Atlantic wide regime shift?

Chris Reid, SAHFOS, Plymouth, UK (pcre@sahfos.ac.uk)

The pronounced changes through time shown in the contour plots of the mean monthly Phytoplankton Colour Index (PCI) averaged for large areas of the North Sea and Northeast Atlantic and first shown in Reid *et al.* (1998) are now well known. This index is a visual estimate of chlorophyll measured on silks from the Continuous Plankton Recorder (CPR). Recent calibrations with SeaWIFS by Raitsos *et al.* (2005) and Leterme and Pingree (in press) have confirmed that the PCI is a good, if crude, measure of chlorophyll; the calibration has enabled the production of a >50 year Chl *a* time series in the central northeast Atlantic and North Sea.

Figure 1 gives an update of the figure shown in the 1998 paper, with similar plots for two areas in the western Atlantic, the Grand Banks and NE Canadian Atlantic. The observed increases in phytoplankton biomass and extension of the growing season that occurred around the mid 1980s in the North Sea and in the Atlantic to the west of the British Isles have continued, a pattern that has also been followed in the sub boreal gyre south of Iceland in the northern northeast Atlantic from 1998. A similar extension in the growing season, but with a different seasonal cycle has also been seen in the western Atlantic. Unfortunately, because of a lack of sampling between the years 1976 to 1991 the timing of the change prior to 1990 and post 1980 is not known. However, a number of other changes in the northwest Atlantic (Brian Petrie, pers. comm.), including the catastrophic decline in the cod stocks and increases in northern shrimp (Worm and Myers, 2003) occurred at this time. They showed that cod biomass was positively related to temperature, but attributed the inverse relationship of cod and shrimp to top down predator control.

The timing of the changes in the northeast Atlantic are part of the North Sea regime shift first noted by Reid *et al.* (2001) and subsequently analysed by Beaugrand (2004) and shown to be related to changes in large-scale hydro-meteorological forcing (temperature and wind intensity and direction and associated changes in the position of oceanic biogeographic boundaries). These events reflect a pronounced change in climate shown especially in the

