

IRISH OCEAN CLIMATE AND ECOSYSTEM STATUS REPORT SUMMARY 2009

The sea is critically important in moderating Ireland's weather, since the majority of weather systems that affect us day to day come from the Atlantic Ocean. However, there has been very little research to date on the affects of climate change on the sea, which will inevitably impact on the various sectors that make up Ireland's maritime economy. A first step in any study of the effect of climate change on our oceans is to study the current status of Irish waters against which any future change can be measured. This can be done by examining existing data sets on oceanography, plankton and productivity, together with information on marine fisheries and migratory species such as salmon, trout and eels. The aim of this report card is to outline the available scientific data on the atmosphere, oceanography, ocean chemistry, phytoplankton, zooplankton, commercial fisheries, seabirds and migratory fish.

Copies of the full report, Irish Ocean Climate & Ecosystem Status Report 2009, are available from Marine Institute, Rinville, Oranmore, Co. Galway, Ireland. Alternatively you can download a pdf version from www.marine.ie

The Atmosphere

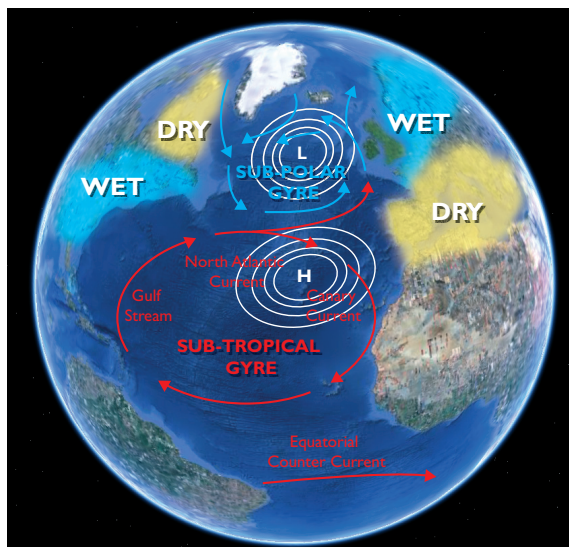
Ireland's climate is by no means stable in time. It is affected by a number of cyclic patterns with timescales varying in length from a year or two, to thousands of years. Some of these variations “flip-flop” or oscillate between two geographical locations on a regular basis and are referred to as Atmospheric Teleconnection Patterns (ATPs).

The most important of these are:

1. the regular variations in atmospheric pressure between a low pressure centre in the Arctic and a high pressure centre in the subtropical Atlantic referred to as the North Atlantic Oscillation (NAO) and
2. between a low pressure centre in the Northeast Atlantic and a high pressure centre over North Africa or the Mediterranean Sea known as the East Atlantic Pattern (EAP).

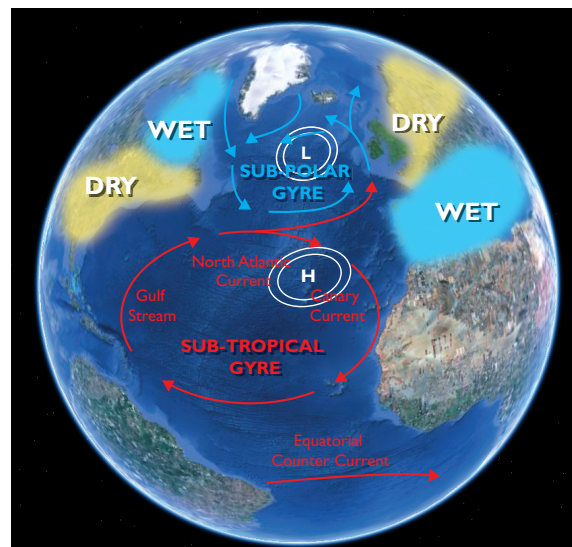
These two ATPs affect the intensity of storms over the Atlantic and it has been discovered, on reviewing existing data, that an increasingly positive shift in the North Atlantic Oscillation can be linked to increased intensity of winter storms, as well as to shifts in temperature and salinity throughout the North Atlantic Ocean.

