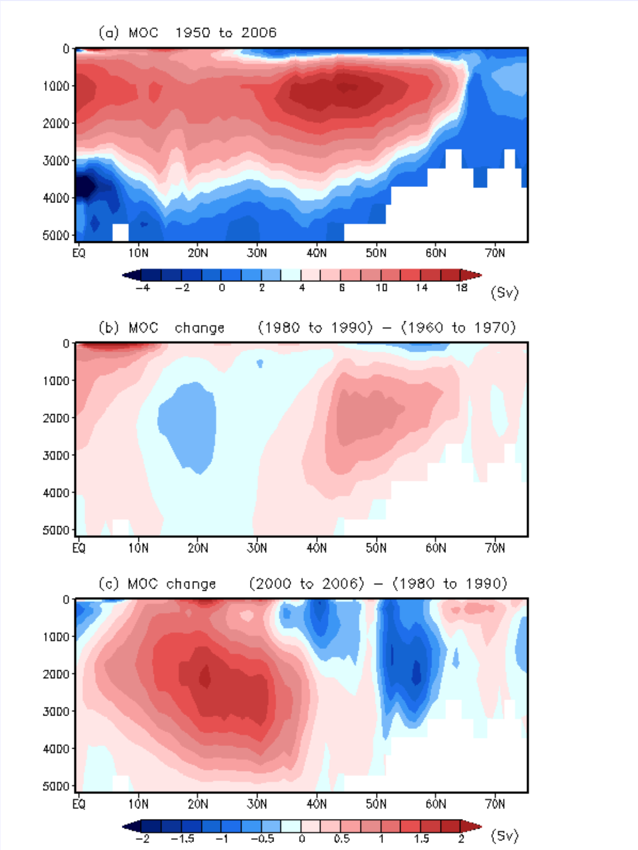
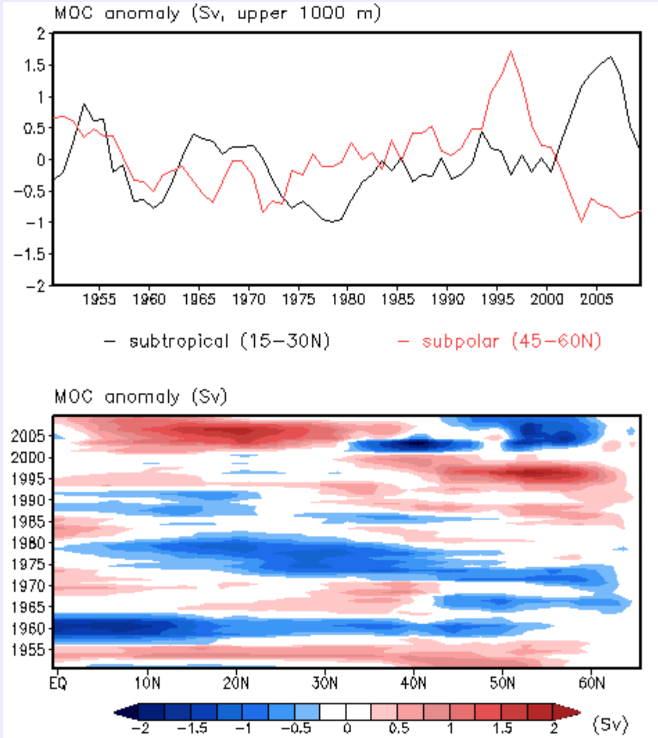
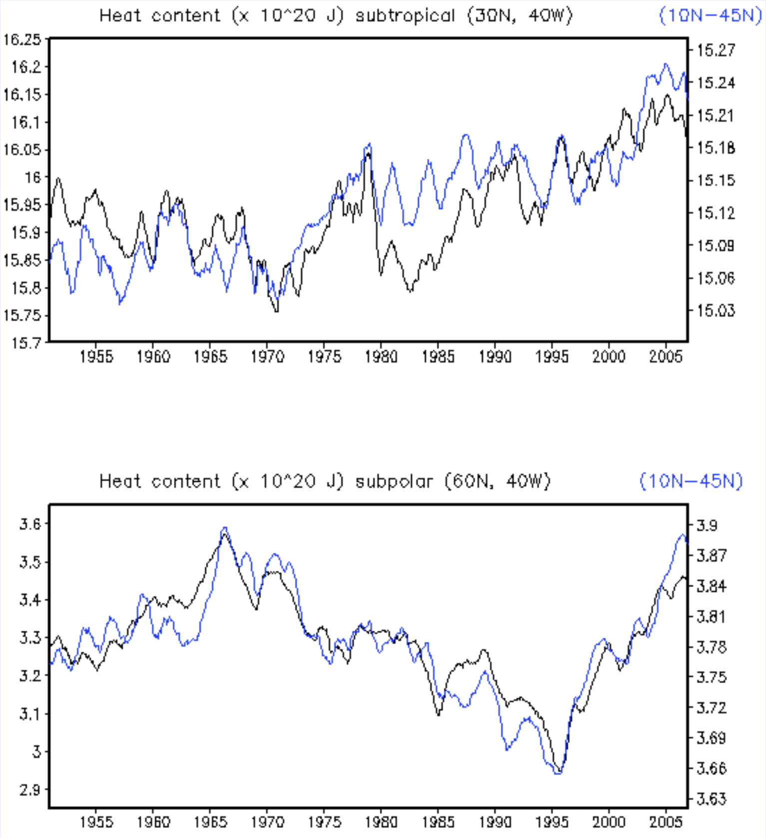




