Bellrock Offshore Wind Farm

Wind Farm Development Area

Environmental Impact Assessment Report - Volume IV

Appendix 18.1: Climate Projection Data Report

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Contents

List of Tables

List of Plates

Glossary of Terminology

Term	Definition
Air temperature anomaly	The difference between the observed air temperature and the average air temperature over a reference period, used to identify trends in temperature changes over time and can be calculated for various regions and time scales.
Bellrock Offshore Wind Farm (or the Bellrock Project)	An offshore wind farm capable of exporting up to 1.8 GW of renewable energy to the National Electricity Transmission System. The Wind Farm Development Area is located 120 km east of Stonehaven, and will connect to the National Electricity Transmission System at the proposed SSEN Transmission Hurlie substation, west of Stonehaven in Aberdeenshire. The Bellrock Offshore Wind Farm comprises of the following Development Areas: ▪ Wind Farm Development Area; ▪ Offshore Transmission Development Area; and ▪ Onshore Transmission Development Area.
Precipitation rate anomaly	Measures the deviation of precipitation (rainfall or snowfall) from the long-term average for a specific period,, calculated by comparing the precipitation rate during a particular time frame to the average precipitation rate over a reference period.
Representative concentration pathway	Different possible trajectories of atmospheric concentrations based on socioeconomic and policy assumptions used in climate change projection modelling.
Sea level anomaly	The difference between the observed sea level and the mean sea level for a specific time and region which helps in identifying changes in sea level over time and can be influenced by factors such as ocean currents, temperature, and salinity.
Shared socioeconomic pathways	Climate change scenarios that project socioeconomic global changes up to 2100, used to derive greenhouse gas emissions scenarios based on different climate policies and socioeconomic developments. Shared socioeconomic pathways provide narratives describing alternative pathways for human society, particularly in relation to fossil fuel use and the social and economic factors driving it.
Time-mean sea level anomaly	The deviation of the sea level from a long-term average over a specific period, calculated by comparing the sea level at a given time to the mean sea level over a reference period.
Wind Farm Infrastructure	Infrastructure located within the Wind Farm Development Area including wind turbine generators; floating substructures, station keeping systems and associated scour protection; inter-array cables and associated cable protection; subsea cable hubs; and ancillary infrastructure including buoys (including activities associated with the Wind Farm Infrastructure construction, operation and maintenance, and decommissioning).

Glossary of Abbreviations

Term	Definition
CCR	Climate Change Risk
EIA Report	Environmental Impact Assessment Report
GHG	Greenhouse gas
IEMA	Institute of Environmental Management and Assessment
IPCC	Intergovernmental Panel on Climate Change
ISEP	Institute of Sustainability and Environmental Professionals
RCP	Representative concentration pathway
SSP	Shared socioeconomic pathway
W/m²	Watts per square meter
WFDA	Bellrock Offshore Wind Farm

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1 Introduction

1. This Climate Projection Data Report is an Appendix to **Chapter 18: Climate Change Risk (Volume II)** of the Bellrock Offshore Wind Farm (WFDA) Environmental Impact Assessment (EIA) Report.

2. The purpose of this Appendix is to present the climate projection data, which forms Step 3 of the four-step Climate Change Risk (CCR) assessment (as detailed in **Chapter 18: Climate Change Risk (Volume II)**). The four-step methodology which has been adopted for the CCR assessment in line with industry good practice for assessment of climate change risk.

3. The climate projection data is used to determine the likelihood of climate hazards and ensure that only hazards with a potential for likely significant effects are captured in the detailed climate risk assessment (Step 4 in **Chapter 18: Climate Change Risk (Volume II)**). Climate hazards which affect the ability of the receptor to achieve or maintain its functions or purpose have been identified in Step 1 of the CCR assessment, as described in **Chapter 18: Climate Change Risk (Volume II)**.

1.1 Representative Concentration Pathways and Shared Socioeconomic Pathways

4. Global scientific guidance cautions that it is challenging to predict which climate change scenario is most likely to occur. Therefore, using multiple scenarios helps cover a range of possibilities and ensures comprehensive planning.

5. The 5th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2014) defines a range of Representative Concentration Pathways (RCP), which are different possible trajectories of atmospheric concentrations of greenhouse gases (GHG), based on socioeconomic and policy assumptions used in climate change projection modelling.