Similarly, the East Atlantic Pattern has showed a tendency to more positive values since 1970, particularly in the period from 1997 to 2007. This is associated with above average surface air temperatures in Europe as well as above average rainfall over northern Europe and Scandinavia, as well as below-average rainfall across southern Europe.



During positive NAO, a large pressure gradient across the North Atlantic creates strong westerly winds that drive winter storms across the Atlantic and into northern Europe.

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During negative NAO, only a weak pressure gradient exists and southern Europe and Africa receive weak winter storms while northern Europe and the eastern United States are cold and dry.

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Oceanography

The oceans and the atmosphere above them are interdependent and highly dynamic systems, since heat, freshwater, gases and momentum are constantly being exchanged between them. Therefore, weather patterns in Ireland are largely driven by the North Atlantic Ocean.

The North Atlantic Gyre

Circulation in the upper 1000 m of the North Atlantic is dominated by two counter-rotating gyres powered by the Gulf Stream, drawing warmer salty water from the equator north eastwards across the Atlantic in a stream called the North Atlantic Current (NAC). This system is highly dependent on wind conditions and is therefore greatly influenced by the North Atlantic Oscillation (NAO) of the atmosphere (see previous Atmosphere section). During positive NAO conditions, the smaller sub-polar gyre increases in strength, shifting the interface between it and the sub-tropical gyre south eastwards. This pushes increased amounts of cold salty water towards Europe.

Analysis of information to date shows a weakening of the North Atlantic Current from the mid 1950s to the early 1970s, followed by a strengthening of the NAC until the mid 1970s.

Thermohaline Circulation (The Ocean Conveyor)

As warm salty water flows northwards from the Equator it loses heat to the atmosphere above it. This causes it to increase in relative density and sink in the colder, northern latitudes around Greenland and Scotland, where it flows southwards again to the Equator. Evidence from the distant past exists for a link between thermohaline circulation and sudden changes in surface temperature over the past 120,000 years. However, while observations suggest significant variability in thermohaline circulation over years and decades, there is no evidence to date of an overall trend in its strength.



'Variability and trends in Irish weather patterns and in oceanic conditions around Ireland are influenced by the large-scale currents of the North Atlantic Ocean.'

The Atlantic Multidecadal Oscillation (AMO)

The oceans also have recognisable long term oscillations that are typically coupled to those in the atmosphere above. Warmer than usual sea surface temperatures (SSTs) were observed throughout the North Atlantic between 1930 and 1960, and from 1990 to the present, with cool periods from 1900 to 1930 and from 1960 to 1990. This Atlantic Multidecadal Oscillation (AMO) is linked to changes in weather patterns on both sides of the Atlantic Ocean and is the most important feature in the variation of North Atlantic and Irish sea surface temperature records.

Observed Trends and Variations

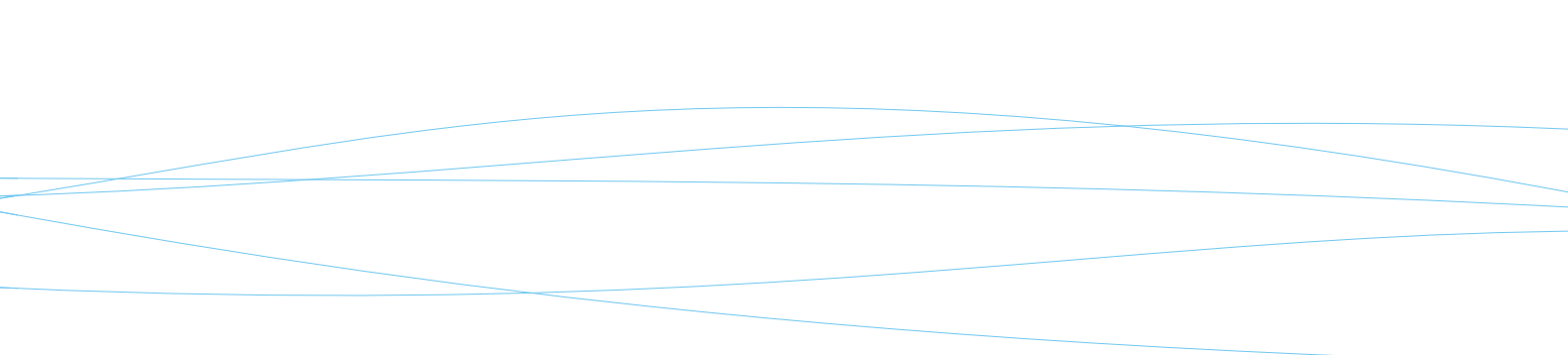
Upper ocean warming has been observed in every ocean across the world since records began in 1850, showing a rise in mean sea surface temperature of 0.74°C up to 2008. Records of sea surface temperature from around Ireland show a mean warming trend below the global average between 1850 and 2008 of 0.3°C . However, the speed at which warming has occurred since 1994 (0.6°C per decade) is unprecedented in all of the 150 year observational period, with the warmest years on record being 2005, 2006 and 2007. Approximately half of the present increase in Irish sea surface temperatures can be accounted for by the present warm phase of the Atlantic Multidecadal Oscillation, with the North Atlantic Oscillation and East Atlantic Pattern playing smaller roles. However, the remaining increase has been attributed to an underlying global warming trend. This warming is evident in Irish waters during each month of the year and is particularly strong in the southeast of Ireland.

