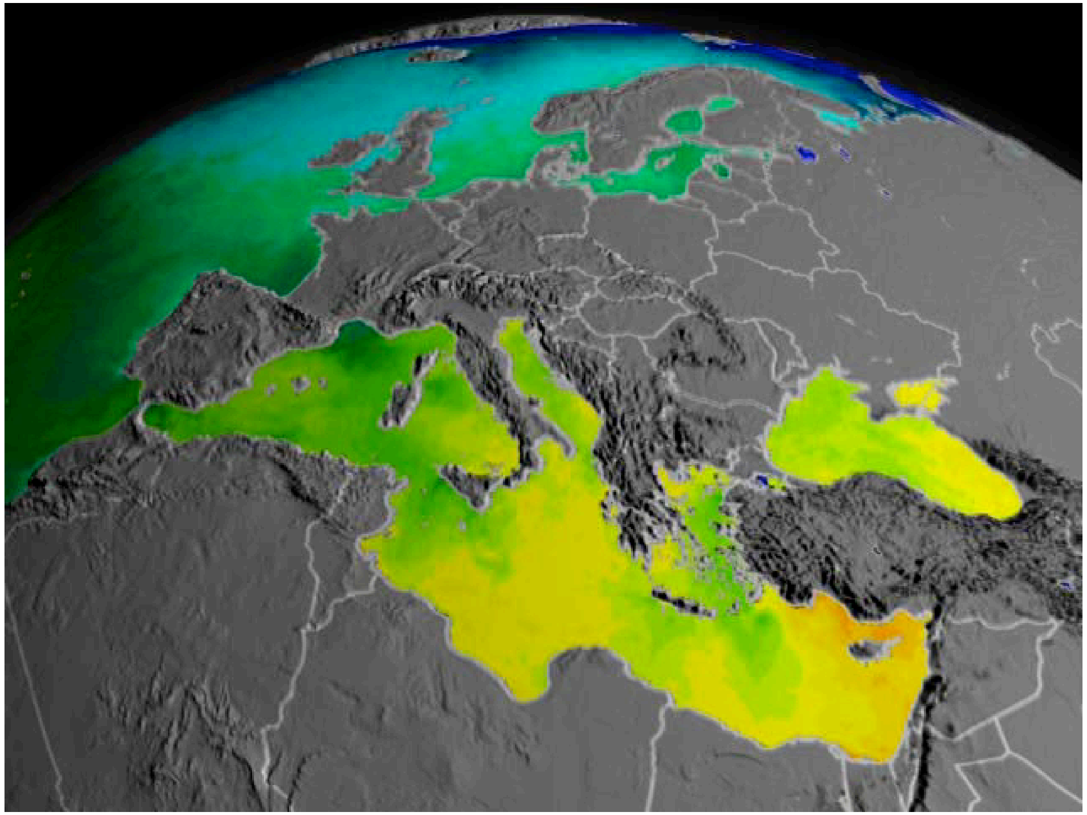
Climate change in the ocean

UNIVERSITY OF LIVERPOOL

1. Exploit historical data
   heat content changes
   implied overturning changes

2. Carbon emissions
   long-term effect of ocean chemistry

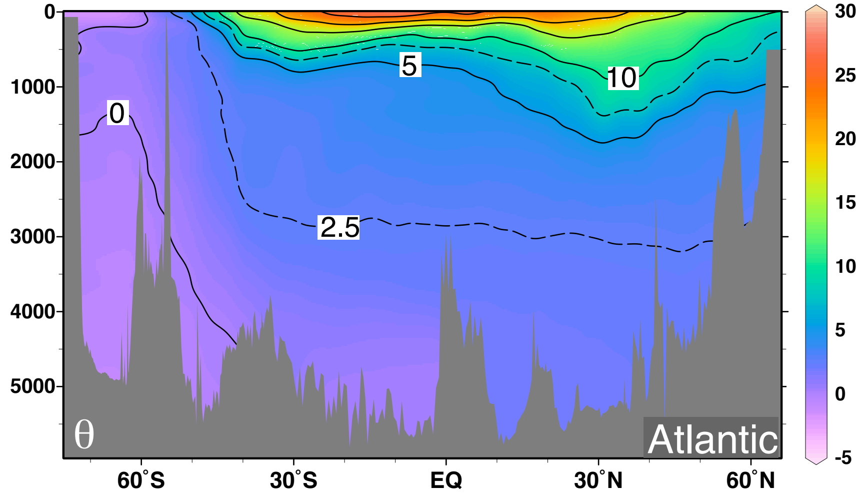


Observed Surface Temperature Highlighting the Gulf Stream (2002 to 2006)

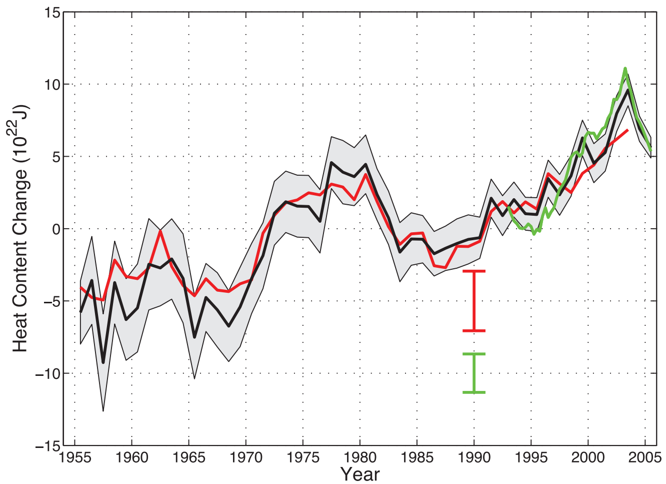
Prof. Ric Williams, Research Centre for Marine Sciences and Climate Change

Why care about the ocean?