6. RCP are used to predict future climate conditions. They help scientists and policymakers understand how different actions today can affect the climate in the future and allow planners to develop strategies to make projects more resilient to climate change. The RCP scenarios provide a range of possible future conditions, helping to assess how climate change might affect the Wind Farm Infrastructure.

7. The RCP scenarios are related to the concentrations of GHGs that would result in target amounts of radiative forcing (measured in watts per square meter (W/m²)) at the top of the atmosphere by 2100, relative to pre-industrial levels. Radiative forcing is a measure of the influence of factors (like greenhouse gases) on the energy balance of the Earth's atmosphere.

8. The RCP scenarios are:

- RCP2.6: Pathway where radiative forcing peaks at approximately 3 W/m² mid-century and then declines to 2.6 W/m² by 2100. This would require significant reductions in greenhouse gas emissions and aims to limit global warming to below 2°C;
- RCP4.5: Represents a stabilisation of radiative forcing at 4.5 W/m² by 2100 without overshooting. It assumes that emissions will peak around 2040 and then decline;
- RCP6.0: Pathway stabilises radiative forcing at 6 W/m² by 2100. Emissions peak around 2080 and then decline; and
- RCP8.5: Radiative forcing reaches 8.5 W/m² by 2100. It assumes continued increases in greenhouse gas emissions throughout the 21st century.

9. The more recent IPCC 6th Assessment Report (IPCC, 2021) uses different scenarios called Shared Socioeconomic Pathways (SSP). The SSPs are scenarios that describe different ways in which global society, demographics, and economics might evolve over the 21st century. They are used alongside the RCPs to explore how different socioeconomic futures could influence greenhouse gas emissions and climate change.

- SSP1: Pathway focused on sustainability, with low challenges to mitigation and adaptation. It can be aligned with lower RCPs (e.g. RCP2.6);
- SSP2: Scenario follows historical trends without significant changes in policy and can be aligned with intermediate RCPs (e.g. RCP4.5);
- SSP3: Pathway describes a fragmented world with high challenges to mitigation and adaptation. It is typically aligned with higher RCPs (e.g. RCP6.0 or RCP8.5);
- SSP4: Scenario envisions a world with high inequality, leading to high challenges for adaptation but lower challenges for mitigation. It can be associated with a range of RCPs depending on the level of emissions control achieved; and
- SSP5: Pathway describes a world with rapid economic growth and high energy use, leading to high challenges for mitigation. It aligns with higher RCPs (e.g. RCP8.5).

10. RCP4.5 and RCP8.5 are often considered more relevant than RCP2.6 and RCP6.0 due to their representation of more realistic worst-case and widely studied scenarios:

- RCP2.6: This pathway requires very stringent mitigation efforts to limit global warming to below 2°C. While desirable, it is considered less likely due to the significant global cooperation and rapid changes needed to achieve such low emissions;
- RCP4.5: This pathway assumes moderate mitigation efforts and is considered an intermediate scenario. It reflects a future where greenhouse gas emissions peak around 2040 and then decline. This scenario is often used in climate modelling because it represents a plausible future with significant but achievable mitigation efforts;

- RCP6.0: This scenario assumes emissions peak around 2080 and then decline. It is less commonly used because it represents a less likely future compared to the more moderate RCP4.5 and the extreme RCP8.5; and
- RCP8.5: Known as the "business-as-usual" scenario, RCP8.5 assumes no significant efforts to curb emissions, leading to continuous growth in greenhouse gas concentrations throughout the 21st century. This pathway is crucial for understanding the potential impacts of unmitigated climate change and is widely used to model worst-case scenarios.

