Observed Trends in Nearshore Wave Characteristics Around the English Coast

Elizabeth Warwick-Champion, Channel Coastal Observatory, Southampton, UK.

Thomas Dhoop, Channel Coastal Observatory, Southampton, UK.

Keywords: wave climate, in-situ observations, climate change, coastal management

1. Abstract

Models suggest that climate change will impact future wave climate, although there is little consensus on the predicted effects. This uncertainty in wave climate trends poses challenges for coastal management and highlights the need for more refined regional studies to better predict localised impacts. In this study, observed wave data from 37 coastal wave buoys sites with an average record length of 16 years were used to discern local trends in the English coastal wave climate. Trends in wave height, period (both wind and swell), direction and bimodality were investigated at the 10%, 5% and 0.5% exceedance levels. Significant upward trends in wind wave periods were present at 17 wave buoy sites, primarily along the Northeast and South coasts, while significant increases in swell wave periods were found at 19 sites spread along the coast. Negative trends in wave periods occurred at two sites in the Southwest. Small but significant shifts in wave direction were identified at six sites. Additionally, the occurrence of bimodal sea states increased over the measured time series at seven sites. No robust trends were detected in wave height. Identifying empirical trends is valuable for improving wave climate models through calibration and validation. Furthermore, understanding how large-scale wave climate processes manifest at a regional level helps practitioners in developing adaptive strategies for effective coastal planning.

2. Introduction

An understanding of future wave climates and the potential effects of anthropogenic climate change is key to effective coastal management and preparedness. While modelling efforts on this subject are not lacking, divergences between wave climate projections send unclear messages to coastal practitioners (Bricheno *et al.*, 2023).

In recent decades, increased cyclone frequency has been reported over Western Europe (Priestley *et al.*, 2020), although models suggest that there will be little change in the frequency or intensity of mid-latitude cyclones in the near future (Seneviratne *et al.*, 2021). Over longer timescales, there are suggestions that structural shifts in storm patterns could emerge, including intensified winter winds - and therefore storm intensity - at the latitude of the UK (Harvey *et al.*, 2020). Yet, projections also indicate a reduction in rough days, shorter storm durations, and decreased wave periods, especially under high emissions scenarios such as RCP8.5 (Amores and Marcos, 2020; Morim *et al.*, 2021). Projected changes to extreme wave events also present diverging information. Some studies suggest that extreme wave heights will remain stable, except for potential increases in the North Sea (Meucci *et al.*, 2020), while others project change along the UK coast in the range of 10-20% by the end of the century, with no consensus on the direction of change (Palmer *et al.*, 2018).

Furthermore, impacts at the coast are subject to greater uncertainties due to complex spatial patterns. Wave climate models are typically run at a spatial resolution that limits their ability to predict changes in the coastal zone, where local bathymetry and regional storm responses play significant roles (Dhoop and Mason, 2018). Understanding how large-scale wave climate processes manifest at a regional level can help practitioners develop adaptive strategies for improved coastal planning. This underscores the need for more local-scale studies to better forecast wave climate trends for coastal management. It also highlights the requirement for high-quality observations in areas that are challenging to model. Long-term wave observations are vital for understanding existing trends, particularly at the coast, and for improving model confidence and validation.

In this study, observed wave data, with an average record length of 16 years, were used to discern local trends in the English coastal wave climate. In similar studies, concerns have been raised about the composite nature of wave observations datasets - inconsistent measurement methods create uncertainty and complicate interpretation (Ardhuin *et al.*, 2019; Gemmrich *et al.*, 2011). However, the National Network of Regional Coastal Monitoring Programmes' (NNRMCP) wave buoy network presents a unique opportunity to study coastal wave climate trends due to the homogeneity of its observations. The same wave buoy model - the industry-standard Datawell Directional Waverider Mk III - has been deployed across all sites for the duration of the time series, eliminating the need for calibration and adding confidence to the identified trends.

Changes to any aspect of the local wave climate can have significant consequences for coastal management. Increases in wave heights or wave periods at a particular location could drive higher erosion rates, reduce the efficacy of existing defences or lead to more frequent coastal flooding and overtopping. Shifts in wave direction could alter local sediment dynamics and may change the relative risk across different sections of the coastline. Moreover, the occurrence of bimodal seas – where both wind-driven and swell waves are present – has been linked to destructive events, for example sea wall failure and overtopping, that cannot be attributed solely to other aspects of the sea state (Mason *et al.*, 2008; Pearce *et al*. 2024). Therefore, identifying local wave climate trends is valuable for evaluating risk strategies and informing boundary conditions for coastal management and engineering.

3. Methods

3.1 Wave Data

Wave data used in this study come from 37 NNRCMP wave buoy sites distributed around the English coastline, with most moorings located at a water depth of 10-12 m CD. The length of the available wave measurements varies by site (Figure 1, Appendix A). The longest record is at Milford, where more than 27 years of wave measurements are available. In the southeast, a further 6 sites have over 20 years of data, while in the southwest, sites typically have more than 16 years of measurements. The remaining buoys provide on average 13 years of measurements. The wave dataset is homogenous; all wave measurements were recorded using a Datawell Directional Waverider (DWR) Mk III, except for Milford between 1997 and 2005, when a Waverider Mk II was used. An assessment of the time series at Milford found no drift in trend or step-change between the two sensors (Dhoop, 2025). Appendix A provides a visual of the overlapping time series across all sites.

