Department for Environment Food & Rural Affairs
Department for Business, Energy & Industrial Strategy
Met Office Hadley Centre
Environment Agency

UKCP18 Factsheet: Sea-level rise and storm surge - supplementary data

Summary

This factsheet summarises the additional information available on the UKCP18 marine projections for sea-level rise and storm surge, added since the original release in 2018. Read this before using any products as it describes the data availability, the caveats and limitations.

As part of the February 2023 release, we have extended the projected future extreme sea levels at all UK tide gauge locations to all open-coast Coastal Flood Boundary[1] point locations around the UK coastline. Existing users of UKCP that wish to know more about the projected future still water return levels should read this document.

We have also corrected a minor inconsistency in how the 1981-2000 baseline was applied to the UK site-specific time-mean sea-level projections. Existing users of UKCP that wish to know more about this sea-level rise update can find more information in the associated Technical Note: UKCP18 time-mean sea-level projections update 2023 (Palmer, 2023).

We recommend that if you are a new UKCP user you read the UKCP18 Science Overview (Lowe et al, 2018) to understand the different components of climate projections. For a comprehensive description of the underpinning science, evaluation and results for marine projections see the UKCP18 Marine Projections Report (Palmer et al, 2018). Projections are based on the Representative Concentration Pathway (RCP) future emissions scenarios, used in the Intergovernmental Panel on Climate Change's 5th Assessment Report (IPCC AR5). Further information is available in the RCP Guidance on the UKCP18 website.

[1] Coastal flood boundary conditions for the UK: 2018 update - GOV.UK (www.gov.uk)

Headline messages

- The amount of time-averaged sea-level rise depends on the location around the UK and increases with higher emissions scenarios (see Figure 1 and Table 1).
- Based on exploratory results to 2300, sea levels continue to increase beyond 2100 even with large reductions in greenhouse gas emissions (see Table 1).
- The largest discrepancy across UK capital cities between the UKCP18 21st century mean annual sea-level change in 2100 relative to 1981-2000 average and the extended projections is 0.1cm, 0.2cm and 0.3cm, for a low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenario respectively.
- We find no evidence for significant changes in future storm surges, although you may wish to carry out sensitivity tests with our scenarios.
- Sea-level rise over the coming centuries may affect tidal characteristics substantially (including tidal range).
- Extreme sea levels will increase due to the rise in mean sea level (see Table 2 and Figure 2). However, our best estimate suggests no additional change due to the atmospheric contribution to extreme sea level.
- Methodological differences between the 21st century projections and the exploratory extended projections to 2300 give rise to small differences in the projected extreme sea levels at 2100 (see Figure 3). The largest discrepancy across Avonmouth, Lerwick, Newlyn and Sheerness, for the projected future 200 yr (0.05%) extreme sea level is 0.0cm, 0.1cm and 0.3cm for a low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenario respectively.
- We have corrected a minor inconsistency in how the 1981-2000 baseline was applied to the UK site-specific time-mean sea-level projections in UKCP18 data. The correction of this error results in an approximately 1 cm uplift of projected values on all timescales relative to the earlier dataset.