- upper 2.5 m of ocean holds as much heat as overlying atmosphere



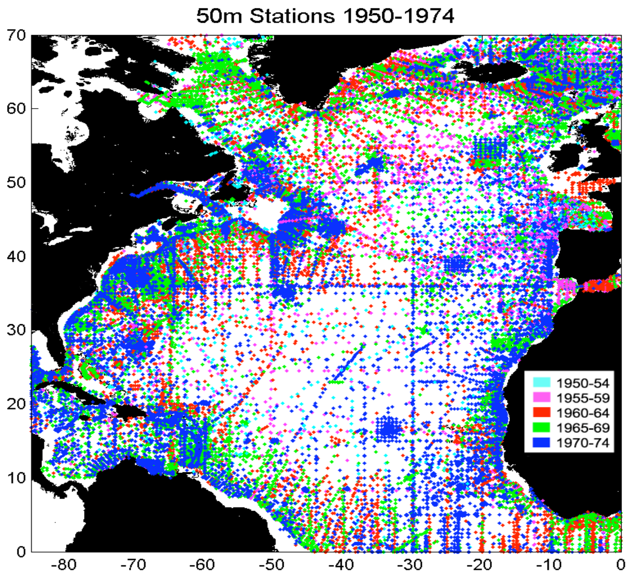
- oceans have absorbed more than 80% of the heat added to the climate system (IPCC, 2007)



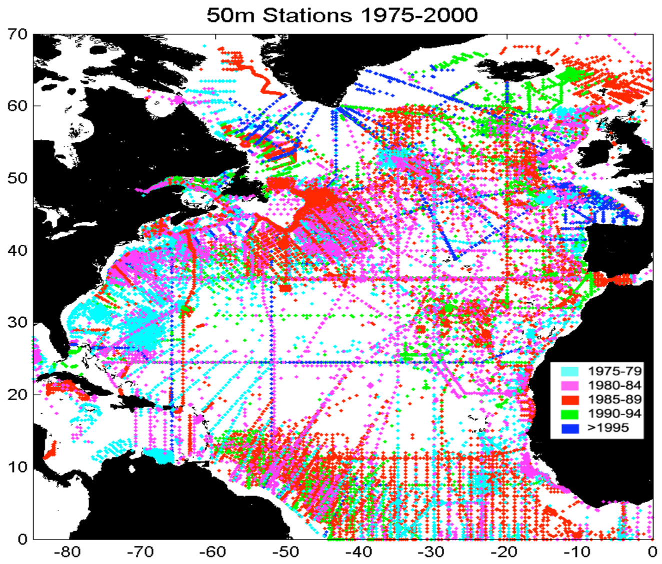
Time series of upper ocean heat content (10^{22}J) for the upper 700m. IPCC (2007) data

1. Historical data

1950-1974



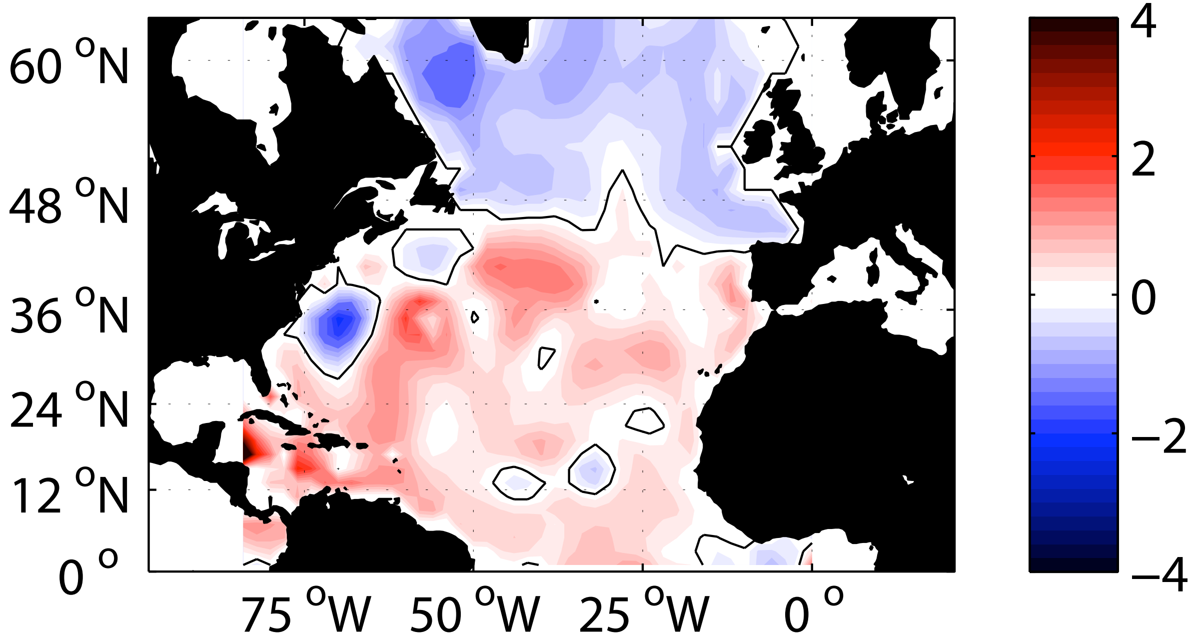
1975-2000



data from NODC World Ocean Atlas (2001)
and WOCE programme

analysed by Susan Lozier, Duke University data

How has ocean warmed over last 50 years?