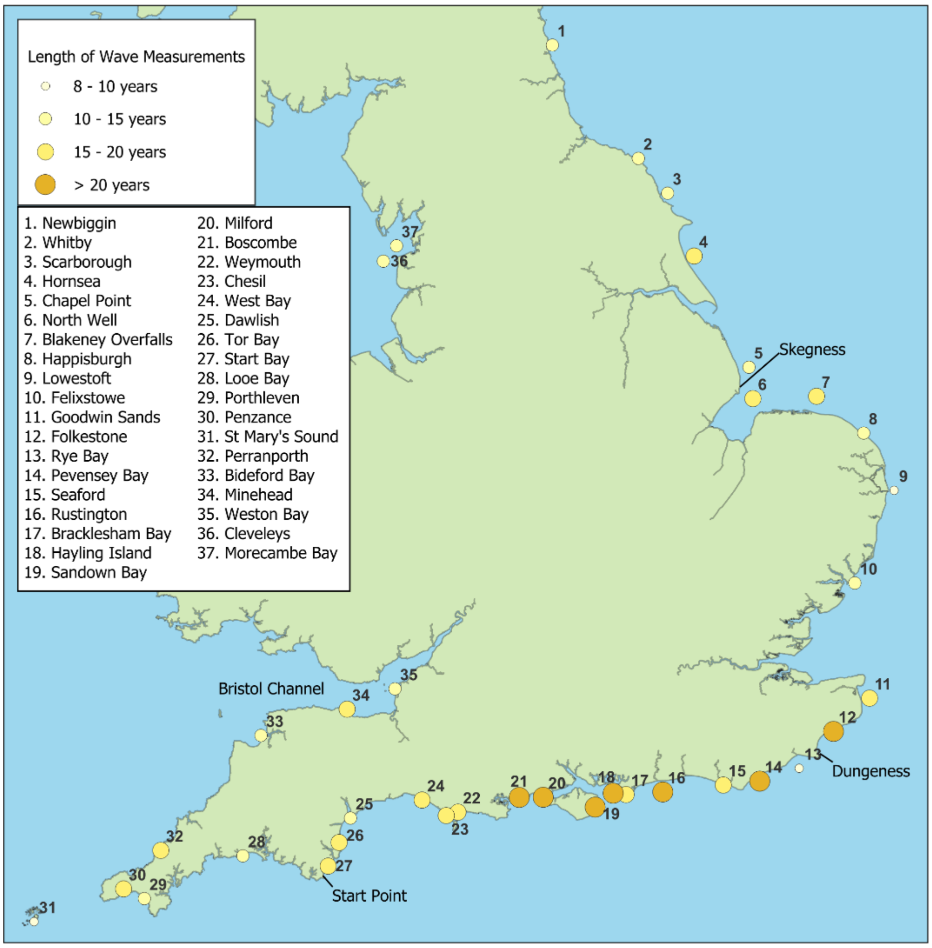


Figure 1: The distribution of the 37 NNRCMP wave buoy sites and the length of wave measurements included in the trend analysis. See Appendix A for a visual of the overlapping time series.

Datawell DWR Mk III wave buoys measure waves using an internal accelerometer, which allows the three-dimensional motion of the buoy to be converted into horizontal and vertical displacements via double integration. Wave parameters are derived from 30-minute measurement bursts.

3.2 Data Preparation

Wave data were divided by storm seasons (1st July to 30th June) for each year, from the start of the time series to 30th June 2024. Any storm season with a data recovery rate below 80% was excluded from the trend analysis. Five aspects of the wave climate were examined for trends: wave height, wind wave period, swell wave period, wave direction and occurrence of bimodal sea states. A multi-parameter approach was used to investigate each aspect of the wave climate, incorporating, where possible, a combination of spectrally-derived and statistically-derived parameters (Table 1). In addition, both quality-controlled (QC) and non-QC parameters were used in the analysis to rule out the potential that trends were introduced by a particular QC process. For QC parameters, the quality flags following Mason & Dhoop (2023) were applied, while storm wave data was subject to an addition layer of QC following Dhoop *et al*. (2024).

Wave Height				
Significant wave height	H_s | H_{m0}	Significant wave height, derived from the spectrum	Spectral	QC
Significant wave height	$H_{1/3}$	Mean height of the highest 1/3rd of waves in the record	Statistical	No QC
Wind wave period				
Zero-crossing period	T_z | T_{m02}	The mean period, estimated from the spectrum	Spectral	QC
Mean wave period	T_{av}	Mean period of the waves in the record	Statistical	No QC
Mean period	T_{m01}	The period associated with the mean frequency of the spectrum	Spectral	No QC
Swell wave period				
Peak period	T_p	The period of the most energetic waves in the spectrum	Spectral	QC
Calculated peak period	T_{pc}	Peak period, estimated from the moments of the spectrum	Spectral	No QC
Energy period	T_e	The period of an energy equivalent regular wave. Alternative for T_p for swell-monitoring	Spectral	No QC
Wave direction				
Peak wave direction	Dir	Direction associated with most energetic waves in the spectrum	Spectral	QC
Peak wave direction above threshold	Dir ($H_s > 0.5$m)	Direction associated with most energetic waves in the spectrum for waves with a significant wave height above 0.5 m	Spectral	QC
Bimodal Seas				
Occurrence of a bimodal sea state	-	A binary parameter indicating the presence of both wind-sea and swell, characterised by two peak frequencies in the spectrum.	Spectral	No QC

Table 1: Wave parameters used in the trend analysis.

For non-QC parameters, a set of automated checks were applied to the full time series (Table 2). An out-of-range test was carried out using the lowest measurable value as the minimum and a site-specific maximum, based on quality-controlled values, as a guide. Rate-of-change tests were also performed. As a final check, boxplots were created for each parameter as a visual check for outliers.

Parameter	**Out of range**		**Rate-of-change over 30 min**
	Minimum	**Maximum**	
$H_{1/3}$	0 m	max. H_{m0}	0.5 m
T_{av}	1.6 s	max. T_{m02} + 2 s	2 s
T_{m01}	1.6 s	max. T_{m02} + 2 s	2 s
T_{pc}	1.6 s	28.6 s	3 s
T_e	-	-	3 s

Table 2: The automated checks performed for non-QC wave parameters.

The multi-parameter approach was not applicable for investigating the occurrence of bimodal seas - a sea state where both the wind-sea and swell are present concurrently, resulting in a characteristic two-peaked spectrum. To quantify bimodality for the trend analysis, each of the half-hourly spectra were categorised as bimodal or not, using the conditions from Mason *et al.* (2008):

1) The minimum total energy of the wave spectrum is equivalent to $H_s = 0.5$ m
2) The peak energy in the smaller peak is at least one-third that of the larger peak
3) The peak energy in the smaller peak is at least 0.4 m^2 Hz^{-1} (equivalent of Hs ~0.2 m at 10 s)
4) The energy at the trough is less than half of the smaller peak

A time series for each storm season was then created by calculating the daily occurrence of bimodal seas, expressed in hours.

