MCCIP Marine Climate Change Impacts Partnership

Topic

Ocean Salinity

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Executive summary

The salinity of the upper ocean (0-800m) to the west and north of the UK has been generally increasing since a fresh period in the 1970s. A minimum occurred in the mid 1990s, and present day conditions are saline. The decadal-scale pattern of change around the UK reflects the mean conditions of the North Atlantic and Nordic Seas, which has evolved from a maximum in the early 1960s and a minimum in the mid 1990s.

West of the UK the water of the **deep ocean** (>1000m) comes from the **Labrador Sea** and has freshened since 1975. North of the UK, the deep water (800m) flows come from the Nordic Seas; they have freshened since 1950 but have been stable for the last decade.

In the northern North Sea the salinity is heavily influenced by inflowing North Atlantic water and has become more saline since the 1970s. The salinity of the southern North Sea is dominated by river run-off and there is no clear trend since the 1970s.

Since the mid-1960s the salinity of the Irish Sea shows no significant long-term trend. The decadal pattern is different to the deep offshore water; maxima occurred in the late 1970s and late 1990s; present conditions are close to the long-term mean.

There is no clear trend in the shelf waters off the west coast of Scotland; observed changes in salinity are due to an east-west migration of salinity gradients, with warm periods being associated with higher inshore salinities.

Full review

Observational evidence for changes in salinity is relatively sparse. There are few long-term measurements of shelf or deep waters in the North Atlantic, though two of the longest (Faroe to Shetland since 1900, and Rockall Trough since 1948) are maintained by UK agencies. Offshore observations in the North Atlantic and Nordic Seas are summarised annually in the International Council for the Exploration of the Seas (ICES) Report on Ocean Climate (IROC) (ICES, 2007). Coastal and shelf sea monitoring stations are maintained around Scotland by the Fisheries Research Services, Marine Laboratory Aberdeen and the Scottish Association for Marine Science, Oban, and in the Irish Sea by the Government Laboratory of the Isle of Man.

The salinity of the waters around the UK are affected by changes which are occurring in the deep oceanic waters of the North Atlantic as well as local processes in the shallower shelf seas. Southwest England and Scotland are most strongly affected by changing oceanic conditions, the influence of which affect the western continental shelf and penetrate into the northern North Sea. The east coast of England is within the southern North Sea. Wales, Northwest England, and the east coast of Northern Ireland border on the Irish Sea. At each sampling site, imposed on the large-scale, long-term pattern are further levels of variability related to locally important processes such as changing positions of fronts, passing of eddies, river run-off, the changing inflow of different water masses, and the exchange of freshwater with the atmosphere.

Oceanic Waters around the UK

Over the last 50-60 years the large-scale, long-term salinity of the northern North Atlantic and Nordic Seas has evolved from a maximum in the early 1960s to a minimum in the mid-1990s (Peterson *et al,* 2006, ICES 2007). It is presently becoming more saline.

The salinity of the surface layer of the ocean (the top 100 m) is most heavily influenced by changes in precipitation and evaporation (Josey & Marsh, 2005) and is more variable than deepwater salinity. Below the surface, the deep ocean around the UK is most strongly influenced by changes in ocean circulation, which in turn is affected by large-scale atmospheric conditions (Holliday, 2003; Hátún *et al*, 2005). Surface conditions in a few key locations remote to the UK, where surface water sinks into the deep ocean, also affect the salinity of UK deep waters (Dickson, *et al,* 2002).

The salinity of the upper ocean (0-800m) to the west and north of the UK has been increasing since a fresh period (the Great Salinity Anomaly) in the 1970s (Figures 1 and 3). A further minimum occurred in the 1990s, and the present day conditions are relatively saline. The pattern reflects the changing balance of the inflow of subtropical (salty) versus subpolar (fresh) water into the area (Holliday, 2003).

Below 1000m the deep ocean west of the UK has become fresher since 1975, reflecting a period of freshening in the Labrador Sea where the deep water originates (Figure 2). The Labrador Sea has become more saline again since the late 1990s, and we expect the deep water west of the UK will also increase in salinity over the next few years. North of the UK, the deep waters (800m) flow from the Nordic Seas and while they have also freshened since 1950, they have been stable for the last decade (Figure 4).