Equivalent to surface heat flux +/− 4 Wm^{-2}
basin change only 0.4 W m^{-2}

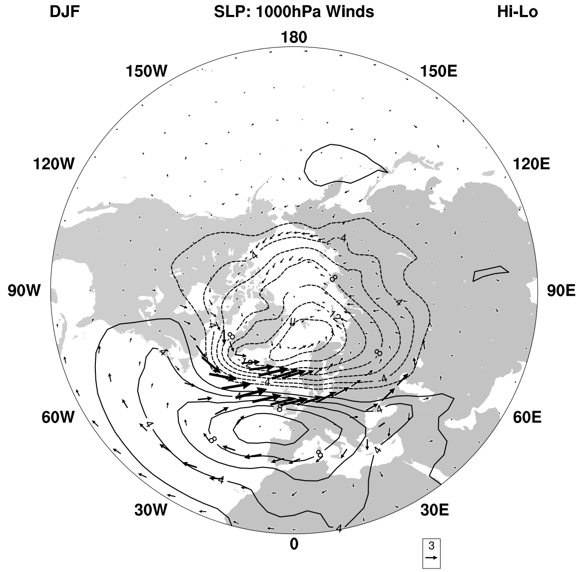
Change in ocean heat content (10^{20}J) between 1980-2000 and 1950-1970

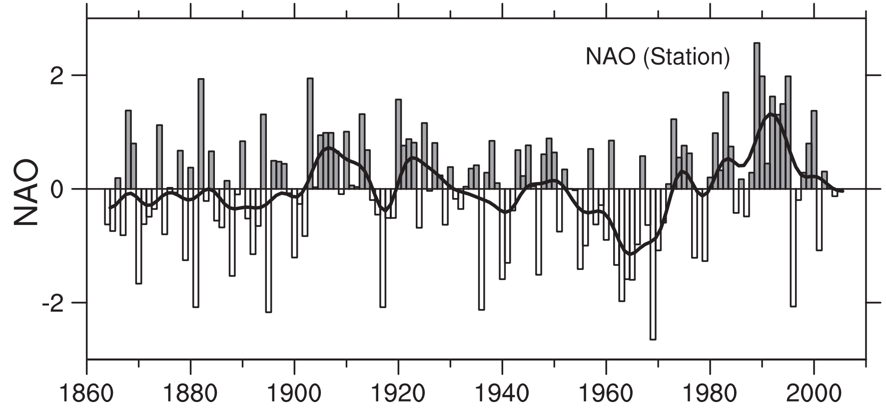
Lozier, Leadbetter, Williams et al. (2008) Science

North Atlantic Oscillation

model

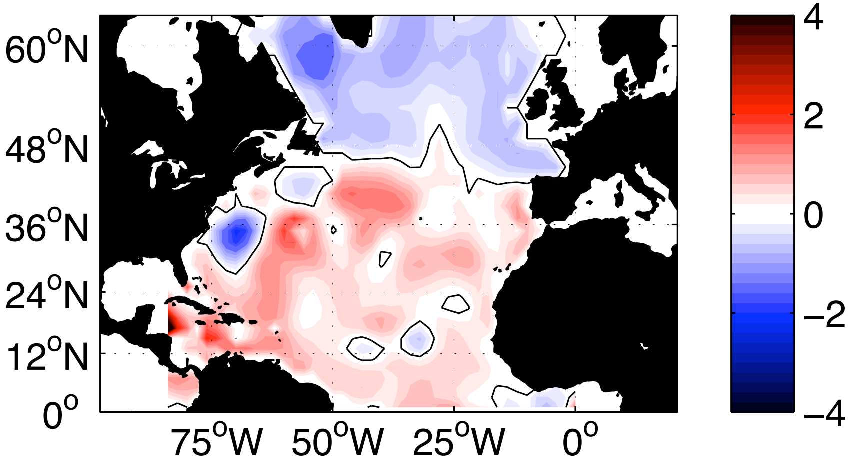
surface wind anomaly for NAO+ minus NAO-



