MCCIP Marine Climate Change Impacts Partnership

Topic

Built Structures

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Executive Summary

The built environment can be split into three sections – the Oil and Gas Industry, the Renewables Industry and structures on the shoreline. Evidence for the impacts of climate change in this area has been drawn from wider information than the traditional peer-reviewed scientific literature.

The Oil and Gas industry is relatively data and experience rich in terms of monitoring and understanding the impacts of climate change on its structures through increased wave heights etc. It uses these measures within the design criteria of new structures.

The Renewables industry, whilst relatively immature, is developing the understanding of the time and space scales of physical processes that can act upon their structures. Particularly important is the changes in geomorphology impacting can the integrity of the inter-array and export cable routes.

In terms of sea-level rise, the impacts on shoreline structures are relatively well understood and built within the guidance produced by Defra in terms of recommend future sea levels. Some more subtle potential effects have been identified such as increased erosion around the toe of structures.

Full review

The "Built Structures" theme can split into three sectors :

a) Oil and Gas

Considerable interest already exists in understanding the impact of changing wave climate on the oil and gas sector. The main drivers for the industry are cost savings, improved safety, and reduced risk enabling better management of the assets in UK waters. In terms of science, this means extremes of the combined tide and wave heights, changes to the current regime around structures (potentially increased scour and operational requirements), changes in temperature (impacting on riser temperatures and hence altering oil viscosity) and changes in suspended sediment concentration (cooling waters needing further filtration).

Historically, in order to achieve this goal a number of metocean parameters have been recorded at a number of oil installations especially wave height and period. Recent analysis of these wave climate data in the northern North Sea since 1973 (Leggett, 2007) has examined the link between regional scale variability in the wind field and changes to the wave height. A broadscale feature of the time-series of annual mean significant wave height was an increase from 1973 into the first half of the 1990s following which it reduced. However, the behaviour over time of the autumn (Oct-Dec) and winter (Jan – Mar) waveheights has been different. These data suggest that significant waveheights have been reducing in the autumn since a peak in 1980-1985 whilst greater increases were seen in the winter in the first half of the 1990s. Both seasons show strong relationships, using 5 year rolling means, to their respective NAO index suggesting the link to the regional scale windfield. These results from the industrial data broadly mirror those in the academic literature (see Winds and Storms). Importantly these data are used to assess the 100-year returns for average waves and peak waves which are then used as part of the design criteria for new structures. These values are seen to be sensitive to the length and timing of the datasets on which they are based. Calculated on the wave data from 1988 to 1996, when waves heights in winter were at their highest, the 100- year significant wave height would be 17.5 m, rather than the 15.6 m now used in design criteria for the northern North Sea based on the longer data set from 1973-1998 (Leggett, 2007). This highlights the need for long period records and the need for robust statistical analysis of the highly variable wave height records (Grant, 2007).

Whilst the design criteria will use statistical measures of 100 year return events the main period of concern for the Oil and Gas sector is actually the period up to 20 years ahead as this is the typical design life of the structures and is linked to the potential available reservoir. This may increase with new recovery techniques and the potential use of the Oil and Gas infrastructure in carbon sequestration.

b) Renewables

Currently, within the renewables sector, the wind sub-sector is the most advanced with four wind farms operational and several others in construction. Current (Round 1) and new (Round 2) wind farms tend to be situated in the three renewable development zones around the Outer Wash, Thames estuary and Liverpool Bay. Potential developments could be very large with up to a 1000 turbines in the London array situated in the Thames Estuary. In the “wet” renewable sub-sector, plans or trials are underway at EMEC (Orkney’s) and WaveHub (Cornwall) for wave devices and Lynmouth (North Devon) and Strangford Lough (Northern Ireland) for current turbine devices. The main climate related concerns for the developers of these structures are:

1. The need for Metocean data in order to support the engineering design
2. Impacts of changes in sediment transport on the local geomorphology.

This is especially important for the inter-cable array in windfarms located on Sand Banks e.g Scroby Sands, Gunfleet and also export cable ashore

3. Impacts on the Operation and Maintenance due to changes in wave climate reducing the access time available (and associated Health and Safety issues).

Future assessments of the wave climate and seabed mobility under different climate scenarios will significantly improve the understanding of these processes on the built environment (see Future section).