Shelf Seas

In the northern North Sea the salinity is heavily influenced by inflowing North Atlantic water and so has also become more saline since the 1970s (Figures 5 and 6). Salinity in the southern North Sea is dominated by river run-off and there is no clear trend since the 1970s (Figure 7 and 8).

Salinity in the Irish Sea can be represented by a time series in the coastal waters adjacent to the Isle of Man at Port Erin Bay (Figure 9). No significant long-term trends have been established, though there are decadal fluctuations as follows. Salinity through the 1970s was relatively stable with little evidence of the Great Salinity Anomaly. There was a period of low salinity through the 1980s into the early 1990s. The 1990s was generally a period of higher salinity followed by a salinity decrease or freshening in the early 2000s and to date.

The North Atlantic is the source water for the Irish Sea, but salinity is not heterogeneous with all regions to some extent influenced by freshwater. Low salinity waters are largely confined to the north-eastern Irish Sea corresponding to high riverine freshwater loadings, with highest salinities being observed in offshore western Irish Sea waters. Overall an inverse relationship exists between the winter **North Atlantic Oscillation (NAO)** index and Port Erin Bay salinity. The relationship is stronger for NAO Index negative years when winter precipitation and thus runoff from land and westerly winds are less persistent. Salinity in these years tends to be higher and more impacted by oceanic water ingressing from the North Atlantic and less impacted by freshwater inputs. Port Erin Bay salinity does tend to be lower during NAO Index positive years but the relationship is somewhat weak and local and regional effects seem to have a much greater impact on salinity. In NAO index positive years westerly and south-westerly airflow tends to be enhanced and in Northern Europe winters tend to be warmer with increased precipitation and airflow. Salinity would be expected to be more impacted by freshwater inputs and thus lower in these years

Reliable continuous measurements of salinity in the Tiree passage on the west coast of Scotland started in 2002 and are, therefore, too short to comment on long-term changes. Observations, however, made between 1975 and 1996 indicate that intra-annual changes from warm high salinity water to cool low salinity water are, in general, associated with the across shelf migration of isohalines rather than a broad scale change over the whole shelf (Inall *et al.,* 2007). However, it has not been possible to detect any link between this movement and local climate, such as rainfall patterns, or the NAO.

Figures

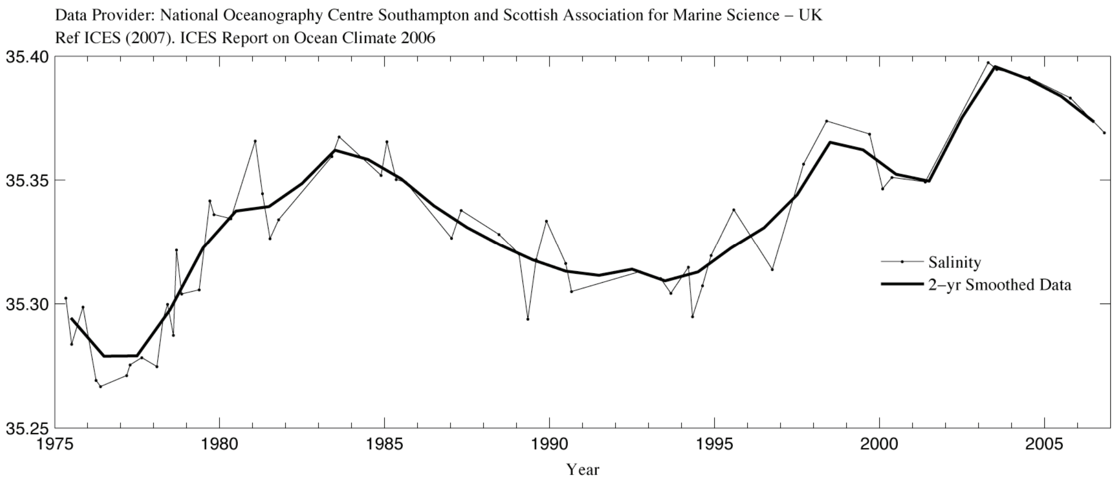

Figure 1. Rockall Trough. Salinity of the upper ocean (0-800m)