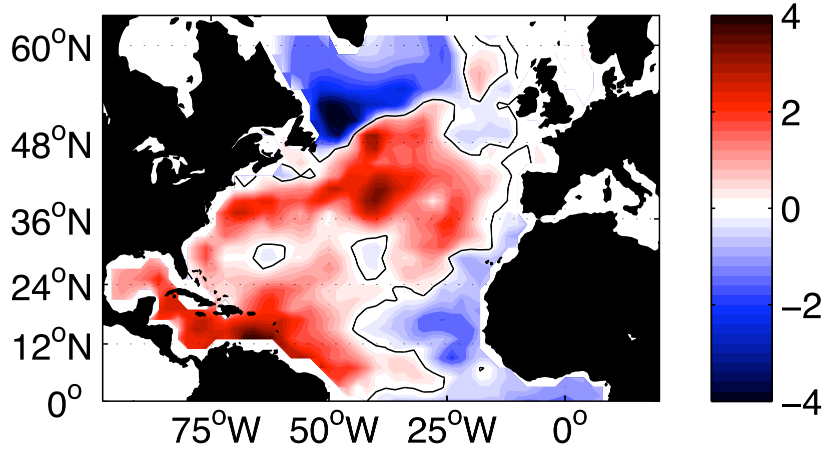


Winter indices of the NAO for sea level pressure from Portugal-Iceland

Observations



Model – NAO+ minus NAO-

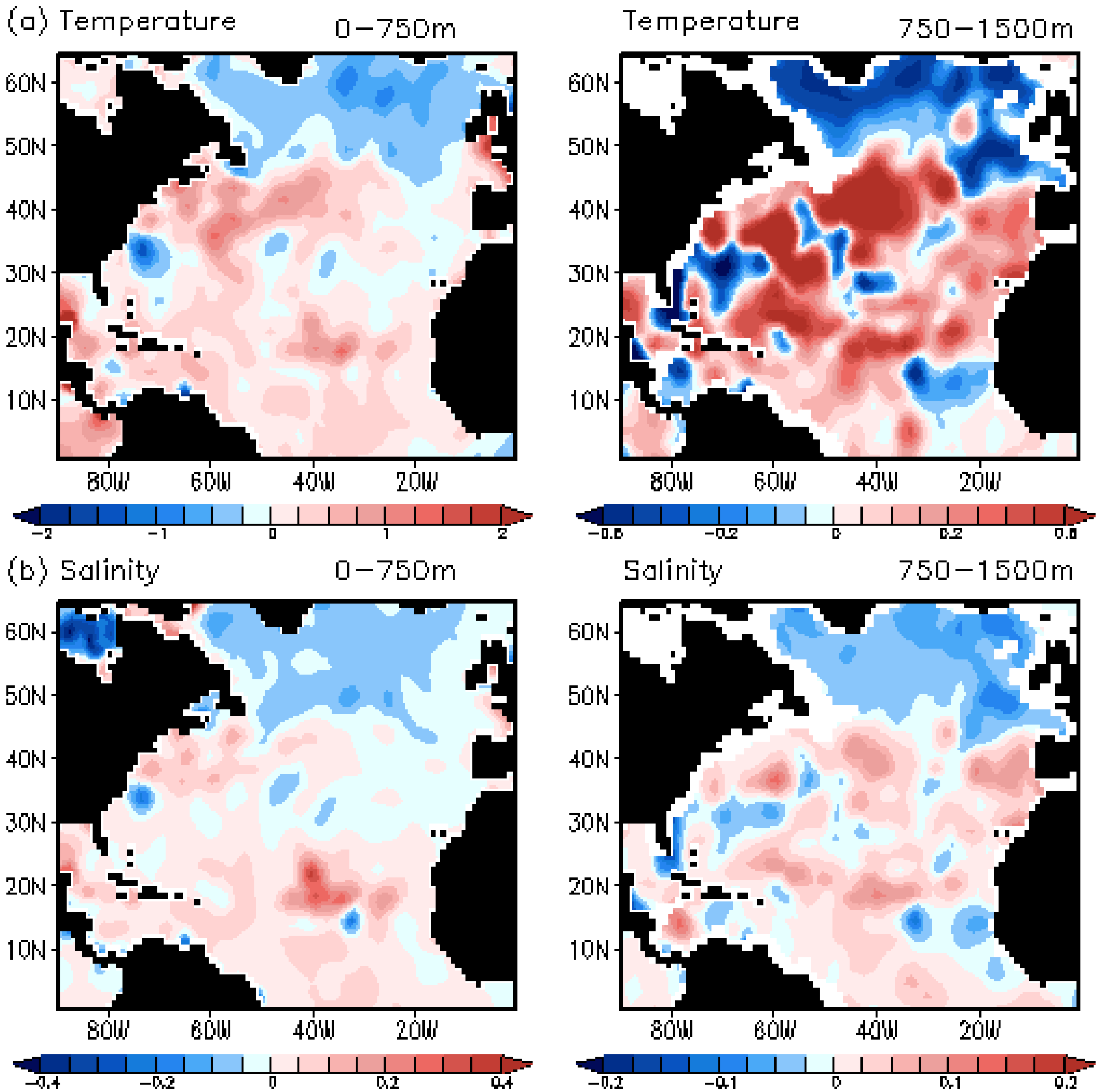


Property changes