3.3 Trend Analysis

Measured wave data typically exhibit a non-normal, positively skewed distribution with a long right tail. The waves of most interest from a coastal management perspective lie in this right tail - these larger or longer waves are most likely to result in material transport or overtopping. Traditional metrics such as the mean, median and mode, which describe the central tendency, do not effectively characterise the right tail. Therefore, exceedances were used to detect trends in the right tail across the time series, aiming to capture changes most relevant to coastal management. The 10%, 5% and 0.5% exceedances were calculated for the parameters in Table 1, excluding wave direction.

For wave direction, the trend analysis was performed on the mean wave direction of each storm season. All wave directions were referenced to true North using the IGRF (1590-2024) model via the NOAA Magnetic Declination Estimated Value tool, with declinations retrieved for 1st January of each year. A trend analysis of mean wave direction where significant wave height exceeded 0.5 m was also performed, to filter out waves of little consequence from a coastal management perspective.

Linear trends were fitted to the annual exceedances (or means for wave direction) for each parameter and tested for statistical significance using a two-tailed *t*-test ($\alpha = 0.05$; $p > 0.95$). A Jackknife analysis was also performed to test the sensitivity of trends to interannual stochasticity; these results are included in Appendix B.

4. Results

4.1 Wave Height

Trends in wave height were notably absent in the analysis. Of the two parameters investigated (H_{m0} and $H_{1/3}$) across the three exceedance levels, only one significant trend was found. At Whitby, the 5% exceedance of $H_{1/3}$ increased 0.05 m per year. However, $H_{1/3}$ at the 10% and 0.5% exceedance levels showed no significant trends, resulting in relatively low confidence in the trend found at Whitby.

4.2 Wind Wave Periods

Positive trends in wind wave periods were found at the majority of sites. A negative trend in wind wave period was found at one site in the Southwest.

The three parameters investigated - T_{m02}, T_{av} and T_{m01} - showed similar regional trends (Figure 2). Increases were noted along the South coast, from Start Point to Dungeness; in the Northeast, from Newbiggin to Skegness; and in the Northwest, in Morecambe Bay. The coastlines of East Anglia, Kent, and both the south and north coasts of Cornwall, as well as the Bristol Channel, showed no positive trends in wind wave periods.

The strongest wind wave period trends were found in the Northeast, where significant positive trends were found for 72% of the parameter and exceedance level combinations between Newbiggin and Skegness. At Scarborough, where all wind wave period trends were significant, increases of approximately 0.05 s per year at the 10% exceedance level, 0.07 s per year at the 5% exceedance level and 0.08 s per year at the 0.5% exceedance level were recorded.

Moreover, strong positive trends in wind wave periods were found at several South coast sites, particularly those more exposed to the east - Pevensey Bay, Sandown Bay, Weymouth and Start Bay.

At Looe Bay in the Southwest, a negative trend in wind wave period was observed at the 5% exceedance level across all three of the wave parameters, reflecting a decrease of approximately 0.03 s per year. Appendix B provides a table of all trend results.