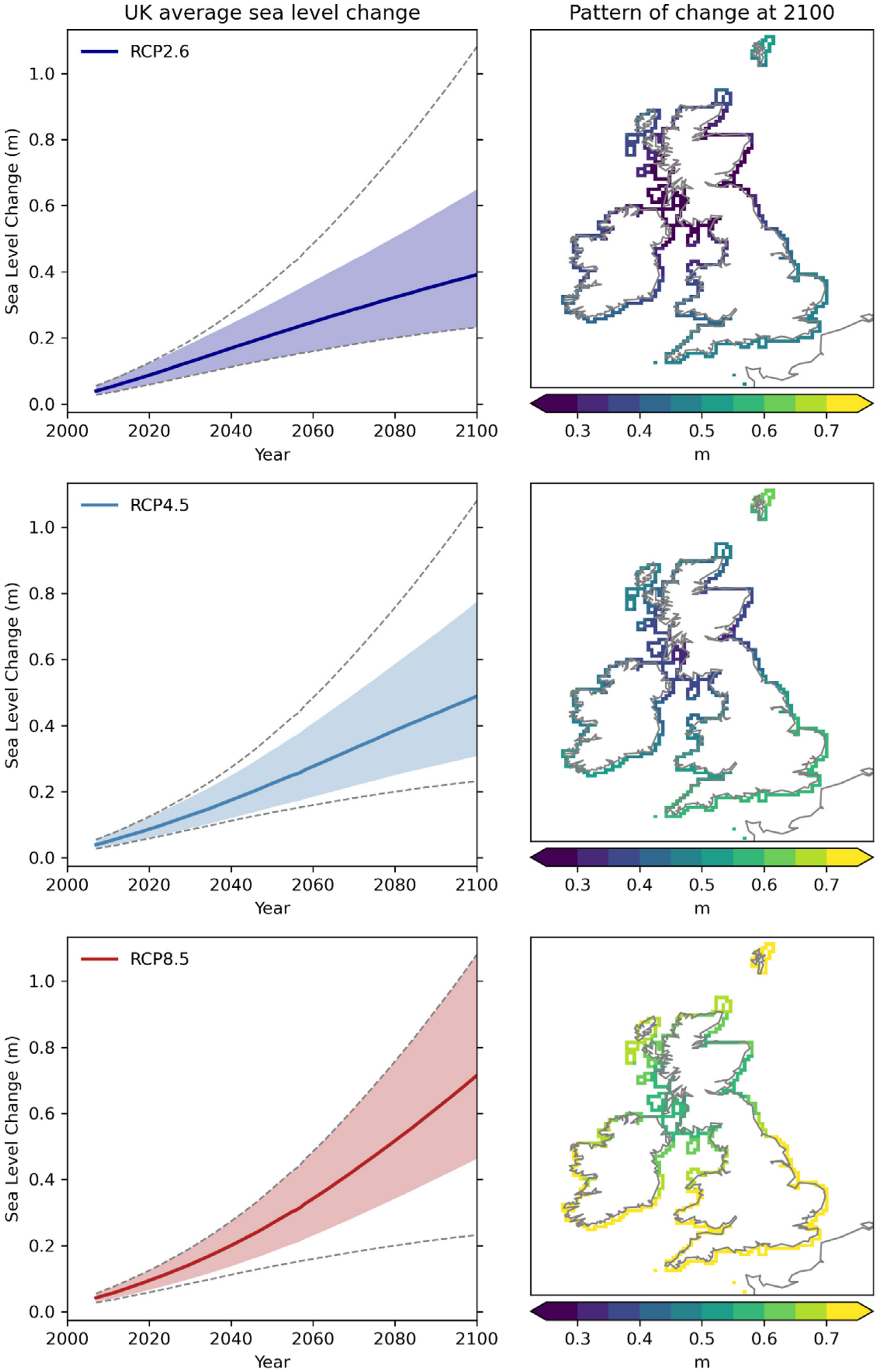

Figure 1 (left) Time series of time-mean sea-level change based on the average of the UK ports. The solid line and shaded regions represent the central estimate and ranges for each RCP scenario as indicated in the legend. The dashed lines indicate the overall range across RCP scenarios. (right) The spatial pattern of change at 2100 associated with the central estimate of each RCP scenario. All projections are presented relative to a baseline period of 1981-2000. Updated from Figure 3.1.3 of Palmer et al, (2018).