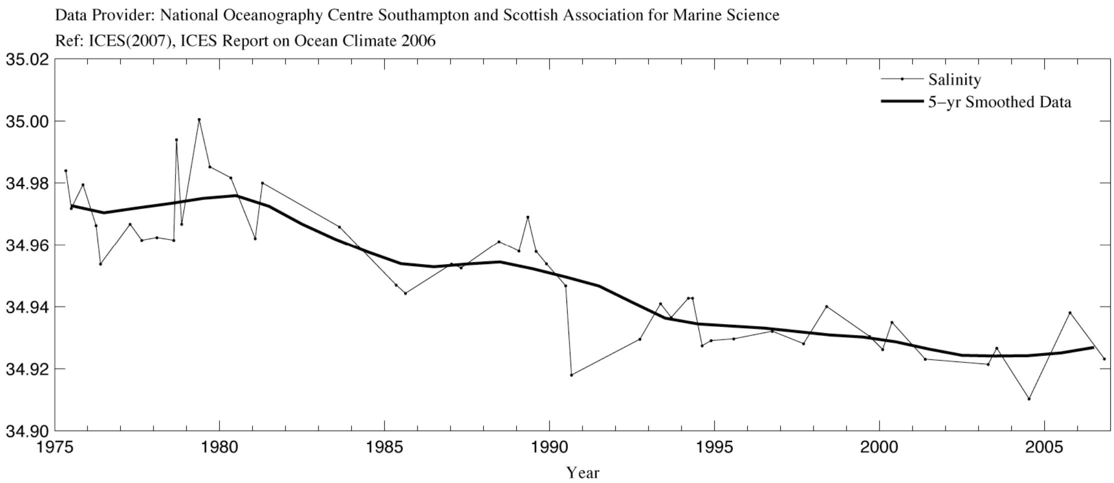

Figure 2. Rockall Trough . Salinity of the deep ocean (Labrador Sea Water, 1800 - 2000m)

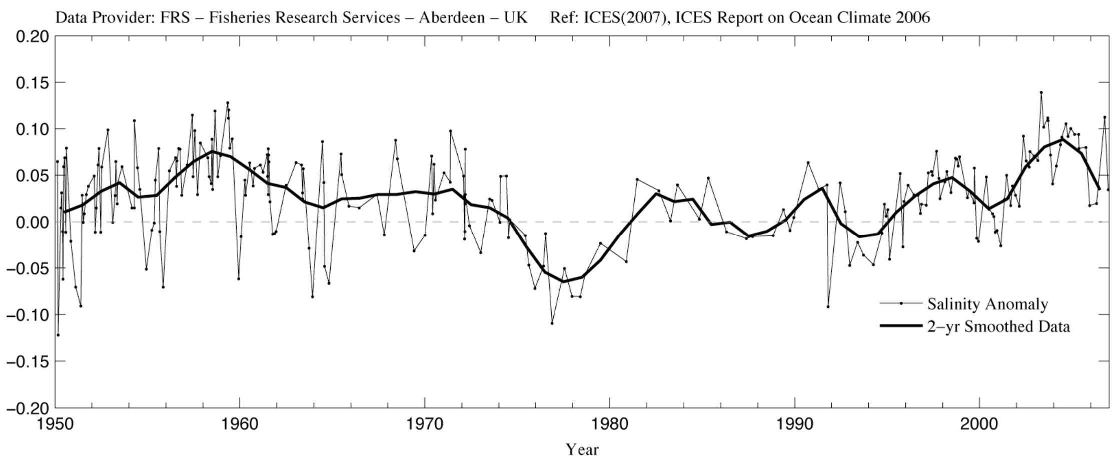

Figure 3. Faroe Shetland Channel. Salinity anomaly of the Atlantic Water in the slope current.