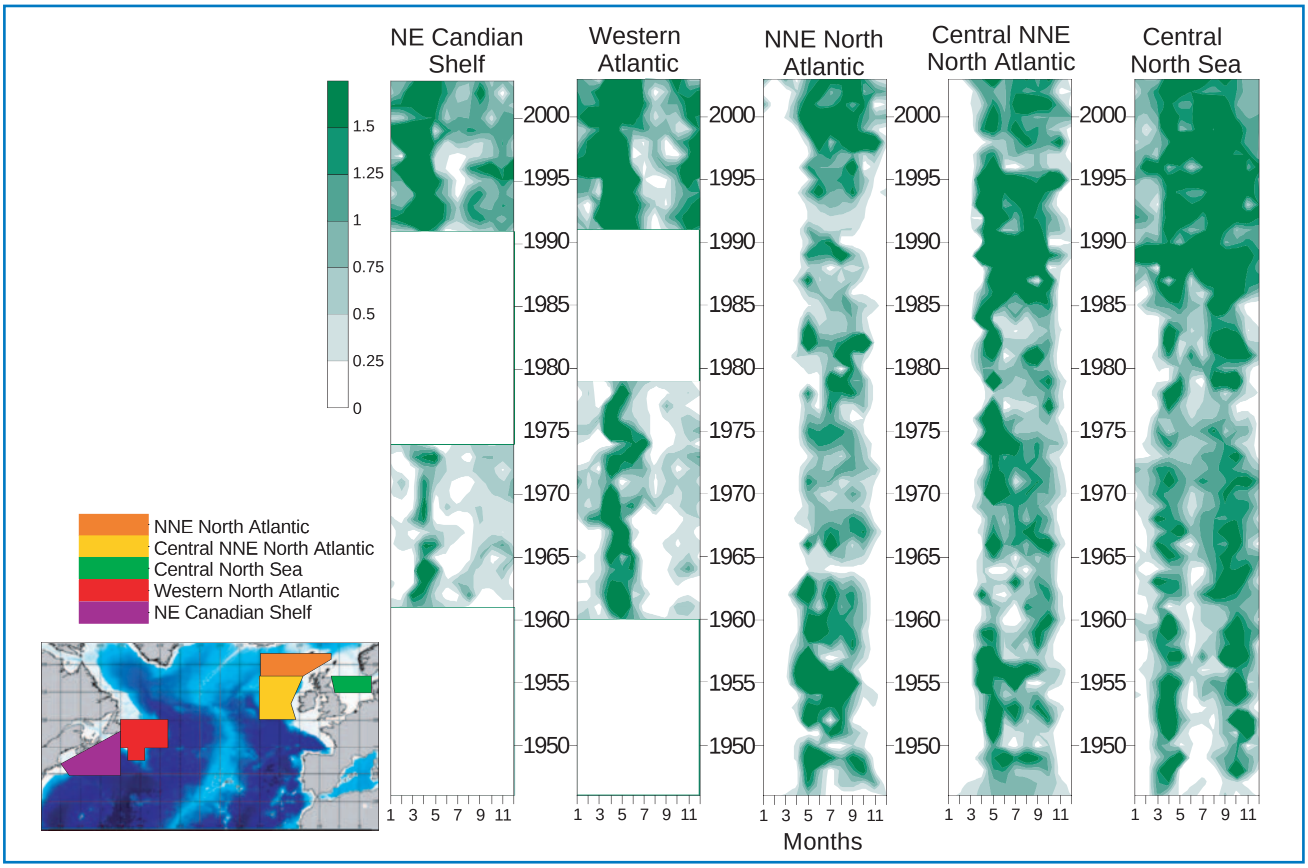

Figure 1. Contour plots of mean monthly Phytoplankton Colour for the NE Canadian Shelf, Western Atlantic, NNE North Atlantic, Central NNE North Atlantic and Central North Sea.

high correlations with Northern Hemisphere temperature. Yasunaka and Hanawa (2002) showed that a regime shift occurred in Northern Hemisphere sea surface temperature fields in 1988/89 coinciding with the changes noted here and that sea surface temperatures averaged for the whole of the North Atlantic showed a similar step wise change to the PCI in the mid 1980s. The evidence suggests that the coincidence of the timing of the changes in cod, shrimp and other variables and especially lower salinities in the northwest Atlantic, as well as evidence for a marked increase in the occurrence of Arctic plankton in this region (Johns *et al.*, 2003) indicates that the regime shift may well be a North Atlantic wide phenomenon.

The changes in Phytoplankton Colour are in essence the same, other than for seasonal differences on both sides of the Atlantic, but occur under contrasting conditions; in the east sea surface temperatures have risen substantially (~0.5°C in the North Sea) over the last few decades whereas salinities have reduced in the western Atlantic region. The latter likely reflecting increased outflow of meltwater from the Arctic. The increases seen since 1998 in the area to the south of Iceland coincide with a return to higher sea surface temperatures after a long period of cooler temperatures since the late 1960s (although this does not explain the considerable relative increase in Colour).

The North Atlantic plays a key role in the meridional overturning circulation, as a reservoir for heat and as a depository for CO_2. Changes of the scale described here are likely to have important consequences for the biological pump and for atmospheric concentrations of CO_2. Because similar programmes to the North Atlantic CPR survey that measure phytoplankton changes for chlorophyll and species composition do not operate in other ocean regions we have no idea if similar changes are taking place elsewhere in the world. There is an urgent need to develop and fund ocean monitoring systems within GOOS and especially to initiate and maintain long-term basin-scale CPR programmes outside the North Atlantic.

I wish to make five points:

- Substantial changes have taken place in ecosystems across the northern North Atlantic circa the late 1980s that have had marked impacts on marine ecosystems and living marine resources.
- The changes in Phytoplankton Colour in contrasting hydrodynamic conditions are difficult to explain. Possible links with increased concentrations of CO_2 in seawater need to be investigated, although this is an unlikely cause.
- Pronounced changes in the circulation of the North Atlantic, especially outflow from the Arctic and in the eastern boundary current may be associated with these events.
- The links with Northern Hemisphere temperature and via this to greenhouse gases (see IPCC) indicate that global warming may be impacting the North Atlantic more rapidly than previously thought possible.
- There is an urgent need to increase the speed of implementation of GOOS and especially to start up long-term plankton monitoring programmes analagous to the CPR survey. If the same standardised and well proven CPR methodology is used inter-ocean comparions will be possible.

References

Beaugrand G. 2004. The North Sea regime shift: evidence, causes, mechanisms and consequences. Progress in Oceanography 60(2-4): 245-262.

Johns D.G., M. Edwards, A. Richardson and J.I. Spicer. 2003. Increased blooms of a dinoflagellate in the NW Atlantic. Marine Ecology Progress Series 265: 283-287.

Leterme S.C. and R.D. Pingree. In press. The Gulf Stream and rings from remote sensing (altimeter and SeaWiFS). Journal of Marine Systems.

Raitsos D.E., P.C. Reid, S.J. Lavender, M. Edwards and A.J. Richardson. 2005. Extending the SeaWiFS chlorophyll data set back 50 years in the northeast Atlantic. Geophysical Research Letters 32(6): Article L06603, doi:10.1029/2005GL022484.

Reid P.C., M. Edwards, H.G. Hunt and A.J. Warner. 1998. Phytoplankton change in the North Atlantic. Nature 391: p.546.

Reid P.C., M.F. De Borges and E. Svendsen. 2001. A regime shift in the North Sea circa 1988 linked to changes in the North Sea horse mackerel fishery. Fisheries Research 50: 163-171.

Worm B. and R.A. Myers. 2003. Meta-analysis of cod-shrimp interactions reveals top-down control in oceanic food webs. Ecology 84:162-173.

Yasunaka S. and K. Hanawa. 2001. Regime shifts found in the northern hemisphere SST field. Journal of the Meteorological Society of Japan 80: 119-135.