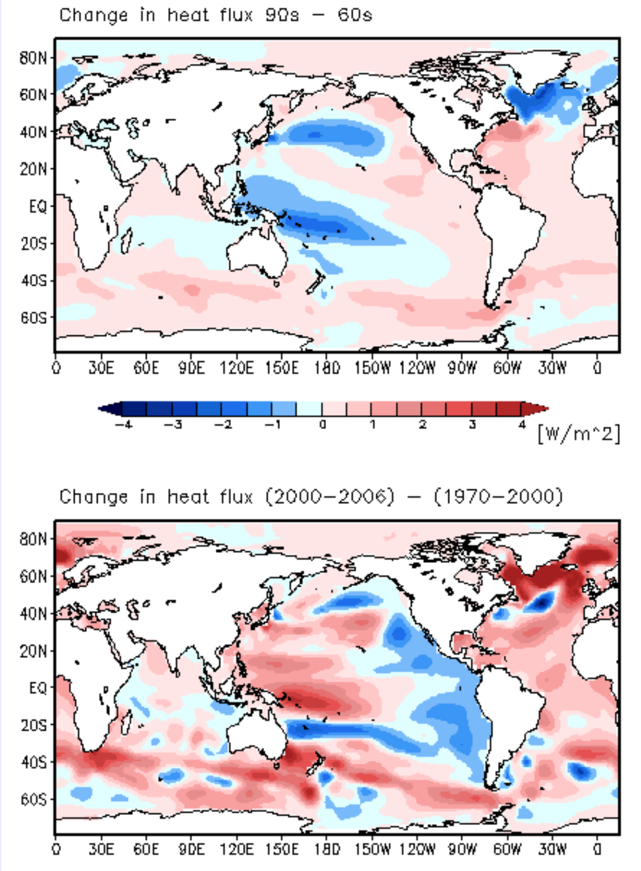
3 year running mean

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 annual amplitudes of 1.5 - 2 SV superimposed on the long term decadal variations.

Heat content changes estimated from the Met Office data



Subtropical gyre heat content increases since 1970 with slightly accelerated trend during the last decade. The heat content of the subpolar gyre decreases from 1965 to 1995, but increases during the last decade.



Changes in the heat flux diagnosed from the heat content changes

Conclusions

Different gyre-scale long term property changes: freshening and cooling in the subpolar gyre; warmer and saltier waters in the subtropigal gyre

Density compensation of T and S changes reflected by reduced density changes, but overall decrease of the density in the later period

SSH changes comparable with reconstructions of sea level rise between 1950 and 2000 of typically 3 mm yr^{-1}

Weakening of the overturning in the subtropical gyre by – 2 Sv (± 1 Sv) and strengthening by + 1 Sv (± 0.5 Sv) for the subpolar gyre from 1960^{s} to 1990^{s}, but this pattern reverses during the last decade

The heat content changes also show opposing trends in the subtropical and the subpolar gyres during the early period, but an increase for both gyres from 1995 till now