11. Overall, RCP4.5 and RCP8.5 are more relevant for UK planning and policymaking as they provide a broader range of realistic outcomes, helping to prepare for both moderate and severe impacts of climate change. These RCP scenarios are deemed most relevant for the lifecycle of the Wind Farm Infrastructure and their relationship to the SSPs is summarised in **Table 1.1.**

Table 1.1: Representative Concentration Pathways and Shared Socioeconomic Pathways Scenarios

RCP Scenario	RCP Scenario Description	SSP Scenario	SSP Scenario Description	Increase in Global Surface Temperature by 2081-2100, Mean (Range)
RCP4.5	Stabilisation scenario, aiming for stabilisation without overshoot pathways to 4.5 W/m² by 2100.	SSP2-4.5	Middle of the road, intermediate emissions	2.7 °C (2.1 °C to 3.5 °C)
RCP8.5	High emissions scenario, leading to high greenhouse gas concentrations by 2100.	SSP5-8.5	Fossil-fuelled development, very high emissions	4.4 °C (3.3 °C to 5.7 °C)

12. The UKCP18 probabilistic projection data used to define the Predicted Future Baseline (**see Chapter 18: Climate Change Risk, Volume II**) for the Wind Farm Infrastructure are available for the RCP emission scenarios and not the SSP scenarios, because at the time of development of the UKCP18 database, the IPCC's Fifth Assessment Report (focusing on RCPs) was current. The latest report (focusing on SSP) has been published in 2021-2023. Subsequently, the updated, verified and authorised climate data (modelled on SSP scenarios) is not available from the UK Government.

1.2 Projection Data

13. Temperature and precipitation anomaly data is available at 25 km grid for all RCP Scenarios. Temperature and precipitation data are available for the land-based grid cells only. Therefore, these land-based projections have been extracted from the nearest grid cells (362500.00,762500.00) for the Bellrock WFDA as shown in **Figure 18.1 (see Volume III of the Bellrock WFDA EIA Report).**

14. Changes in the annual average temperature and precipitation rate anomalies compared to the 1981-2000 baseline are presented for the Bellrock WFDA in **Table 2.1** for the RCP4.5 (intermediate emission) scenario and in **Table 2.2** for the RCP8.5 (very high emission) scenario. These scenarios are considered the most likely to occur during the construction, operation and maintenance (O&M), and decommissioning phases of the Wind Farm Infrastructure and present a range of outcomes in terms of climate change projection data.

15. The UKCP marine climate change projection data are most applicable to onshore and coastal areas. Time-mean sea level anomaly values are only available for two RCP scenarios – RCP4.5 and RCP8.5. These marine-based projections have been extracted from the nearest grid cells (Area: 56.72, 2.25) for the Bellrock WFDA as shown in **Figure 18.2 (see Volume III of the Bellrock WFDA EIA Report).**

16. Wind speed anomaly at 10 m values are available at 12 km grids for RCP8.5 scenario only. This data has been extracted for Administrative Region - East Scotland.

17. Models and observations suggest that there has been an increase in the frequency of severe storms and in significant wave heights in UK waters since the 1950s (MCCIP, 2020). However, Horsburgh et al. (2020) concluded that there is no observational evidence for long-term trends in either storminess across the UK or resultant storm surges, and simulations for storm surges over the 21st century suggest that there are likely to be no significant changes to storm surges in the UK. The Wolf et al. (2020) summary of future projections for storms and waves concluded that future projections in waters surrounding the UK are sensitive to climate model projections for the North Atlantic storm track, which includes significant uncertainty. In the near future, natural variability dominates any climate-related trends in storms and waves. Towards the end of the 21st century, there is some consensus that mean significant wave height is decreasing while the most extreme wave heights are increasing.

18. For *likelihood*, climate change projection data was obtained from the UKCP18 database, which was used to provide an understanding of trends in climate variables within the Bellrock WFDA over the construction, O&M, and decommissioning phases for the two RCP scenarios considered in the CCR assessment (RCP4.5 and RCP8.5).

19. RCP scenarios are based on recent assumptions about future population, economy, and global targets to cut GHG emissions. The RCP scenarios considered in the assessment, and how they relate to the SSP scenarios in the IPCC's Sixth Assessment Report are described in **Table 1.1**.

20. RCP8.5 is used as a realistic worst-case scenario for climate change projection data relevant to the O&M, and decommissioning phases of the Bellrock Wind Farm Infrastructure, whilst RCP4.5 projection data is included to provide a comparison with the RCP8.5 data.

21. For each RCP scenario, where relevant and available, climate change projection data was obtained for three probabilities: 10% (unlikely), 50% (central estimate of projections) and 90% (projections

unlikely to be less than). This is in accordance with the requirements of NPS EN-1 and IEMA's best practice guidance (IEMA[1], 2020) to consider impacts cross a range of climate change scenarios.