data

1980 to 2000
minus
1950 to 1970

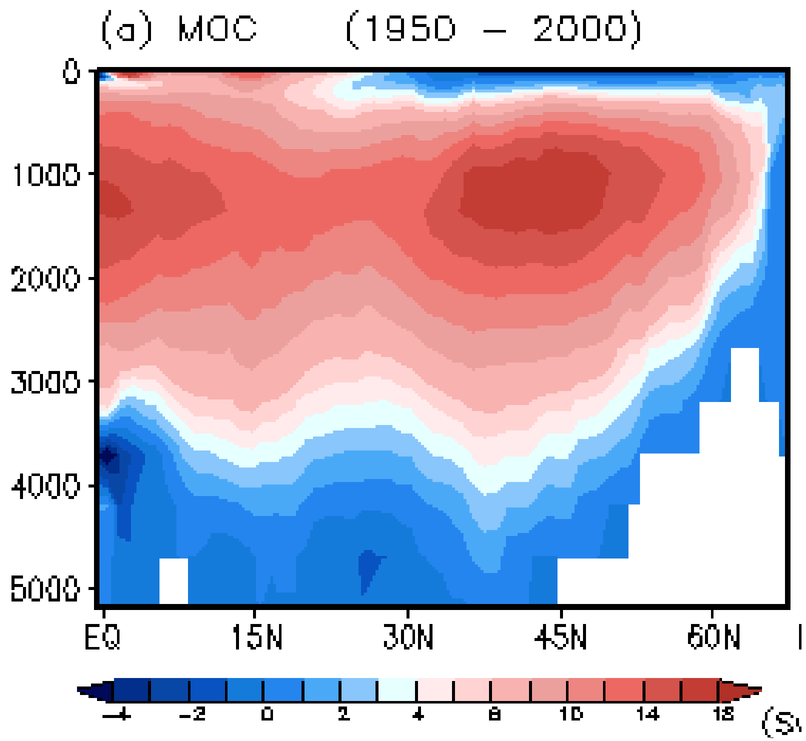
clear gyre contrast in T/S



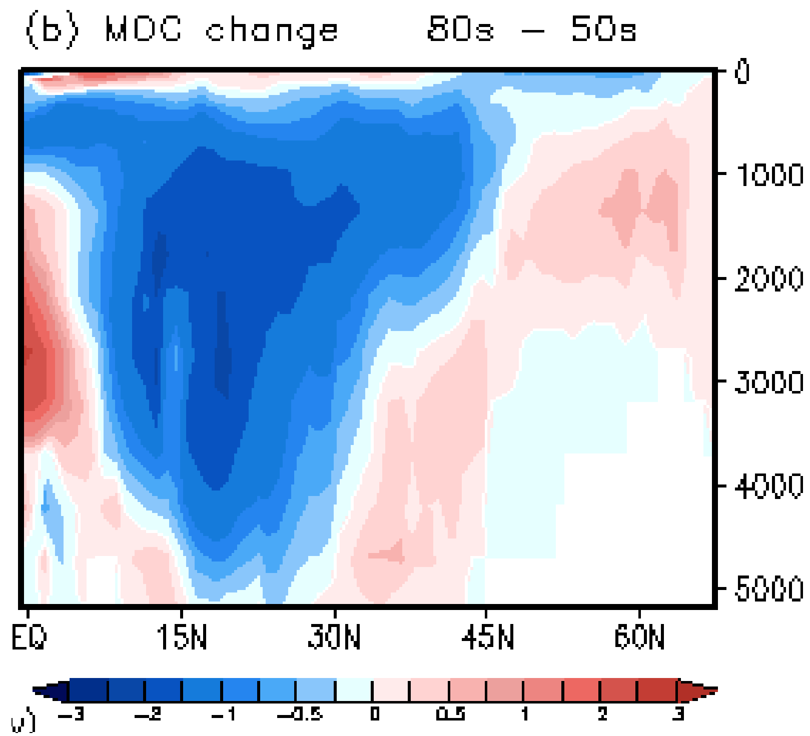
Overturning estimates using MIT model relaxed to historical data