The renewables sector is mainly concentrated on the medium timescale (defined as upto 20 years) as the design life of current monopile structures is typically 25 years.

c) Shoreline structures

These structures are associated with flood defence around the UK and can be sub divided into two sectors

Protection from Coastal Erosion

The Foresight report on Flooding and Coastal Defence (Evans et al 2004 and the foresight website) shows that coastal erosion will increase due to climate change. Even present levels of expenditure on coastal defences will not keep pace with coastal erosion in the coming decades and approximately one-third of existing coastal defences will be destroyed. Erosion rates increase in all climate scenarios and show that the average annual damage is set to increase by 3-9 times by the 2080s. However, note that even the worst case scenario (£126 million per year) is still much less than the current flood losses per year (£1 billion per year).
The areas under greatest risk identified in the Foresight report are those around major estuaries and the east coast (see Figure 2.2 from Executive summary). Some structures e.g. oil refineries could be relocated at the end of their working life but other assets such as coastal towns will be difficult to relocate. In terms of coastal processes, the key parameters are changes to the extremes and frequency of tides and tidal surges, waves, sediment transport patterns/pathways and any currents associated with freshwater inputs e.g. floods in estuaries and cliff erosion associated with freshwater springs

Protection from Coastal Flooding

The impacts of changing sea level and storminess on existing structures has also been assessed (Burgess and Townend, 2004; Townend and Burgess, 2004). A number of key findings have been made:

1. The performance of coastal structures in "depth limited" conditions is very sensitive to even modest changes in water depth allowing larger wave to reach the structure
2. While there is a focus upon raising crest levels to accommodate sea

level rise, we shall often need to re-engineer the whole structure due to increased scour around the toe of the structure
3. The increase in costs will usually be substantially greater than the relative change in water level arising from sea level rise
4. That increase is likely to be two to four times the present cost to provide a similar level of performance.

The critical coastal processes are similar to those in Coastal erosion. This sector is concerned with the long-term (next century) as some structures have very long design lives due to their relatively high cost. For instance, a review of the flood management plan for the Thames Estuary for the year 2100 is currently underway - http://www.thamesweb.com/page.php?page_id=60&topic_id=9

Future

A key update for this sector will be the assessment of wave statistics under different climate scenarios currently underway by Judith Wolf at POL as part of the Coastal Simulator project lead by Prof Robert Nicholls (Nicholls *et al.*, 2007) and http://www.tyndall.ac.uk/research/programme5/. This will significantly improve the predictions of future wave climate scenarios, the impacts on the coastline and also hopefully the confidence associated with these predictions.

There are plans for a joint workshop with JCOMM / WCRP in Geneva in 2008. Working title: "Storms in a changing climate – impact on Metocean interests"

Confidence assessments

'What is already happening' – Low

'What could happen in the future' - Low

Starting with the amount of evidence available, this is very variable. The Oil and Gas industry in the offshore zones of the North Sea is relatively data rich, whilst wave data from the inshore zones is still relatively sparse. However, this is slowly changing with initiatives such as WaveNet and the Channel Coastal Observatory. Assessing the level of agreement is also not straight forward as there is lack of robust statistical tools, the implications for wave climate for various scenarios has not been fully explored and regional variations have not been assessed (inshore Scottish waters is particularly lacking in wave data). Since the 2006 ARC, longer datasets have become available and some re-assessment has taken place but little overall progress can be made until the implications of future climate scenarios for the wave climate have been fully assessed (see below).
Therefore the overall assessment of the level of confidence is **LOW** for both 'What is happening' and 'What could happen'.

The evidence presented here is drawn from many sources rather than the peer-reviewed literature, as the majority of information in this area comes from the commercial sector itself. As such this article has not itself been peer-reviewed.

Knowledge gaps

The importance of the impact of waves in this area suggests that the current low confidence in our scientific understanding of how storms and waves will change in the future is a key gap in knowledge. Some of the more subtle effects of sediment transport around structures is an area that may require further knowledge particularly in light of offshore renewables development and changes in coastal protection needs.

Commercial impacts

This topic is entirely related to commercial impacts of climate change.

References

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WaveNet - www.cefas.co.uk/wavenet