22. UKCP18 probabilistic projections have been obtained for time periods which align with the construction, O&M, and decommissioning phases of the Bellrock Wind Farm Infrastructure, to represent the temporal scope of predicted future climate conditions within the Bellrock WFDA. The following 20-year time slices are used:

- Construction - 2020s (i.e. 2020-2039);
- O&M- 2030s (i.e. 2030-2049), 2050s (i.e. 2050-2069) and 2070s (i.e. 2070-2089); and
- Decommissioning - 2070s (i.e. 2070-2089).

23. The UKCP18 probabilistic projection data are available for the RCP emission scenarios defined in the IPCC's Fifth Assessment Report (2014), as this was the relevant IPPC report at the time of development of the UKCP18 database. These scenarios and their relationship to the SSP scenarios defined in the IPPC's Sixth Assessment Report (2021) are described in **Table 1.1.**

24. The predicted future baseline is based on the anomaly relative to conditions for the baseline period of 1981-2000.

25. The UKCP18 marine climate change projection data provide sea level rise projections for the UK coast. The marine climate change projection data for the grid cells closest to the Bellrock WFDA shows limited spatial variation so is considered to provide an appropriate representation of sea level rise for the Bellrock WFDA.

26. Average sea level rise data for the nearest coastal grid square to the Bellrock Project's expected landfall (coordinates 56.72, -2.25) were obtained for the RCP4.5 and RCP8.5 scenarios for the period between 2020 and 2080, as displayed in **Plate 1.1** (Met Office, 2018) and **Plate 1.2** respectively (Met Office, 2018).

[1] Currently referred to as the Institute of Sustainability and Environmental Professionals (ISEP).

Plate 1.1: Time Mean Sea Level Anomaly (m) for Grid Cells Closest to the Bellrock WFDA Under RCP4.5 Relative to the 1981 to 2000 Baseline Period