model /data

average overturning from model+data

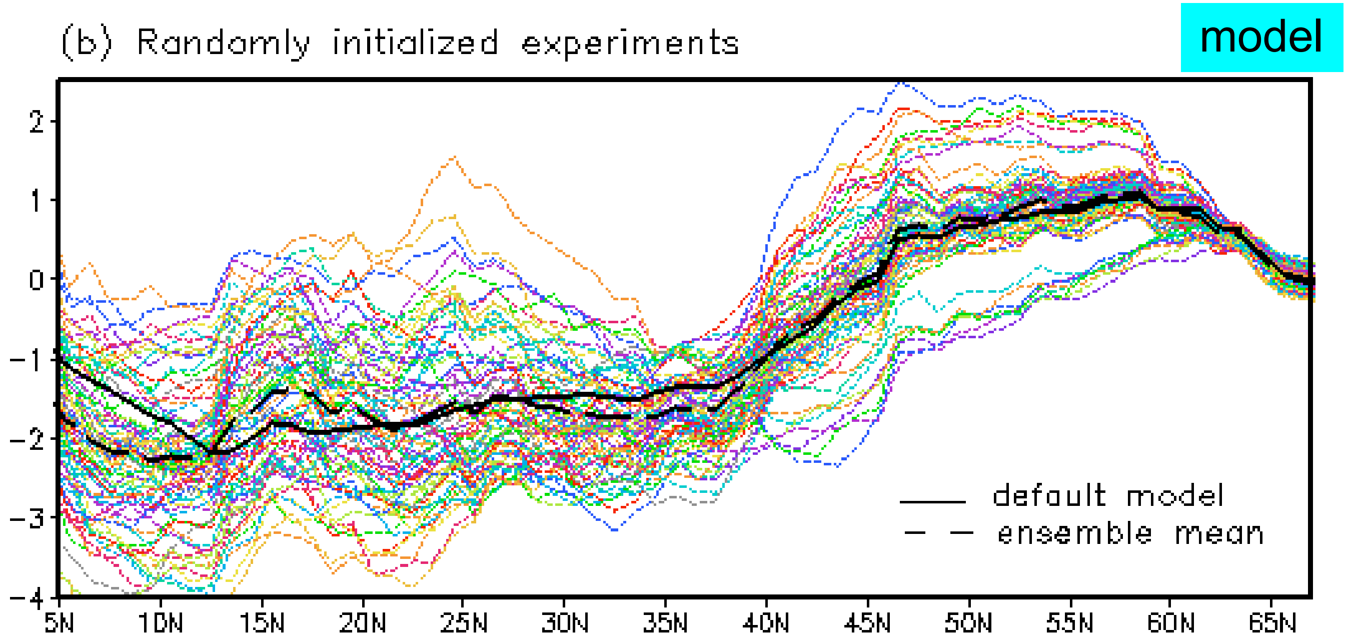


overturning **change** from model+data



model

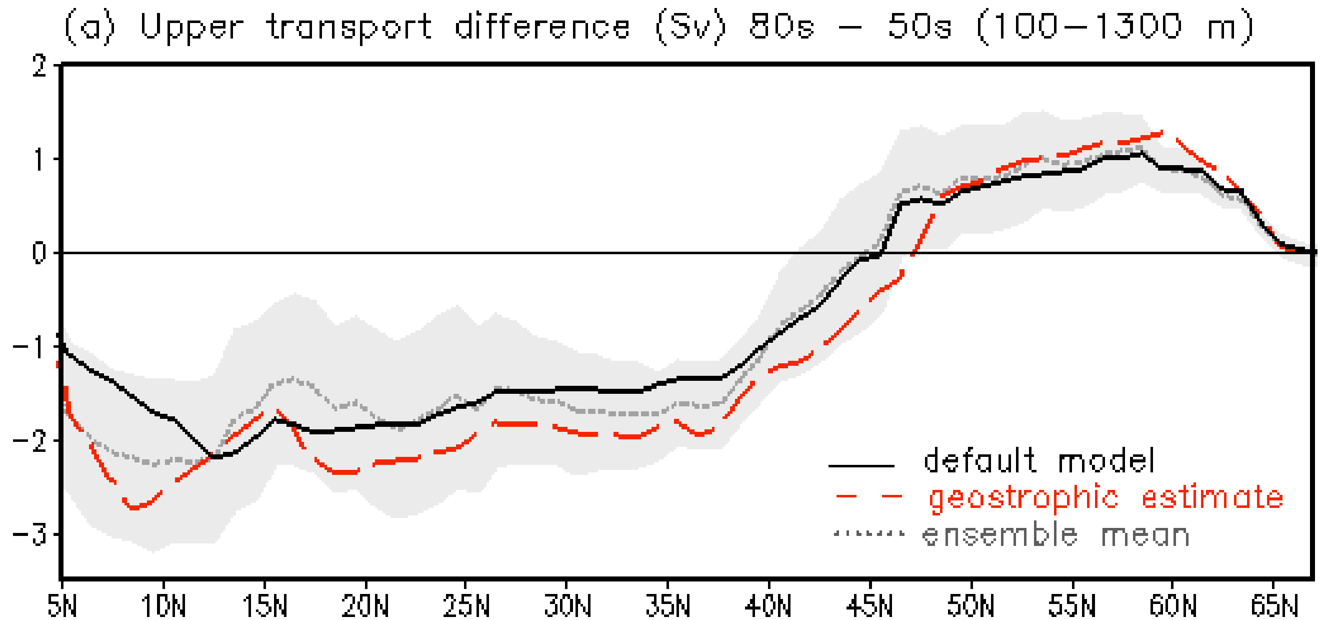
80 ensemble integrations using Baysian approach



Over last 50 years, overturning changes:

subtropical weakening -1.6+/- 0.9 Sv

subpolar strengthening 1 +/- 0.5 Sv

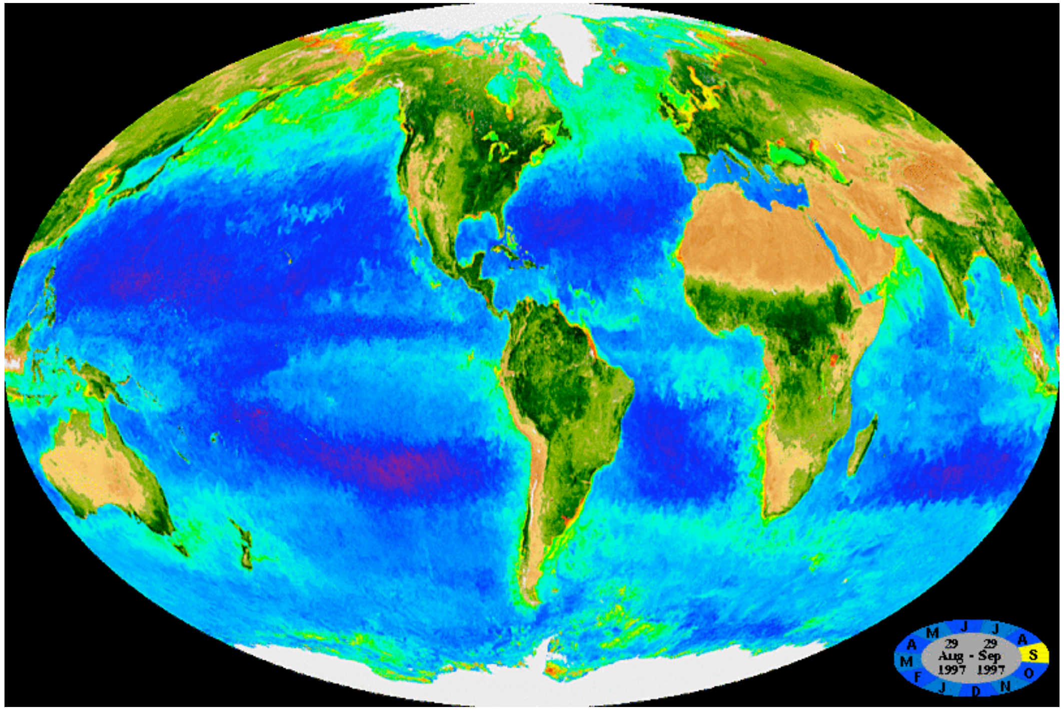


Not a weakening over the entire basin

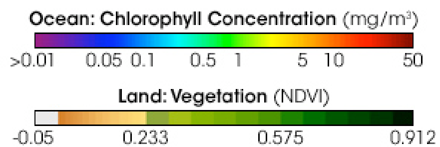
2. Carbon emissions and ocean chemistry

- Ocean holds ~ 50 as much carbon as in the atmosphere

- 1/3 of the recent industrial emissions of carbon has gone into ocean



Remotely-sensed picture of surface chlorophyll (NASA)