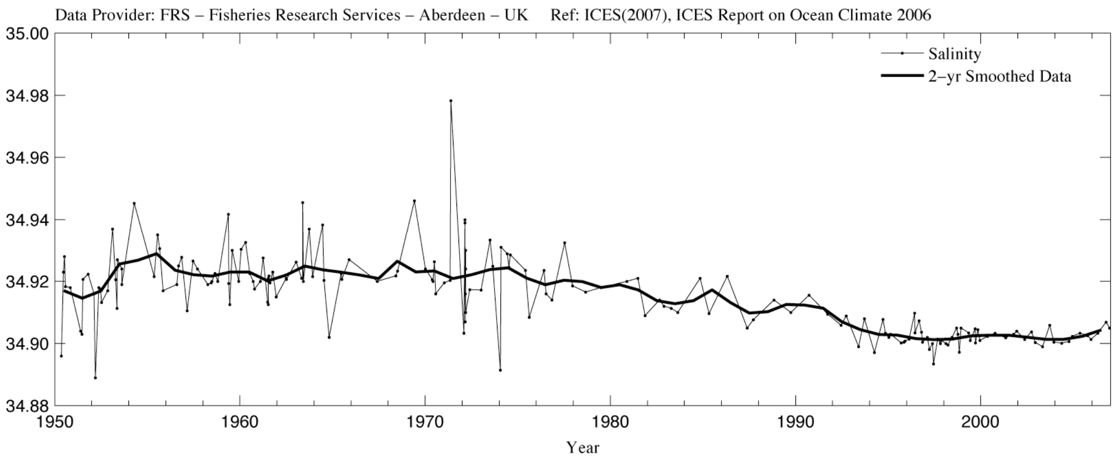

Figure 4. Faroe Shetland Channel. Salinity of overflow water at 800m.

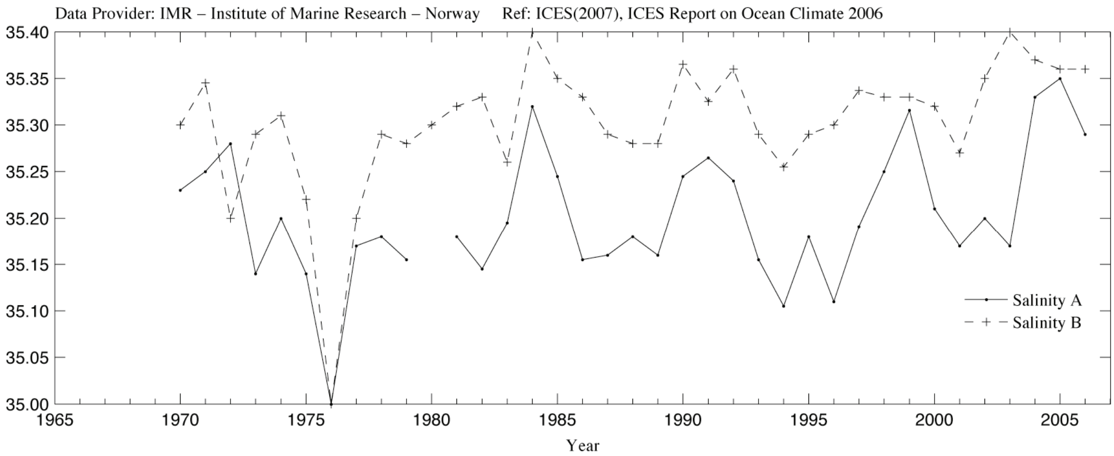

Figure 5: Northern North Sea. Salinity near the sea-floor in the northwestern part of the North Sea (A) and in the core of Atlantic Water at the western shelf edge of the Norwegian Trench (B) during the summers of 1975- 2006.

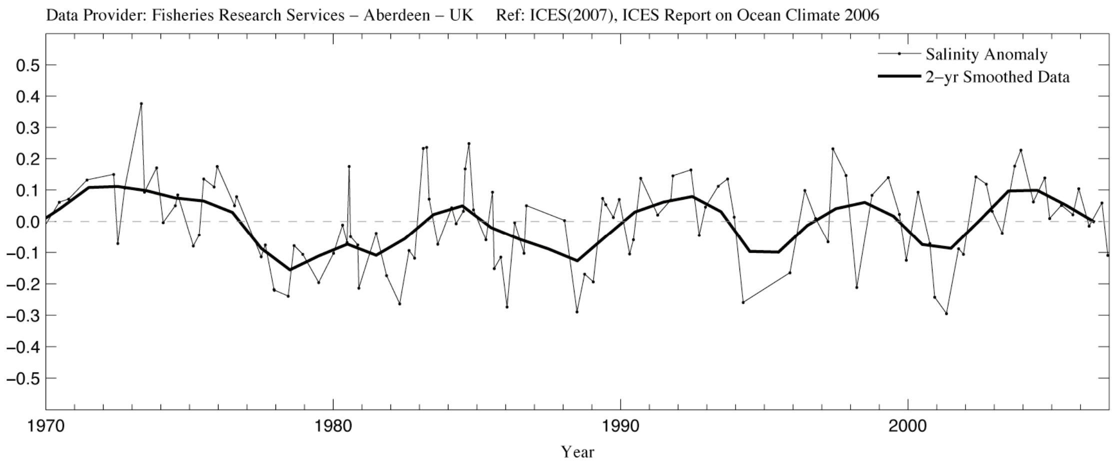

Figure 6: Northern North Sea. Salinity anomaly in the Fair Isle current entering the North Sea from the North Atlantic.