Salinity

Overall estimates of salt content in the oceans across the globe suggest an increased input of freshwater, although lack of data from many regions makes it difficult to accurately quantify any recognisable trends. In Irish shelf waters, salinity varies cyclically, which appears to coincide with the North Atlantic Oscillation. Coastal waters vary in salinity according to increased winter rainfall and the Eastern Atlantic Pattern, while there appear to be no trends in salinity in deeper waters (below 200 m).

'Records of sea surface temperature from around Ireland show a mean warming trend below the global average between 1850 and 2008 of 0.3°C '.





‘Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m’.

Sea Level

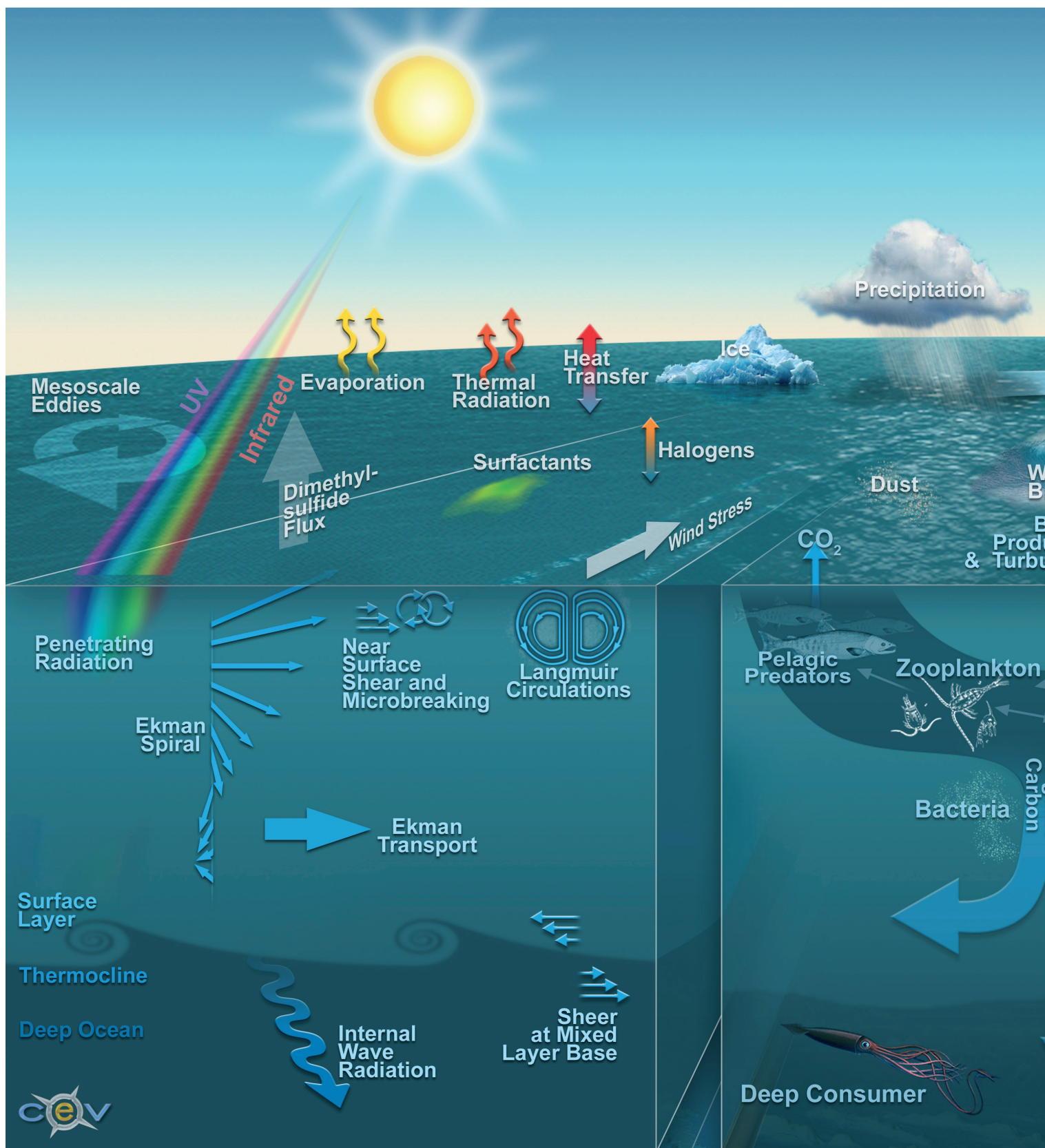
Since there are no historic sea level measurements on the geographic or time series scales required to accurately assess changes around Ireland’s coast, heavy reliance must be placed on computer models to predict future trends. Such models predict a global mean sea level rise of between 0.09 m and 0.88 m by the year 2100, with sea levels rising at rates around two to four times faster than they are today. Coastal retreat rates along the Atlantic coast are currently 0.5 to 1.0 m/year in those areas most affected by storms and will be increased in future as sea levels rise.