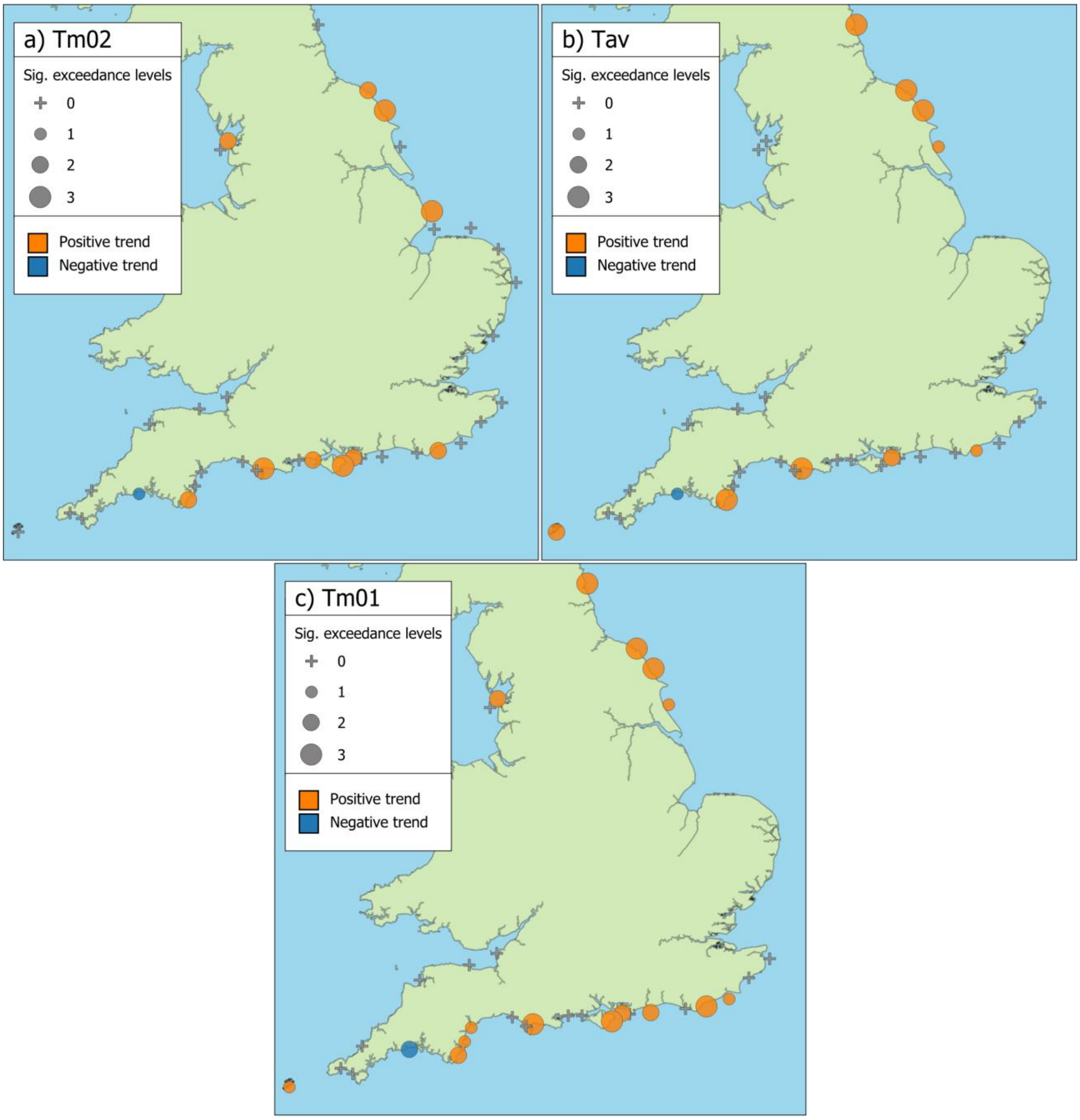


Figure 2: Sites where significant trends in wind wave periods were found, using **a)** T_{m02}, **b)** T_{av} and **c)** T_{m01}. Circle size indicates the number of exceedance levels where the trend was found. Circle colour indicates the direction of the trend.

4.3 Swell Wave Periods

Trends in swell wave periods were found at a majority of sites. A greater number of significant trends were found in T_e compared to T_p and T_{pc}, but the overall distribution and direction of trends around the coast were similar (Figure 3).

Swell wave trends were consistently found at a number of South coast sites, including Hayling Island, Sandown Bay, Weymouth, Looe Bay, and Porthleven. Increasing swell wave periods were also observed in the Northern and East Anglian regions, although the trends were relatively weaker.

The strongest trend was found at Folkestone, where all but one parameter and exceedance level combination showed a significant increase in swell wave periods. This corresponded to increases of approximately 0.03 s per year at the 10% exceedance level, 0.07 s per year at the 5% exceedance level, and 0.12 s per year at the 0.5% exceedance level.

At Looe Bay and West Bay, negative trends in swell wave periods were found. The trend was more pronounced at Looe Bay, where swell wave periods decreased by about 0.08 s per year at the 10% and 5% exceedance levels.

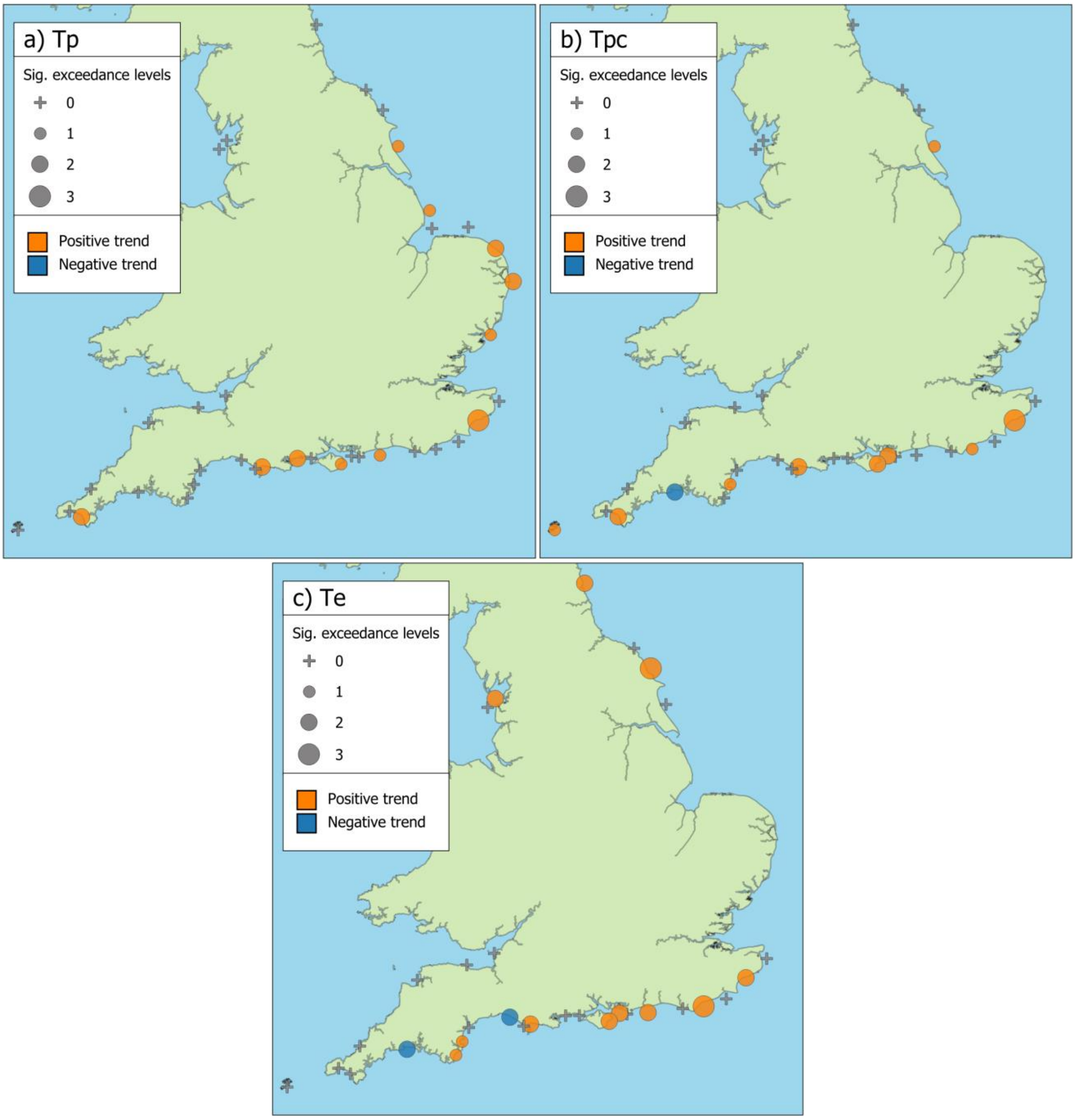


Figure 3: Sites where significant trends in swell wave periods were found, using **a)** T_p, **b)** T_{pc} and **c)** T_e. Circle size indicates the number of exceedance levels where the trend was found. Circle colour indicates the direction of the trend.