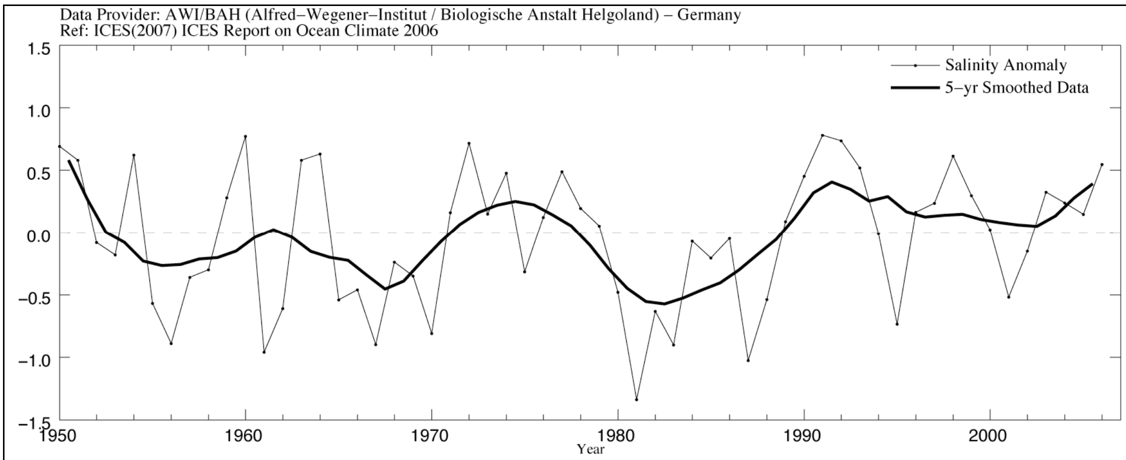

Figure 7: Southern North Sea. Annual mean surface salinity anomaly at Station Helgoland Roads.

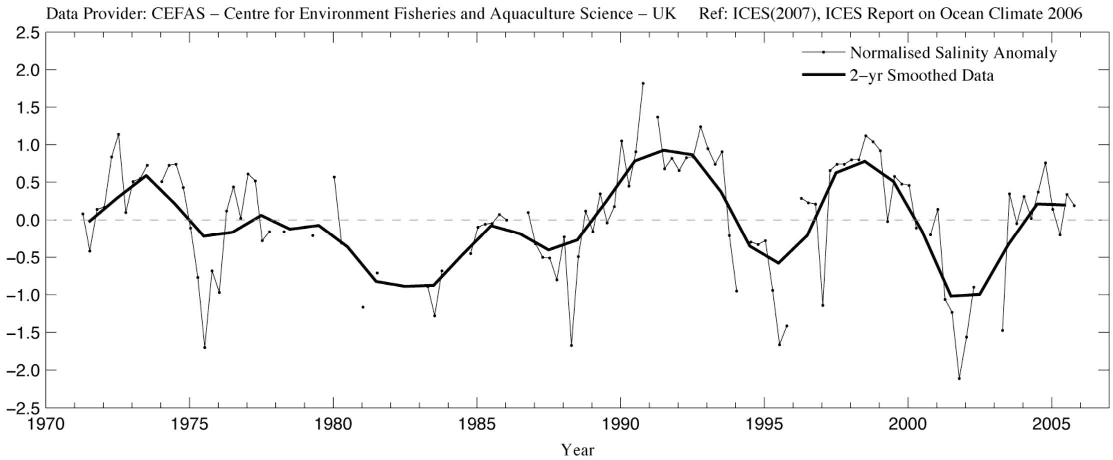

Figure 8: Southern North Sea. Normalised sea surface salinity anomaly relative to the period 1971-2000 measured along 52°N, a regular ferry at six standard stations. The time series show the seasonal section average (DJF, MAM, JJA, SON) of the normalised variable.