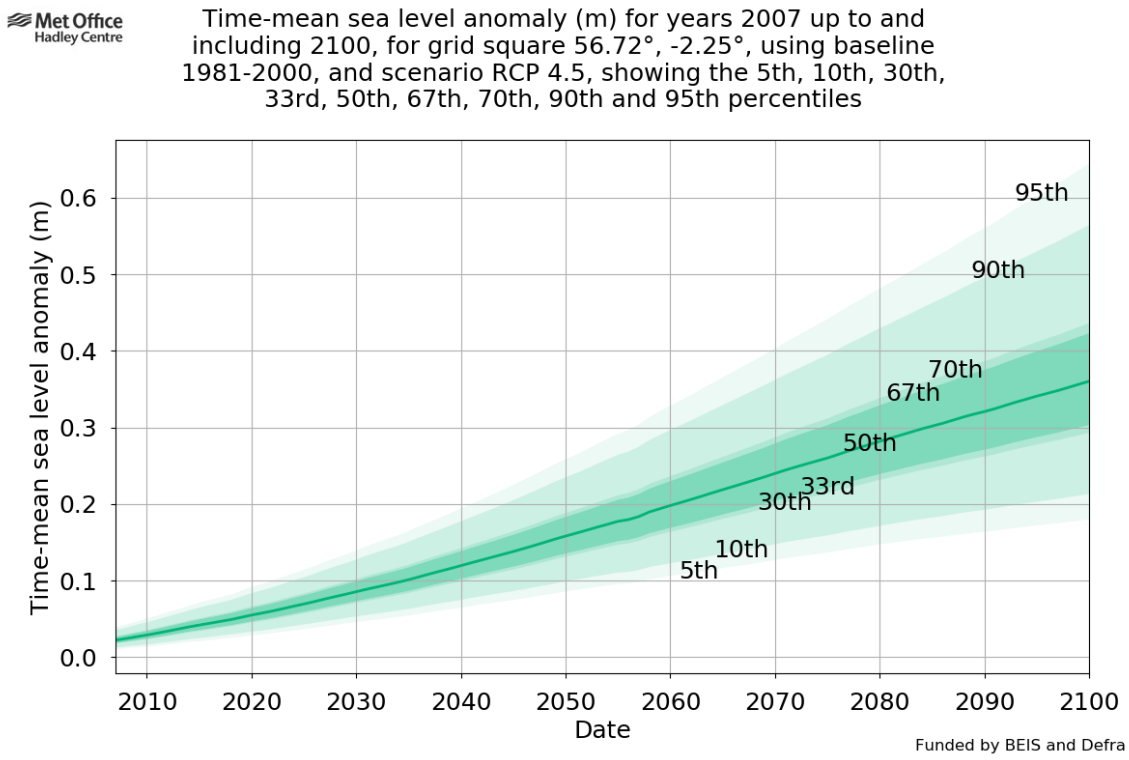
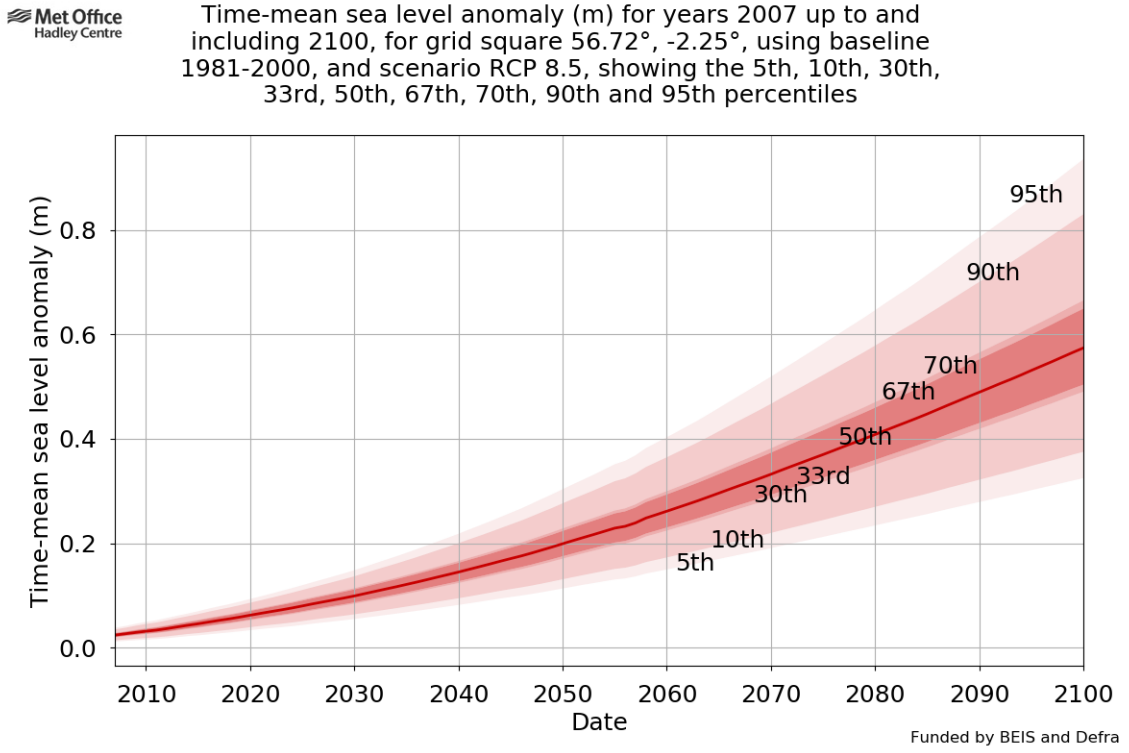


Plate 1.2: Time Mean Sea Level Anomaly (m) for Grid Cells Closest to the Bellrock WFDA Under RCP8.5 Relative to the 1981 to 2000 Baseline Period



27. As shown in **Plate 1.1** and **Plate 1.2**, it is projected that the average sea level in the vicinity of the Bellrock WFDA would increase over the construction, O&M, and decommissioning phases for both RCP4.5 and RCP8.5 scenarios.

28. Under RCP4.5, average sea level rise by 2030 (construction phase) is predicted to be between 0.04 m and 0.13 m (5^{th} and 95^{th} percentile respectively) compared to the 1981-2000 baseline.