4.4 Wave Direction

Trends in wave direction were found at 6 sites, with no clear regional or exposure-related pattern observed (Figure 4). At 3 sites – Newbiggin, Goodwin Sands and Start Bay – a trend was present for both wave direction parameters. For waves over 0.5 m H_s, Newbiggin experienced a shift of 0.76 degrees per year towards East-North-East, Goodwin Sands saw a shift of 0.82 degrees per year towards South-South-East, and Start Bay experienced a shift of 0.50 degrees per year towards South-South-East.

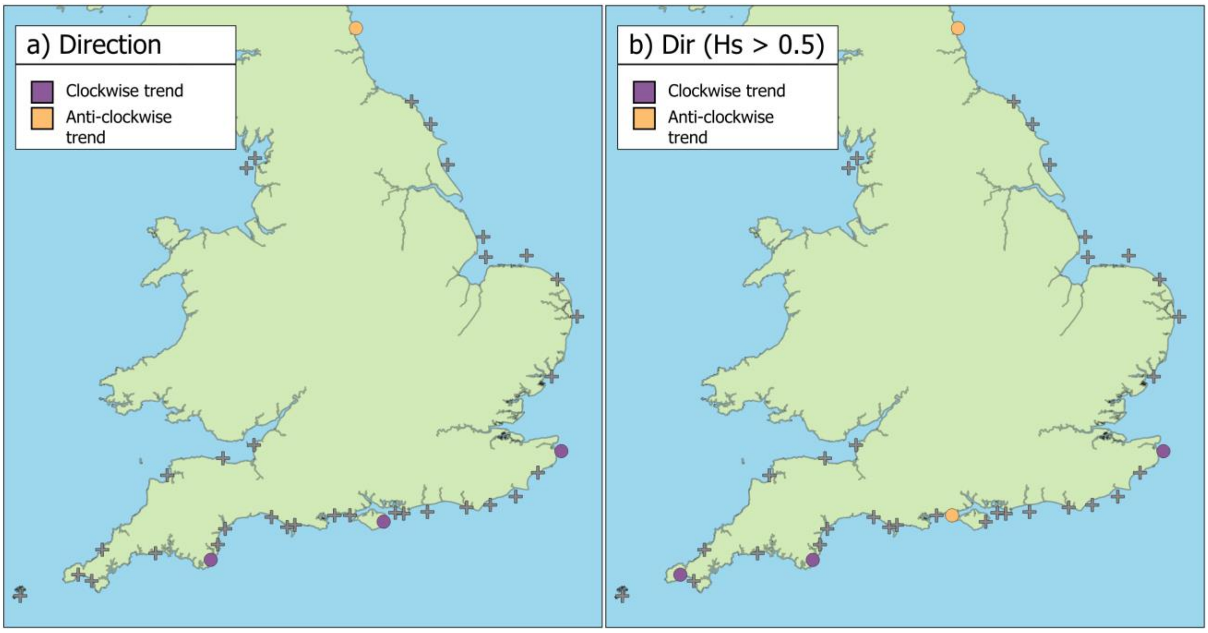


Figure 4: Sites where significant trends in wave direction were found, using a) mean wave direction and b) mean wave direction where H_s is greater than 0.5 m. Circle colour indicates the direction of the trend.

4.5 Occurrence of Bimodal Seas

Positive trends in the occurrence of bimodal seas were found at 7 sites. These trends were observed along both the Northeast and South coasts, with stronger trends on the South coast (Figure 5). On the South coast, two areas showed trends: east Lyme Bay (sites 23 and 24 in Figure 1) and the Sussex coast (sites 14-16 in Figure 1).

The increase in the occurrence of bimodal seas was most pronounced at the sites in east Lyme Bay, where the bimodality of the overall sea state increased by 0.2% per year, equating to an additional 11.5 days of bimodal conditions per storm season. Along the Sussex coast, the bimodality of the overall sea state increased by approximately 0.06% per year, equating to an additional 4.4 days of bimodal conditions per storm season.

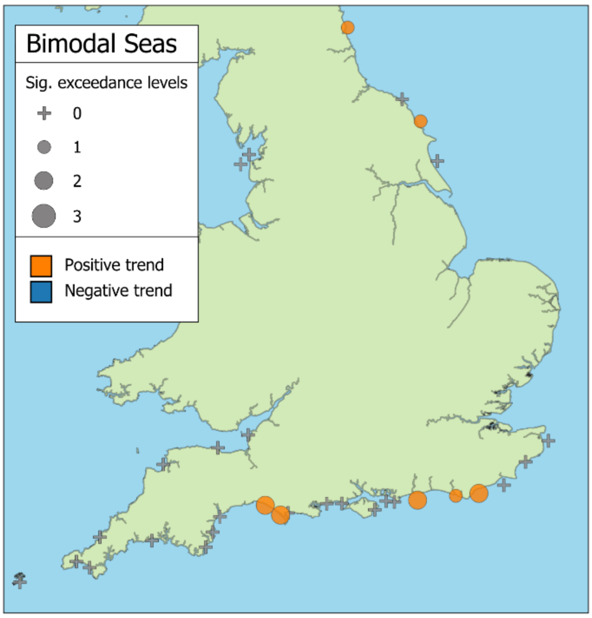


Figure 5: Sites where significant trends in the occurrence of bimodal seas were found. Circle size indicates the number of exceedance levels where the trend was found. Circle colour indicates the direction of the trend.