Wave Climate

Wave heights in the Northeast Atlantic are significantly correlated with the North Atlantic Oscillation. Increases in significant wave height (i.e. the mean height of the highest one third of all waves) have been demonstrated in the North Atlantic between 1988 to 2002. Increases in the monthly significant wave height of up to 0.6 m in the Northeast Atlantic between 1988 and 2002 have been linked to changes in the North Atlantic Oscillation. In the southwest of Ireland, significant wave heights have increased by 0.8 m per decade.

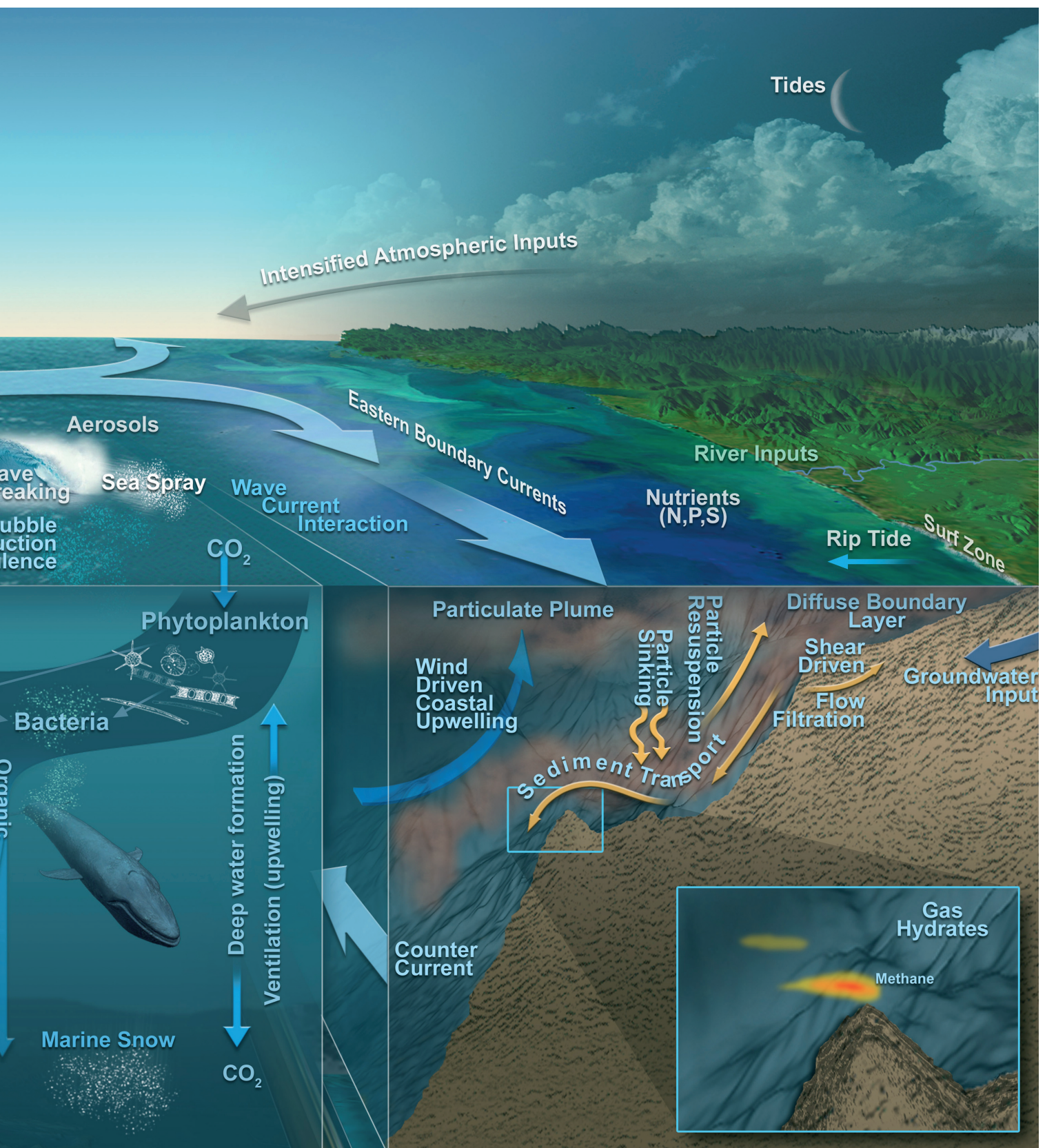
Shelf Sea Stratification

During summer months warmer more buoyant layers of seawater float on top of denser cooler layers creating stratification and limiting vertical ocean mixing. Density-driven currents at the boundary zones between the upper warmer and lower cooler layers form important transport pathways for nutrients, fish eggs and larvae in the shallower shelf seas. Evidence suggests that the earlier onset of stratification, caused by ocean warming, results in more persistent coastal currents in summer months.



KEY POINTS

- Atmosphere** The North Atlantic Oscillation and the Eastern Atlantic Pattern alter wind and rainfall patterns in Ireland. Both have been positive in recent decades enhancing westerly winds.
- Oceanography** Increases of sea surface temperature of 0.6°C per decade since 1994 is unprecedented in the past 150 years. Global mean sea level predicted to rise by between 0.09 m to 0.88 m by 2100. Increase in wave heights of 0.8 m off southwest Ireland.
- Phytoplankton** Increased numbers of diatoms and dinoflagellates around the Irish coast since 1998.
- Zooplankton** Increase in warm water *Calanus* species in recent years. Gelatinous species increasing since 1997.



- Marine fisheries** Increased numbers of most warm water species in Irish waters. Poor cod and lesser spotted dogfish are suitable indicator species. More sightings of exotic fish species in our waters.
- Ocean chemistry** Median winter nutrient values are well below internationally acceptable thresholds. Research underway to examine the effect of ocean acidification in Irish waters.
- Migratory fish** Declines in salmon, trout and eel populations since the 1980s. Increased freshwater temperatures in Burrishoole, Co. Mayo affecting survival.
- Seabirds** Numbers of seabirds on Rathlin Island have decreased since 1999. Declines in numbers and failures in breeding may have a climate link.

Ocean Chemistry

Chemical elements such as carbon, nitrogen, phosphorus and silica are the vital building blocks of all living things. Simple unicellular plants called phytoplankton at the base of the food chain transform these inorganic elements to living material which act as food for higher organisms in a process called the “biological pump”. These phytoplankton account for 50% of global primary production. Carbon is usually abundant in the oceans, but primary production can be limited by a scarcity of the other elements nitrogen, phosphorus and silica.