29. Under RCP8.5, average sea level rise by 2070 (end of the O&M phase) is predicted to be between 0.19 m and 0.52 m (5^{th} and 95^{th} percentile respectively) compared to the 1981-2000 baseline. By 2080 (post-decommissioning), average sea level rise is predicted to be between 0.23 m and 0.64 m (5^{th} and 95^{th} percentile respectively) compared to the 1981-2000 baseline.

30. It is predicted that future extreme sea levels will be driven by changes in mean sea level and not by the storm surge component or changes to tides.

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2 Land-based Climate Projections – Temperature, Precipitation and Wind

Table 2.1: Temperature and Precipitation Projections for Grid Cells Closest to the Bellrock WFDA Under RCP4.5 Relative to the 1981 to 2000 Baseline Period

Climate Variable	Season	Unit	2020 – 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Air temperature anomaly	Annual mean	°C	0.25	0.77	1.34	0.34	0.95	1.64	0.55	1.35	2.23	0.86	1.84	2.92
	Annual maximum	°C	0.23	0.77	1.37	0.32	0.97	1.68	0.51	1.38	2.31	0.84	1.93	3.08
	Annual minimum	°C	0.24	0.80	1.40	0.35	0.98	1.71	0.56	1.37	2.31	0.83	1.84	3.00
	Summer maximum	°C	-0.33	0.65	1.58	-0.30	0.83	1.94	0.03	1.50	3.00	0.37	2.18	4.10
	Summer minimum	°C	0.08	0.79	1.51	0.20	0.97	1.75	0.47	1.46	2.47	0.37	1.62	2.97
	Winter maximum	°C	-0.06	0.75	1.58	0.04	0.92	1.83	0.21	1.24	2.36	0.80	1.99	3.26
	Winter minimum	°C	-0.08	0.77	1.67	-0.02	0.94	1.99	0.18	1.33	2.68	0.33	1.70	3.29
Precipitation rate anomaly	Annual	%	-1.77	4.21	10.87	-1.36	3.86	9.64	-5.44	2.88	11.87	-4.37	3.82	13.13
	Summer	%	-13.43	1.04	14.67	-17.17	-1.10	14.94	-26.73	-8.11	11.40	-35.35	-14.96	7.49
	Winter	%	-5.16	10.91	28.60	-2.44	14.34	33.75	-8.57	11.31	33.79	-2.63	20.51	47.45

Notes:

The green coloured cells represent “Low” anomalies; orange coloured cells represent “Medium” anomalies; and red coloured cells represent “High” anomalies.