5. Discussion

The results of this study show that while coastal wave heights around England have remained broadly stable over the last 16 years, there is a clear pattern of change in wave periods, wave directions at some sites, and in the occurrence of bimodal seas. The lack of a consistent or robust trend in wave height is notable, suggesting that perhaps the high interannual variability of storm seasons is masking any underlying trend at these nearshore locations. It is also possible that changes in storm intensity, frequency, or duration have not yet generated a sustained positive or negative trend.

In contrast, wave period trends – both wind wave and swell – stand out for their spatial coherence and statistical significance, most visibly along sections of the South and Northeast coasts. It is noteworthy that many of these sites have an easterly or south-easterly exposure. This is obvious for those sites in the Northeast, but sites such as Pevensey Bay, Sandown Bay, and Weymouth along the South coast also show an upward trend in wind and swell wave periods. Looe Bay (and to a lesser extent West Bay) is a clear exception on the South coast and exhibits negative trends in wave periods. This demonstrates how localised factors such as local bathymetry, coastal orientation, or shifts in the dominant fetch or storm-track alignment can override broader regional tendencies.

Changes in wave direction, though detected at fewer sites, also appear at a number of points around the coast, including Newbiggin, Start Bay, and Goodwin Sands. Because these directional shifts are dispersed rather than regionally clustered, they likely originate from site-specific factors, such as changes in nearshore bathymetry, fetch influences, or local wind regimes. Importantly, even a small directional change can have notable implications for sediment transport pathways, beach orientation, or wave loading on coastal structures.

An additional finding is the rise in the occurrence of bimodal sea states – where both wind-driven and swell peaks coexist – at several South Coast sites, especially along eastern Lyme Bay and the Sussex coast. The superimposition of locally-generated wind waves and longer-period swell can compound coastal impacts, resulting in (sometimes unexpected) overtopping or shoreline erosion. Therefore, even though wave height trends are absent, the rise in bimodality alone can lead to more demanding design conditions for coastal infrastructure and beach management (Pearce *et al*. 2024; Polidoro *et al.*, 2018).

5.1 Potential Drivers of the Observed Trends

Although this study did not extend to a comprehensive exploration of cause mechanisms, it is worth contextualising some of the observed patterns. The observed differences between wave height and wave period trends could result from nuances in how storms develop over time. For example, variations in the dominant storm tracks in the North Atlantic, as well as changes in wind speed or fetch length during storm events, may directly affect wave periods, while leaving short-term wave height variability primarily governed by year-to-year fluctuations.

On the South coast, the strong positive trends in swell wave periods suggest shifts in distant wave-generation areas, potentially linked to changing storm patterns in the North Atlantic, resulting in more frequent, more intense, or longer duration swell events being measured along the English Channel. Conversely, the decline in wave periods seen at Looe Bay may reflect the interplay of nearshore topography with wave transformation processes, or a changing storm-fetch alignment that results in fewer longer period waves.

An increase in the occurrence of bimodal seas likely arises from subtle changes in the timing of local wind-wave events with incoming swell. An increase in the prevalence of distant swell coinciding more often with nearshore wind waves will produce an overall rise in bimodality.

5.2 Implications for Coastal Management

Even modest changes in wave direction, period, or bimodality can translate into disproportionately large effects on coastal geomorphology and flood risk. Longer wave periods, and a higher incidence of bimodal seas generally means more energetic wave impacts, affecting both coastal erosion rates and the potential of overwashing.

Shifts in wave direction in particular, if sustained, can alter sediment pathways or the equilibrium orientation of beaches, potentially requiring more flexible sediment management interventions. Moreover, an increase in bimodal sea states might raise coastal flood risk and increase beach drawdown, underscoring the need for multi-parameter wave modelling, including a bimodal sea state. Locations where wave period trends diverge from broader regional patterns may benefit from focused studies, ensuring that site-specific conditions are fully understood.

Finally, this study highlights the value of high-quality, consistent wave observations. Continued long-term monitoring will improve trend detection. The results also offer ground-truth data for refining site-specific and regional wave models, potentially reconciling the known discrepancies between large-scale projections and local measurements and reducing uncertainty in climate scenarios.

6. Conclusion

Using consistent, high-quality observations from the NNRCMP's network of wave buoys, this study shows that while significant wave heights along England's coastline exhibit no statistically significant trend over the measured time period, wind and swell wave periods, wave directions at certain sites, and the occurrence of bimodal seas have all undergone measurable changes.

Wave period trends – both wind wave and swell – stand out due to their spatial coherence, particularly along sections of the South and Northeast coasts. Many of the strongest positive trends in wave period occur at sites with easterly or south-easterly exposures. At the same time, site-specific exceptions – such as a decrease in wave periods at Looe Bay – underscore the importance of understanding localised responses that may deviate from broader regional patterns. Changes in wave direction, though detected at fewer sites, appear at several points around the coast and are likely driven by localised factors, given their dispersed distribution. Bimodal sea states – where wind and sea swell peaks coincide – have risen in frequency, in particular along the South coast at eastern Lyme Bay and the Sussex coast.

Coastal practitioners should take account of changes in the sea state demonstrated in this study. Adopting a multi-parameter perspective is recommended to fully capture the complexities of evolving sea states, both when developing adaptive coastal strategies and when scoping the modelling that often informs those efforts. Moreover, maintaining long-term, consistent, high-quality observations can provide clarity and direction for coastal practitioners in the short term (0-20 years), even as consensus on the longer-term wave climate remains elusive.

7. Acknowledgements

A pilot study was funded by the Standing Conference for Problems Associated with the Coastline (SCOPAC). The Channel Coastal Observatory is funded by DEFRA (GIA), administered via the Environment Agency. Wave data are from the National Network of Regional Coastal Monitoring Programmes (NNRCMP).

8. References

Ardhuin F *et al.* (2019) Observing sea states. *Frontiers in Marine Science* 6(124).

Amores A and Marcos M (2020) Ocean swells along the global coastlines and their climate projections for the twenty-first century. *Journal of Climate* 33(1): 185–199, 10.1175/JCLI-D-19-0216.1.

Bricheno LM *et al.* (2023) Climate change impacts on storms and waves relevant to the UK and Ireland. *MCCIP Science Review 2023*, 20pp, 10.14465/2023.reu09.str.