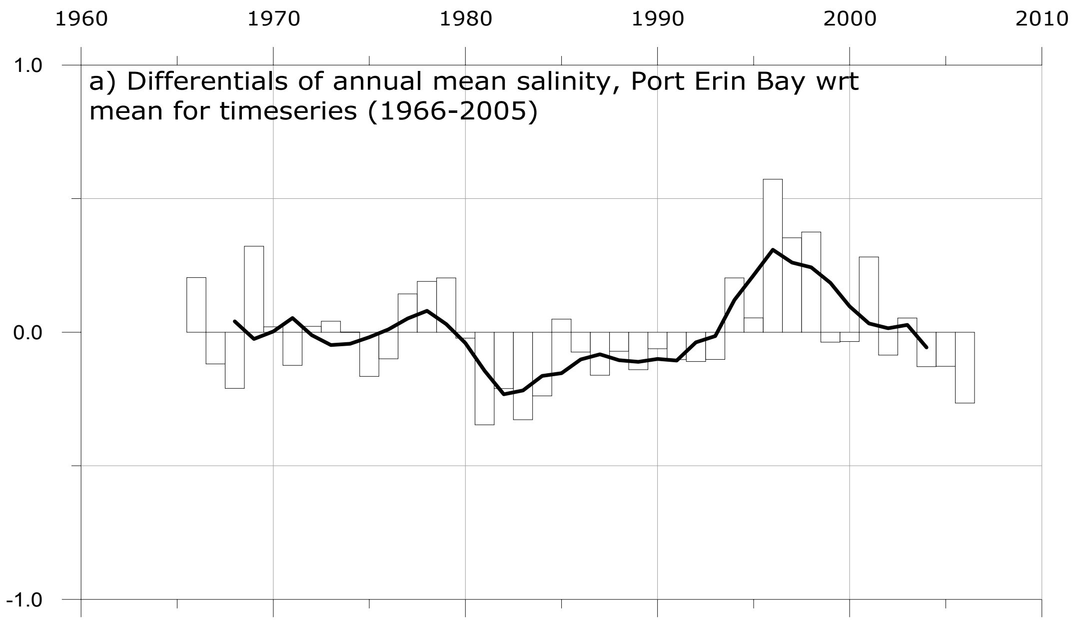

Figure 9. Anomalies of annual salinity means at Port Erin Bay (long-term mean 1966-2005).

Confidence assessments

'What is already happening' - Medium
(consensus=high, evidence=moderate)

'What could happen in the future' - Low
(consensus=low, evidence=low).

Measurements of salinity at offshore sites are made 1-3 times per year, under-sampling the seasonal cycle which may alias the results . Shelf sea and coastal stations are sampled more frequently (up to daily), so the seasonal cycle is usually better resolved. Calibration is good (although data prior to 1970 are less reliable), so high confidence can be put on actual measurements.

The number of sites for which long-term records exist are limited, so it is difficult to make an overall assessment of changes in salinity around the UK. However, the variability at the **deep ocean** sites on time scales of years to decades are consistent across the region and with the North Atlantic region, giving us overall moderate confidence in the results.

Knowledge gaps

1. Sparse availability of data

The number of **deep ocean** sites for which long term measurements have been made are small. This problem is being addressed in the deep ocean by the **Argo float** programme, which has greatly increased the amount of subsurface data since the early 2000s. The free-ranging instruments are programmed to float at a depth of 2000m, carried along by the ocean currents. Every 2 weeks they rise to the surface to report their new location and the temperature and salinity of the water they rose through. This new data source across the global ocean, combined with numerical models, will in time reduce some of the difficulties due to sparse observations. The recent installation of **thermosalinographs** on a number of ferries and **voluntary observing ships** using UK waters should help to redress the shortfall of surface salinity observations in shelf waters.

2. Under-sampling of the seasonal cycle.

The surface and upper layers of the ocean exhibit a strong seasonal salinity cycle with an amplitude greater than longer-term changes. Usually surface salinity is higher in the winter. When looking at long term variability in time series that are sampled only 1-3 times per year, we need to take account of the season in which the measurements were made. The under-sampling of the open ocean seasonal cycle and how it may be changing over time is a major uncertainty for interpreting long term changes. The key to resolving the open ocean signal cycle lies in assimilating temperature and salinity from profiling floats and other devices into numerical models. The models can fill the gaps between the data points, and the data can keep the model close to reality. Progress is being made with developing this technique.

Commercial impacts

Not stated

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Isle of Man Government Laboratory Marine Monitoring http://www.gov.im/dlge/enviro/govlabs/marine_water.xml