	RCP2.6				RCP4.5				RCP8.5			
	2100*	**2100†**	**2200†**	**2300†**	**2100***	**2100†**	**2200†**	**2300†**	**2100***	**2100†**	**2200†**	**2300†**
London	0.30 – 0.71	0.30 – 0.72	0.5 – 1.5	0.6 – 2.2	0.38 – 0.84	0.36 – 0.84	0.7 – 1.8	0.8 – 2.6	0.54 – 1.16	0.52 – 1.13	1.1 – 2.8	1.5 – 4.3
Cardiff	0.28 – 0.70	0.28 – 0.71	0.4 – 1.5	0.5 – 2.2	0.36 – 0.83	0.34 – 0.82	0.6 – 1.8	0.8 – 2.6	0.52 – 1.14	0.50 – 1.11	1.1 – 2.8	1.4 – 4.2
Edinburgh	0.09 – 0.50	0.08 – 0.51	0.1 – 1.1	0.0 – 1.6	0.16 – 0.62	0.14 – 0.61	0.2 – 1.4	0.2 – 2.0	0.30 – 0.91	0.28 – 0.88	0.6 – 2.3	0.7 – 3.5
Belfast	0.12 – 0.53	0.11 – 0.54	0.1 – 1.2	0.0 – 1.7	0.19 – 0.66	0.17 – 0.65	0.3 – 1.5	0.3 – 2.1	0.34 – 0.95	0.31 – 0.92	0.7 – 2.4	0.8 – 3.6

Table 1 Comparison of the UKCP18 21st century mean annual sea-level change (m) at UK capital cities in 2100 relative to 1981-2000 average, for a low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenario (left most column for each scenario) and the extended projections in 2100, 2200 and 2300. Numbers beyond 2100 are quoted to the nearest 0.1m, given the lower confidence associated with projections on these extended time horizons. *UKCP18 21st century projections. *Extended projections.

Sea-level rise and storm surges: what are they and why are they important?

Sea-level rise is the primary mechanism by which we expect coastal flood risk to change in the UK in the future (Howard et al, 2019; Fox-Kemper et al, 2021). It describes the increases in coastal water levels driven primarily by melting of land-based ice and global mean thermosteric sea-level change (thermal expansion of the oceans as global temperatures rise). In UKCP18, we provide the relative sea-level rise, i.e., the local sea-level rise experienced at a particular location including vertical land movements.

In addition, there is potential for changes in the severity of future storm surge events (see section 3.2 of Palmer et al, 2018; Howard et al, 2019). However, the UKCP18 model results suggest a relatively small contribution from storm surge changes. We don't yet know whether these likely small changes in storm surges will become more severe, less severe or remain the same. The response of the storm track under climate change is an important driver of storm surge changes. However, the response of atmospheric circulation under climate change remains a key uncertainty (Shepherd, 2014).

The projected extreme sea levels at all UK tide gauge locations, released as part of UKCP18, were uplifted using the exploratory extended time-mean sea-level projections and available from 2020-2300. These were produced using the climate change emission scenarios RCP2.6, RCP4.5 and RCP8.5 and for the 5th, 50th and 95th percentiles (as described in Table 3). As part of the 2023 update, we have extended these projections to all open-coast Coastal Flood Boundary point locations around the UK coastline, using both the 21st Century time-mean sea-level projections and available from 2020-2100 as well as the exploratory extended time-mean sea-level projections and available from 2020-2300. These were also produced using the climate change emission scenarios RCP2.6, RCP4.5 and RCP8.5 and for the 5th, 50th and 95th percentiles (as described in Table 3), but they also include the 70th percentile to align with Environment Agency's climate change allowances[2].

When combined with local information on sea defences and coastline structure, the sea-level and storm surge projections enable vulnerability assessments along the UK coastline to be made. Examples of the use of previous sea-level and storm surge information include the Environment Agency's climate change allowances, coastal and flood defence management for the Thames Estuary 2100 project[3] and the UKCP18 demonstration project on coastal erosion management (Walkden, 2018).