Since the industrial revolution the concentration of carbon dioxide, both in the atmosphere and in the oceans, has increased dramatically leading to ocean acidification. Model forecasts have indicated that, at the present rate of atmospheric increase, ocean pH at the surface could decrease by ~ 0.3 to 0.5 by the end of the century. This increase in acidification could affect ocean chemistry to the point where the element aragonite, which is essential for shell-forming animals such as pteropods and essential planktonic organisms, would no longer be biologically available in the surface Southern Ocean by the year 2050. In the shorter term, the upwelling of deeper acidic waters along the productive shallow margins of Europe could have a negative effect upon important fish nursery grounds.

In Ireland, studies on the impacts of increased atmospheric carbon dioxide on ocean chemistry and the ecosystem are being carried out by National University of Ireland, Galway and the Marine Institute to determine whether and under which conditions Irish shelf waters are either a source of or a sink for carbon dioxide.

The median winter values of nutrients, such as total oxidized nitrogen and orthophosphates, in Irish waters are safely below the threshold levels at which eutrophication (the condition in which oxygen levels fall to levels below that necessary to sustain life) can occur.





Phytoplankton

The growth of phytoplankton, which includes groups such as diatoms and dinoflagellates (the latter can be toxic to marine life) is critical to marine ecosystems. The diversity of these tiny organisms is strongly influenced by the complex water circulation patterns which, further offshore, are strongly influenced by the subtropical gyre. Further inshore, however, the overall abundance of phytoplankton in all coastal regions appears to have increased since 1998. This has been accompanied by an expansion of the growth season of diatoms and a percentage increase in the occurrence of some harmful species during winter months since 2000. It is important to recognise that these datasets are for short time periods (ranging from 13-46 years) which may not be significant in terms of the much longer term phenomenon of climate change. However, if earlier and more prolonged stratification of the water column does continue due to global warming, then a depletion of surface nutrients in shelf seas is likely to result in a decline in phytoplankton biomass. Since phytoplankton represent the base of the food chain for the entire marine ecosystem, this change has the potential to cascade through the marine food web with unknown consequences. Also, since most of the toxic and harmful phytoplankton recorded in Irish waters prefer stratified waters, it is possible that an increase in the frequency of harmful events will occur, which could have direct commercial implications for the fishing and aquaculture industries.

Zooplankton

Moving up to the next level in the marine food web, zooplankton (the animal plankton of the sea) are a vital link in the “biological pump” that passes organic matter to the higher predators of the ocean. They are also sensitive to temperature and have very short life cycles (sometimes as short as days) which makes them vulnerable to climate change impacts. Studies have already shown that spatial patterns in the biodiversity of calanoid copepods (a group of tiny lobster-like zooplankton) have changed in response to general ocean warming, with a general movement northwards of warm water species and a retreat of cold water species. It also appears that production of these copepods starts earlier in the year. In deeper waters below 200 m, gelatinous zooplankton such as jellyfish and comb jellies are more abundant in warmer years. While their population sizes have differed between shelf and oceanic areas in the past, since 1997 they have been increasing simultaneously in both waters.

Commercial Fisheries

Closer to the apex of the food web, the commercial fisheries which sustain rural economies and communities in Ireland and are valued at an estimated €500 million per annum to the country, stand to be affected by changes in ocean temperature and water chemistry. Fisheries scientists have already noticed that a number of warm water species, including sprat, anchovy, pilchard and blue mouth, have increased in abundance to the north of Ireland and in the Celtic Sea, while poor cod and lesser spotted dogfish have not only increased to the north of Ireland but also decreased in the south. Many exotic species of fish are being sighted in both Irish and United Kingdom waters and such sightings appear to be on the increase. Climate change may lead to an increase in what is known as the “Lusitanian community” of warm water fish to the west of Ireland, although both the Lusitanian community and the “boreal community” of cold water fish appear to be stable to the north of Ireland at present. As with plankton studies, however, the relatively short period of data sets must be considered carefully against the much longer term trends suggested by climate change studies before drawing definite conclusions. Any over exploitation of a stock by commercial fisheries is likely to increase its response to climatic fluctuations. This could lead to a decline of traditional fisheries for such species as cod and the emergence of new fisheries for such Lusitanian species as boarfish, which unfortunately is of lower commercial value.