Dhoop T (2025) Assessing Drift or Step-Changes in the Significant Wave Height Time Series from a Wave Buoy Site at Milford, Hampshire, UK. *Channel Coastal Observatory, UK,* Technical Report TN06.

Dhoop T *et al*. (2024) Re-processing Datawell Directional Waverider MkIII heave data affected by breaking waves. *Proceedings of the Institute of Civil Engineers – Maritime Engineering*, 10.1680/jmaen.24.00022

Dhoop T and Mason T (2018) Spatial characteristics and duration of extreme wave events around the English coastline. *Journal of Marine Science and Engineering* 6(1): 14, 10.3390/jmse6010014.

Gemmrich J *et al.* (2011) Observational changes and trends in northeast Pacific wave records. *Geophysical Research Letters* 38(22).

Harvey BJ *et al.* (2020) The response of the Northern Hemisphere storm tracks and jet streams to climate change in the CMIP3, CMIP5, and CMIP6 climate models. *Journal of Geophysical Research: Atmospheres* 125(23): e2020JD032701.

Mason TE *et al.* (2008) Nearshore wave climate of the English Channel - Evidence for bimodal seas. *Proceedings of the 31st International Conference on Coastal Engineering*. American Society of Civil Engineers, pp. 605-616.

Mason TE and Dhoop T (2023) Quality Assurance & Quality Control of Wave Data. *Channel Coastal Observatory, UK.* Available at: https://coastalmonitoring.org/ccoresources/dataqualitycontrol/WavesQCManual_v1.2.pdf

Meucci A *et al.* (2020) Comparison of wind speed and wave height trends from twentieth-century models and satellite altimeters. *Journal of Climate* 33(2): 611–624, 10.1175/JCLI-D-19-0540.1.

Morim J *et al.* (2021) Global-scale changes to extreme ocean wave events due to anthropogenic warming. *Environmental Research Letters* 16(7): 074056.

Palmer M *et al.* (2018) UKCP18 marine report. *The Met Office, UK*. Available at: www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Marinereport.pdf.

Pearce A *et al*. (2024) Understanding bimodal seas, shingle beach response and flood risk at Hayling Island, UK. *Proceedings of the Institute of Civil Engineers – Maritime Engineering* 177(3-4): 107-116, 10.1680/jmaen.24.00008

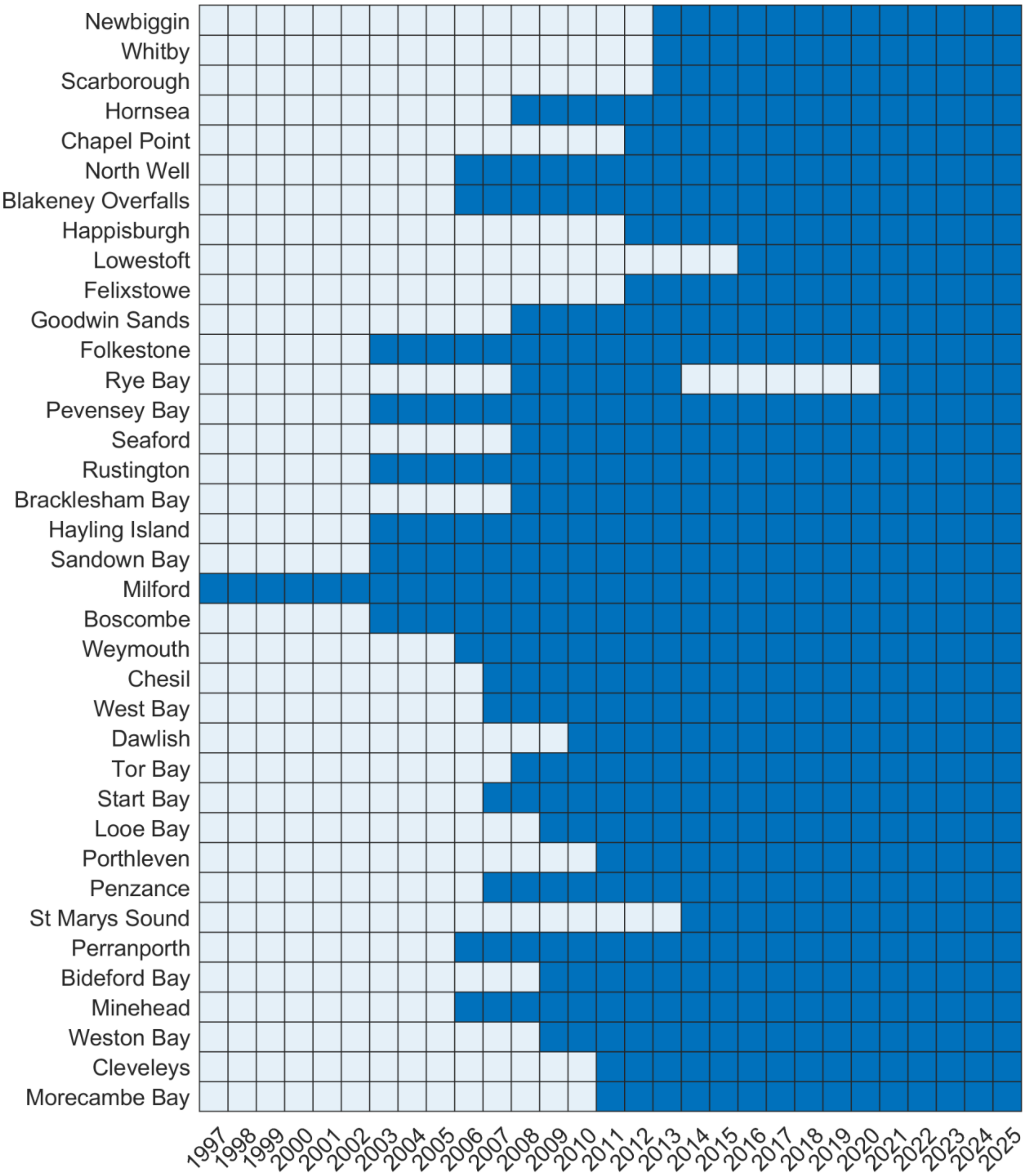
Polidoro *et al.* (2018) Gravel beach profile response allowing for bimodal sea states. *Proceedings of the Institute of Civil Engineers – Maritime Engineering* 171(4): 145-166, 10.1680/jmaen.2018.11

Priestley MD *et al.* (2020) An overview of the extratropical storm tracks in CMIP6 historical simulations. *Journal of Climate* 33(15): 6315-6343.