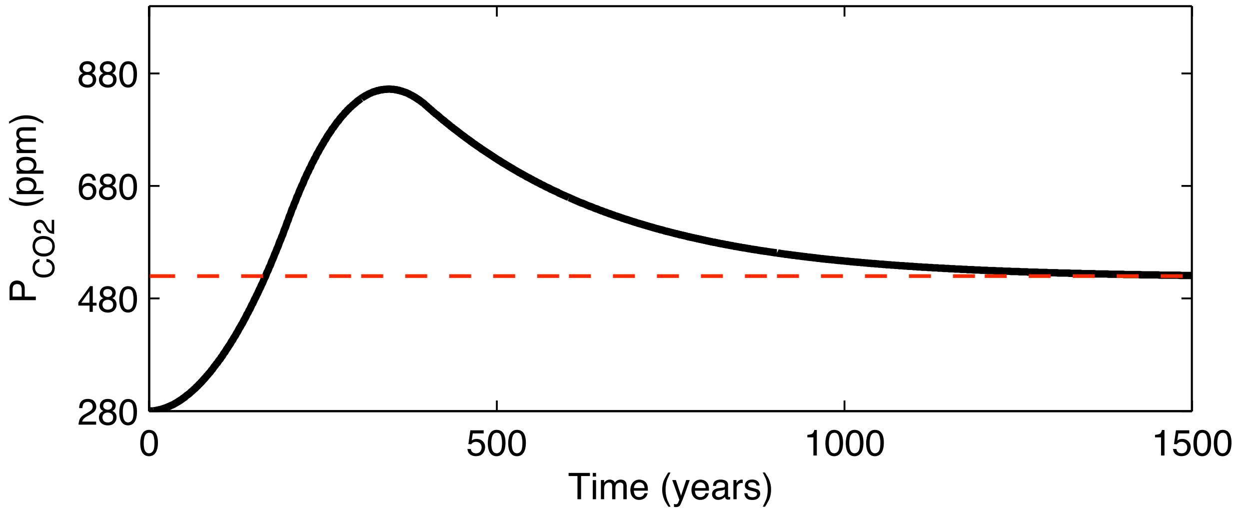
What is the problem?

- Ocean takes up less carbon dioxide as it becomes more acidic

What happens if we burn all our fossil fuels?

model

atmospheric CO_2



- Initial fast rise in atmospheric CO_2

- Eventually approach a steady state

model

As add CO_2 into atmosphere & ocean, larger fraction goes into CO_2 dissolved pool (& less into carbonate)

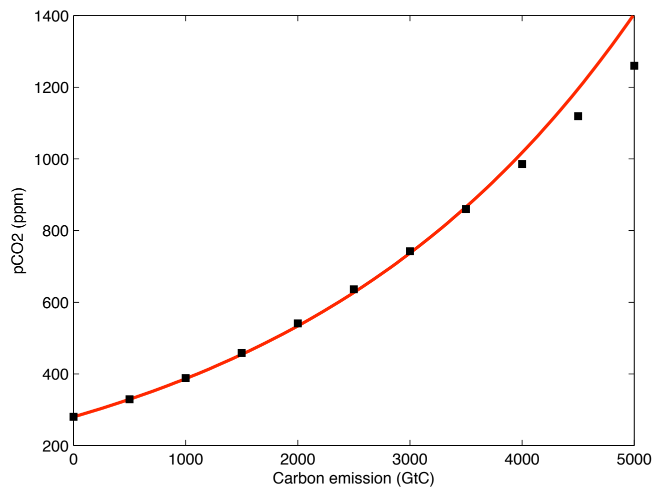
For a long term steady state:

partial pressure of CO_2 varies *exponentially* with C emissions

$$P_{CO2} = 280 \exp\left(\frac{\Delta C}{I_B}\right)$$

$$I_B = I_A + I_o/B$$

buffered carbon inventory	atmos inventory	ocean inventory / buffer factor
3500 PgC	600 PgC	2900 PgC



Carbon emissions

analytical relationship - red line
general circulation model - dots

radiative forcing varies *linearly* with C emissions

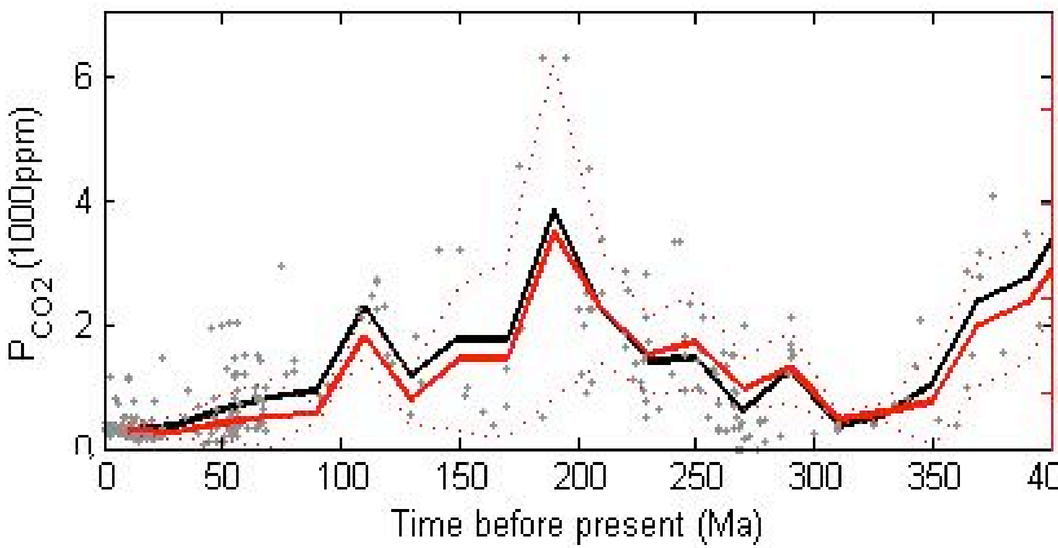
$$\Delta F_{CO2} \approx \frac{\alpha}{I_B} \Delta C$$