‘Between 1988 and 1989, sea trout stocks in the west of Ireland showed stock collapses in the majority of catchments in the midwest as indicated by rod catch statistics and corroborated by trap census in four key west of Ireland fisheries’.



‘Whole colony surveys and annual monitoring plot counts show that numbers of seabirds on Rathlin Island have decreased since 1999’.

Seabirds

A number of recent studies have reported a decline in seabird numbers in Britain and Ireland, as well as breeding failures at seabird colonies in the United Kingdom. Some studies have linked these phenomena to climate change, suggesting that changes in sea temperature affect seabirds directly through their prey particularly in the North Sea where sand eels, the main seabird prey species, have been on the decline.

Migratory Fish

“Diadromous” migratory fish (including salmon and eels) that migrate between the sea and fresh water to complete their life cycle exhibit high sensitivity to environmental conditions and are particularly vulnerable to changes associated with climate. The main three species of diadromous fish in Ireland - salmon, sea trout and eels - have all shown a decline in numbers and marine survival over the past three decades, which are thought to be at least partly related to the interactive effects of changing climate and oceanic conditions, along with human impacts. Data from the Marine Institute’s experimental catchment in Burrishoole, Co. Mayo shows that marine survival of salmon has been declining since the 1970s, sea trout stocks collapsed in the 1980s, with adult returns still at a low level, and that European eels have had a sharp fall in recruitment since the 1980s, in line with similar declines throughout Europe. Data also shows that freshwater temperatures from the Burrishoole catchment have been increasing significantly from the 1970s to the present day, which is thought to have strong knock on effects on the survival and development of juvenile fish populations.



Recommendations

This report card briefly describes key regulators of ocean climate around Ireland and examines relevant environmental datasets available in 2009. It represents the current status of knowledge regarding the influence of climate on Ireland's marine ecosystems and resources. Improvements in the information base will require:

1. Long term monitoring of essential climate variables is maintained and Ireland contributes as planned to climate monitoring activity planned under the UN Global Climate Observing System (GCOS)
2. Long-term monitoring should be considered in an integrated national sense to represent terrestrial, atmospheric and oceanic measurements.
3. Capacity is retained and strengthened in Irish research groups particularly in climate modelling, chemical analyses, plankton ecology, aging and genetic techniques and analysis and interpretation of sediment cores from lakes and oceans
4. Basic research needs to take place to examine the processes and interactions within ecosystems so that sense can be made of the long-term data and the observed changes within the marine climate system.
5. Research needs to be initiated to increase confidence in estimates of certain climate impacts including sea level rise, ocean acidification, alteration of food webs and downstream affects on coastal communities and to prepare a mitigation and adaptation strategy.
6. The socioeconomic importance of Ireland's marine resources affected by climate change must be better defined (i.e. quantified) so that policymakers can be informed of the full significance of the changes revealed through scientific investigation.
7. Linking marine climate change research in Ireland to major initiatives at the international level is extremely important. Irish researchers should interact with international climate scientists so that technology transfer and capacity building can take place (both ways) and that a flow of research findings exists to and from the Irish marine climate research community.
8. Contributing scientific findings to the Intergovernmental Panel on Climate Change (IPCC) is a necessary and beneficial process that Irish scientists should be involved in.
9. Adaptation measures are best formulated on the basis of robust data.



Under the Discovery Research Programme of Sea Change – A Marine Knowledge, Research, & Innovation Strategy for Ireland 2007 – 2013 (www.marine.ie), marine climate change is recognised as one of the key policy areas where future research should take place. Recognising the need for a national programme to address marine climate change, the Marine Institute has undertaken a preliminary programme of research relating to ocean mediated climate change.

This report card summarises the key findings from this preliminary programme. A future Marine Climate Change Research Plan will be produced in 2009 to document the next steps in implementing the national marine climate change priorities for the 2009-2013 period.

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