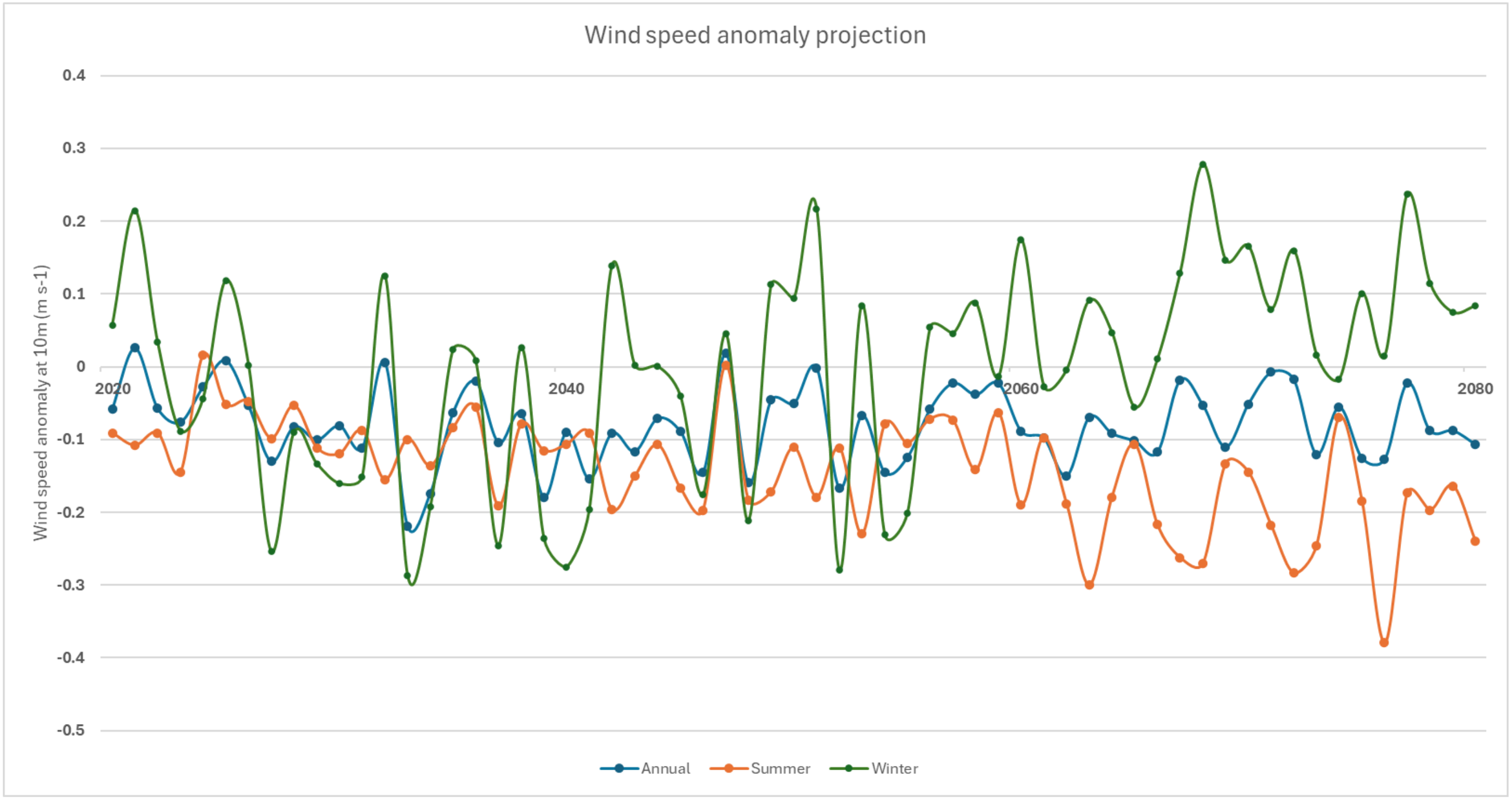
Table 2.2: Temperature and Precipitation Projections for Grid Cells Closest to the Bellrock WFDA Under RCP8.5 Relative to the 1981 to 2000 Baseline Period

Climate Variable	Season	Unit	2020 - 2039			2030 – 2049			2050 - 2069			2070 - 2089		
			10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Air temperature anomaly	Annual mean	°C	0.34	0.90	1.50	0.51	1.20	1.94	0.96	1.95	3.00	1.61	2.98	4.46
	Annual maximum	°C	0.33	0.92	1.53	0.49	1.23	1.99	0.91	2.01	3.14	1.57	3.11	4.70
	Annual minimum	°C	0.32	0.92	1.56	0.49	1.23	2.00	0.93	1.97	3.10	1.53	2.98	4.56
	Summer maximum	°C	-0.22	0.77	1.81	-0.14	1.09	2.32	0.35	2.19	4.04	0.87	3.49	6.07
	Summer minimum	°C	0.19	0.93	1.68	0.37	1.23	2.08	0.89	2.10	3.35	0.84	2.61	4.43
	Winter maximum	°C	0.03	0.85	1.71	0.16	1.11	2.09	0.48	1.74	3.08	1.55	3.25	4.95
	Winter minimum	°C	-0.01	0.88	1.83	0.09	1.15	2.32	0.40	1.87	3.54	0.74	2.74	5.02
Precipitation rate anomaly	Annual	%	-1.79	4.58	11.15	-1.29	4.33	10.28	-5.21	4.02	13.69	-4.32	5.72	17.12
	Summer	%	-14.53	-0.37	14.31	-19.90	-3.20	14.31	-33.96	-12.35	11.75	-46.48	-21.82	9.01
	Winter	%	-4.51	11.82	29.71	-1.20	16.25	36.22	-6.32	15.62	42.18	0.20	29.63	64.15

Notes:

The green coloured cells represent “Low” anomalies; orange coloured cells represent “Medium” anomalies; and red coloured cells represent “High” anomalies.