Goodwin, Williams et al. (2007), *Nature Geoscience*

Climate sensitivity

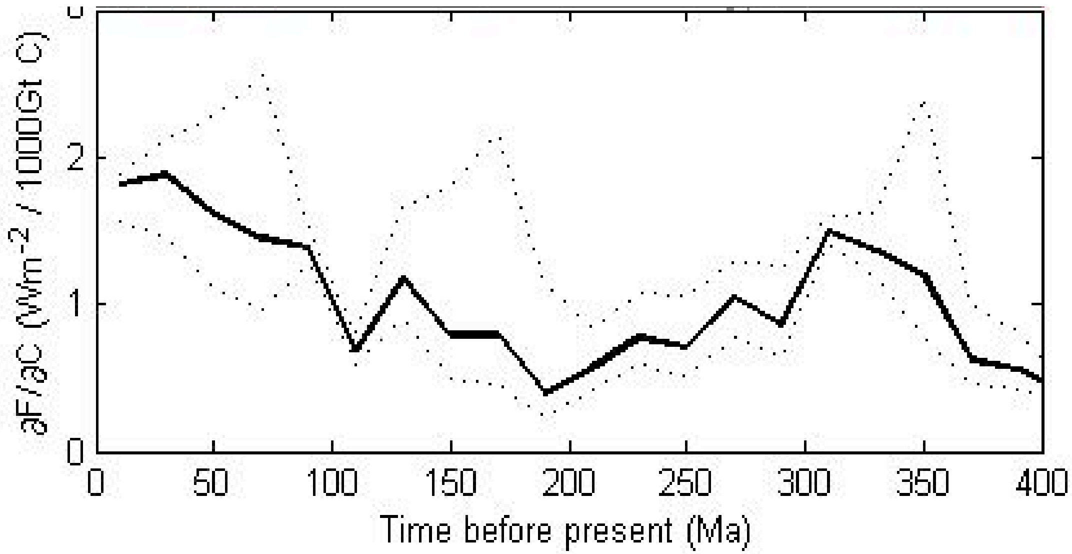
data/ theory

P_{CO2} from paleo data (grey dots, mean black line)



Sensitivity of radiative forcing to carbon emissions

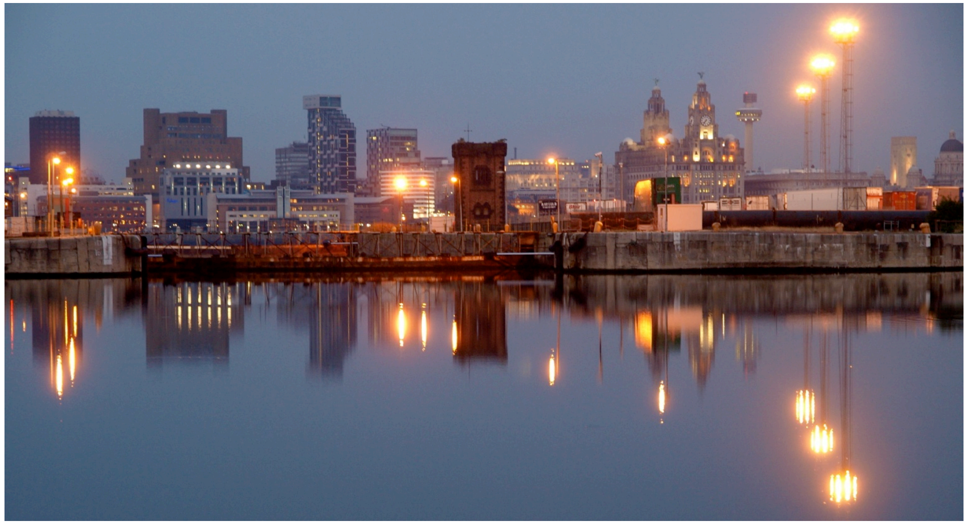
$$\frac{\Delta F_{CO_2}}{\Delta C} = \frac{\alpha}{I_B}$$



The present day has a high climate sensitivity

Legacy for future generations

if release all the carbon in conventional fossil fuels,
~ 5 x present anthropogenic heating lasting for millennia



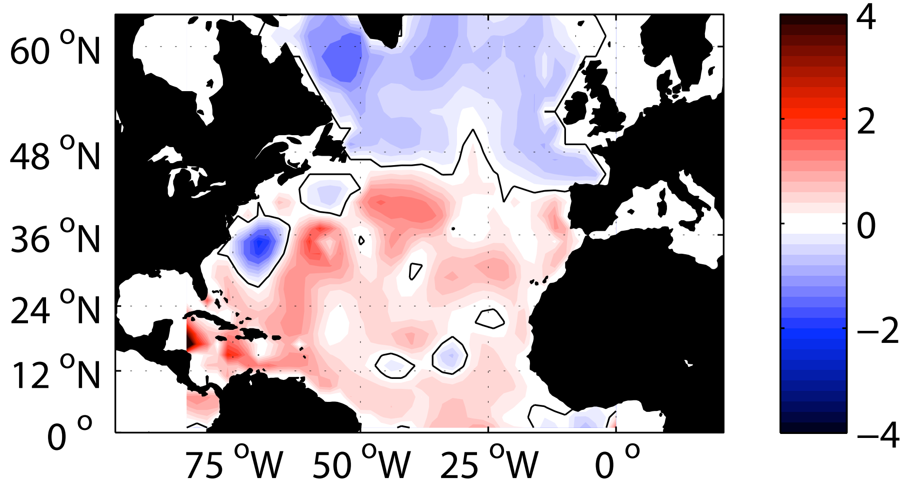
This joint research centre is engaged in providing climate briefings to local civic leaders (Bishop James, Archbishop Kelly, local politicians)

Our institutional response, Liverpool is setting up an Energy Institute

Conclusions

1. Science

North Atlantic Ocean is taking up heat, but much larger decadal variability



N. Atlantic overturning is not collapsing.

Carbon emissions exacerbated by ocean acidification.

2. Implications

Need to take long term and ethical perspective

Personal : Institutional : National : International