Seneviratne SI *et al.* (2021) Weather and climate extreme events in a changing climate. In: Masson-Delmotte V *et al.* (eds) *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*, Cambridge, UK and New York, NY, USA, pp. 1513–1766, 10.1017/9781009157896.013.

9. Appendices

A. The overlapping time series at each wave buoy site. Blue indicates the presence of wave data.



B. All trend results. Orange indicates a positive trend, while blue indicates a negative trend. For wave direction, purple indicates a clockwise trend, while peach indicates an anti-clockwise trend. A hyphen indicates the absence of a statistically significant trend. Values indicate the annual rate of change; where values are in bold font and underlined, the trend was significant at ≥ 90% of Jackknife tests. Non-quality-controlled wave parameters were not available for sites in East Anglia.

Site name	Hm0 (m)			H1/3 (m)			Tm02 (s)			Tav (s)			Tm01 (s)			Tp (s)			Tpc (s)			Te (s)			Dir (°)	Dir(°) (Hs >0.5)	Bimodal (%)		
	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%	10%	5%	0.5%			10%	5%	0.5%
Newbiggin	-	-	-	-	-	-	-	-	-	**0.05**	**0.05**	**0.08**	**0.06**	**0.06**	**0.09**	-	-	-	-	-	-	**0.07**	0.07	-	0.59	0.76	-	**1.44**	-
Whitby	-	-	-	-	0.05	-	0.04	-	0.06	**0.05**	**0.06**	**0.08**	0.06	0.06	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scarborough	-	-	-	-	-	-	0.04	**0.05**	0.06	**0.55**	**0.65**	**0.76**	**0.07**	**0.08**	0.11	-	-	-	-	-	-	**0.09**	0.09	**0.16**	-	-	-	-	3.22
Hornsea	-	-	-	-	-	-	-	-	-	-	0.03	-	-	0.03	-	0.05	-	-	-	-	**0.25**	-	-	-	-	-	-	-	-
Chapel Point	-	-	-				0.03	**0.03**	**0.07**							**0.13**	-	-							-	-	-	-	-
North Well	-	-	-				-	-	-							-	-	-							-	-	-	-	-
Blakeney Overfalls	-	-	-				-	-	-							-	-	-							-	-	-	-	-
Happisburgh	-	-	-				-	-	-							0.11	0.16	-							-	-	-	-	-
Lowestoft	-	-	-				-	-	-							0.08	0.16	-							-	-	-	-	-
Felixstowe	-	-	-				-	-	-							0.05	-	-							-	-	-	-	-
Goodwin Sands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.56**	0.82	-	-	-
Folkestone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.04**	**0.12**	**0.12**	**0.04**	**0.07**	**0.18**	-	**0.02**	**0.07**	-	-	-	-	-
Rye Bay	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pevensey Bay	-	-	-	-	-	-	-	**0.01**	**0.01**	-	-	0.02	**0.01**	**0.02**	**0.02**	-	-	-	0.04	-	-	**0.02**	**0.02**	**0.04**	-	-	**0.21**	**0.31**	-
Seaford	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.47	-
Rustington	-	-	-	-	-	-	-	-	-	-	-	-	**0.02**	**0.02**	-	0.04	-	-	-	-	-	**0.03**	**0.03**	-	-	-	0.49	0.62	-
Bracklesham Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hayling Island	-	-	-	-	-	-	**0.02**	0.02	-	-	-	-	**0.02**	**0.03**	-	-	-	-	**0.06**	0.05	-	**0.04**	0.04	-	-	-	-	-	-
Sandown Bay	-	-	-	-	-	-	**0.01**	**0.01**	**0.02**	-	-	-	**0.01**	**0.02**	**0.04**	**0.14**	-	-	**0.07**	**0.08**	-	**0.02**	**0.03**	-	**0.21**	-	-	-	-
Milford	-	-	-	-	-	-	**0.02**	**0.02**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.10**	-	-	-
Boscombe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	**0.04**	-	-	-	-	-	-	-	-	-	-	-	-
Weymouth	-	-	-	-	-	-	**0.01**	**0.01**	**0.03**	**0.01**	**0.02**	**0.04**	**0.01**	**0.03**	**0.05**	0.09	0.13	-	**0.08**	**0.10**	-	**0.03**	**0.04**	-	-	-	-	-	-
Chesil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.76**	**0.88**	-
West Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.04	-	-	-	0.82	**0.98**	-
Dawlish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.04**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tor Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	0.04	-	-	0.04	-	-	-	-	-	-
Start Bay	-	-	-	-	-	-	0.02	**0.02**	-	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	-	-	-	-	-	-	-	0.02	-	-	0.33	0.50	-	-	-
Looe Bay	-	-	-	-	-	-	-	**0.03**	-	-	0.03	-	-	0.03	0.05	-	-	-	**0.11**	0.10	-	**0.04**	**0.05**	-	-	-	-	-	-

Porthleven	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.12**	-	0.16	-	**0.10**	0.18	-	-	-	-	-	-	-	-
Penzance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.25**	-	-	-
St Mary's Sound	-	-	-	-	-	-	-	-	-	0.03	0.04	-	0.03	-	-	-	-	-	-	-	**0.28**	-	-	-	-	-	-	-	-
Perranporth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bideford Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Minehead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weston Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleveleys	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Morecambe Bay	-	-	-	-	-	-	-	0.03	0.04	-	-	-	0.03	-	**0.05**	-	-	-	-	-	-	0.03	-	0.08	-	-	-	-	-