Plate 2.1: Wind Speed Projection Data for Administrative Region - East Scotland Under RCP8.5 Relative to the 1981 to 2000 Baseline Period



3 Marine Climate Projections – Sea Level Rise

Table 3.1: Sea Level Anomaly Projections for Grid Cells Closest to the Bellrock WFDA Under RCP4.5 Relative to the 1981 to 2000 Baseline Period

Climate Variable	Unit	2020 - 2039			2030 – 2049			2050 - 2069			2070 - 2089		
		10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Time-mean sea level anomaly	m	0.03	0.06	0.08	0.05	0.09	0.13	0.07	0.12	0.18	0.12	0.20	0.30

Notes:
The green coloured cells represent “Low” anomalies; orange coloured cells represent “Medium” anomalies; and red coloured cells represent “High” anomalies.

Table 3.2: Sea Level Anomaly Projections for Grid Cells Closest to the Bellrock WFDA Under RCP8.5 Relative to the 1981 to 2000 Baseline Period

Climate Variable	Unit	2020 - 2039			2030 – 2049			2050 - 2069			2070 - 2089		
		10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Time-mean sea level anomaly	m	0.04	0.06	0.09	0.06	0.10	0.14	0.09	0.14	0.20	0.17	0.26	0.36

Notes:
The green coloured cells represent “Low” anomalies; orange coloured cells represent “Medium” anomalies; and red coloured cells represent “High” anomalies.

4 Wave Height

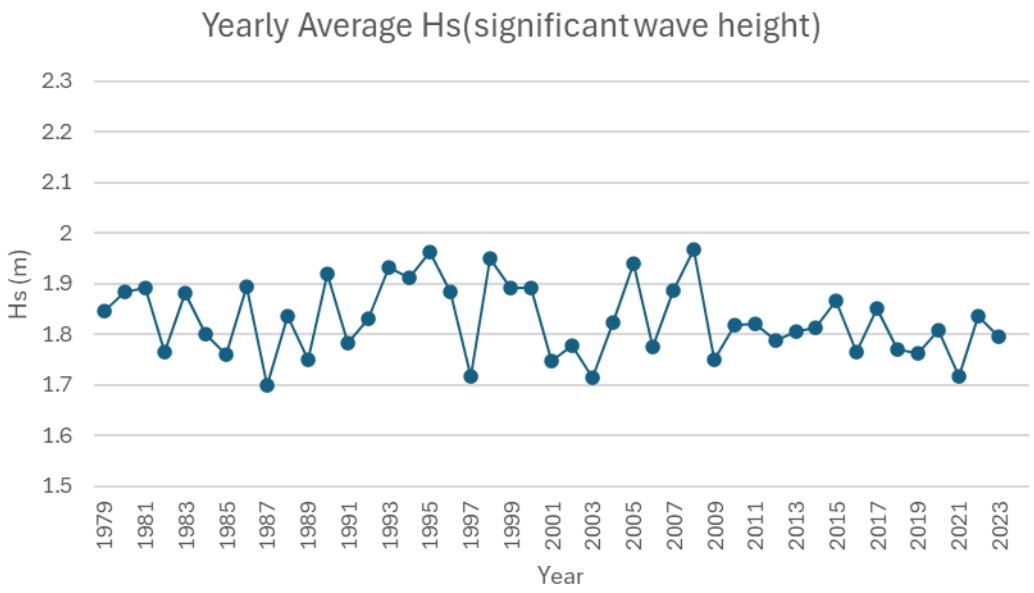
31. Recorded wave data, as provided in **Plate 4.1**, has been received from ERA5 (node 56.75N, 0.00E). Data provided covered the period 01/01/1979 to 21/04/2024.

32. The rate of change in significant wave height (Hs) per year is 0.00025 m/year meaning that the significant wave height at the closest North Sea monitoring location (56.75°N, 0.00°E) to the Bellrock WFDA, has been remarkably stable from 1979 to 2024.

33. Despite natural variability, there is no evidence of a long-term increase or decrease in wave energy. This could suggest that climate change impacts on wave height are either:

- Not present at this location, or
- Too small to detect with this dataset and method.

Plate 4.1: Graph of Recorded Wave Height from 1979 to 2023 at North Sea Location (56.75°N, 0.00°E)



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