[2] Flood risk assessments: climate change allowances - GOV.UK (www.gov.uk)
[3] Thames Estuary 2100 (TE2100) - GOV.UK (www.gov.uk)

	RCP2.6				RCP4.5				RCP8.5			
	2030	2050	2100	2300	2030	2050	2100	2300	2030	2050	2100	2300
Avonmouth	9.13	9.22	9.43	10.0	9.13	9.23	9.51	10.3	9.14	9.27	9.72	11.4
Lerwick	1.89	2.00	2.23	2.9	1.89	2.01	2.30	3.2	1.90	2.04	2.48	4.0
Newlyn	3.64	3.74	3.98	4.6	3.64	3.75	4.06	5.0	3.65	3.79	4.27	6.0
Sheerness	4.71	4.80	5.02	5.6	4.71	4.81	5.11	6.0	4.72	4.85	5.32	7.0

Table 2 Projected future 200 yr (0.05%) still water Return Level (m) at Avonmouth, Lerwick, Newlyn and Sheerness, based on extended projections of future changes in water level around the UK coastline for a low (RCP2.6), medium (RCP4.5) and high (RCP8.5) emissions scenario (50th percentile). Numbers beyond 2100 are quoted to the nearest 0.1m, given the lower confidence associated with projections on these extended time horizons. Baseline still water Return Levels were provided by the Environment Agency's (EA) Coastal Flood Boundary Conditions, 2018.

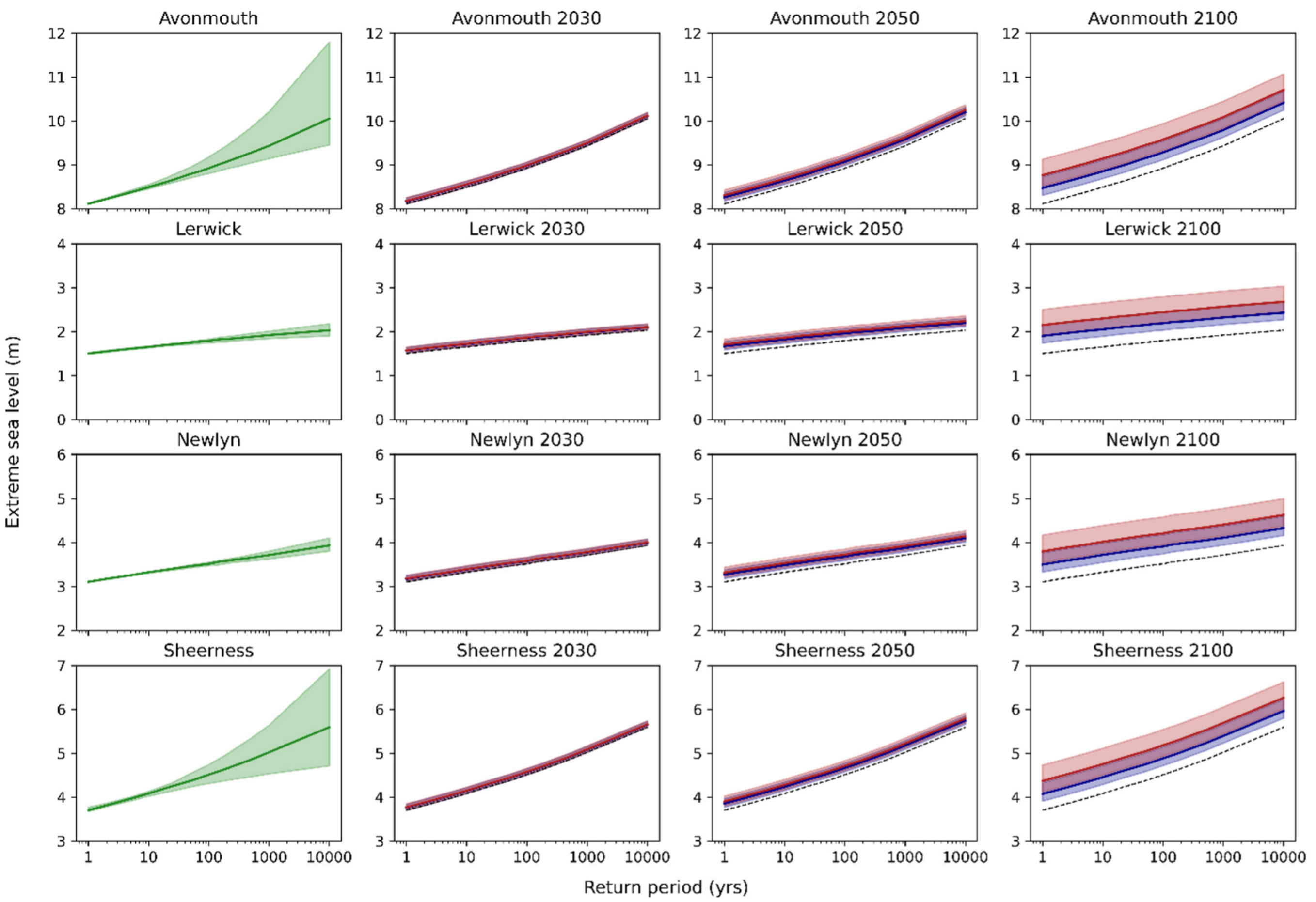

Figure 2 Projected extreme sea levels at Avonmouth, Lerwick, Newlyn and Sheerness, based on exploratory extended time-mean sea-level projections around the UK coastline. The present-day extreme sea levels from the Environment Agency (2018) are shown in the left-hand panels along with an estimate of the present-day uncertainty (green shading, showing 5th to 95th percentile). The present-day extreme sea levels are also represented as black dashed line in the remaining plots. The blue (red) lines show the projected extreme sea levels under the central estimate of time-mean sea-level change from the RCP2.6 (RCP8.5) scenario. The blue (red) shading shows the respective UKCP18 projection ranges. Uncertainty from the time-mean sea-level projections is included. Uncertainty due to storminess changes is not included. Uncertainty in the present-day extreme sea levels is not included. Projections are shown for years 2030 (left column), 2050 (centre) and 2100 (right column). The uncertainties shown should be regarded as minimum uncertainties: for details see main text. To give sensible scales and aid comparison, different Y-axis limits are applied for each site, but adjusted such that the range of each Y-axis is 4 metres. Present-day extreme sea levels are in ordnance datum Newlyn (ODN), which is an absolute datum. Projected extreme sea levels are not strictly in ODN because they are relative to the local land level, which is not fixed relative to ODN.

What data are available and where can you find it?

Dataset	Description [format]	Sea level method	Emissions Scenario	Percentile	Time period [frequency]	Domain
Projected extreme sea levels	UKCP projected future extreme sea levels at approximately 2km spacing around the UK coastline for 2020-2100, using 21st Century time-mean sea-level projections [shapefile]	MSL-std	RCP 2.6 RCP 4.5 RCP 8.5	5th 50th 70th 95th	2020-2100 [decade]	UK coastline
Projected extreme sea levels	UKCP projected future extreme sea levels at approximately 2km spacing around the UK coastline for 2020-2300, using exploratory extended time-mean sea-level projections [shapefile]	MSL-ext	RCP 2.6 RCP 4.5 RCP 8.5	5th 50th 70th 95th	2020-2300 [decade]	UK coastline
Projected extreme sea levels	UKCP18 projected future extreme sea levels at selected tide gauge locations for 2020-2300, using exploratory extended time-mean sea-level projections [netcdf]	MSL-ext	RCP 2.6 RCP 4.5 RCP 8.5	5th 50th 70th 95th	2020-2300 [decade]	UK tide gauges*

Table 3 Summary of additional data available from UKCP18 marine projections. All based on the latest EA Coastal Flood Boundary Conditions, 2018. *The 46 UK tide gauges included are shown in Fig 3.1 of the UKCP18 marine report.

You can access the time-mean sea-level data and visualisations up to 2100 and 2300 via the UKCP18 User Interface.

You can access the projected extreme sea levels data up to 2100 and 2300 via the UKCP18 User Interface.

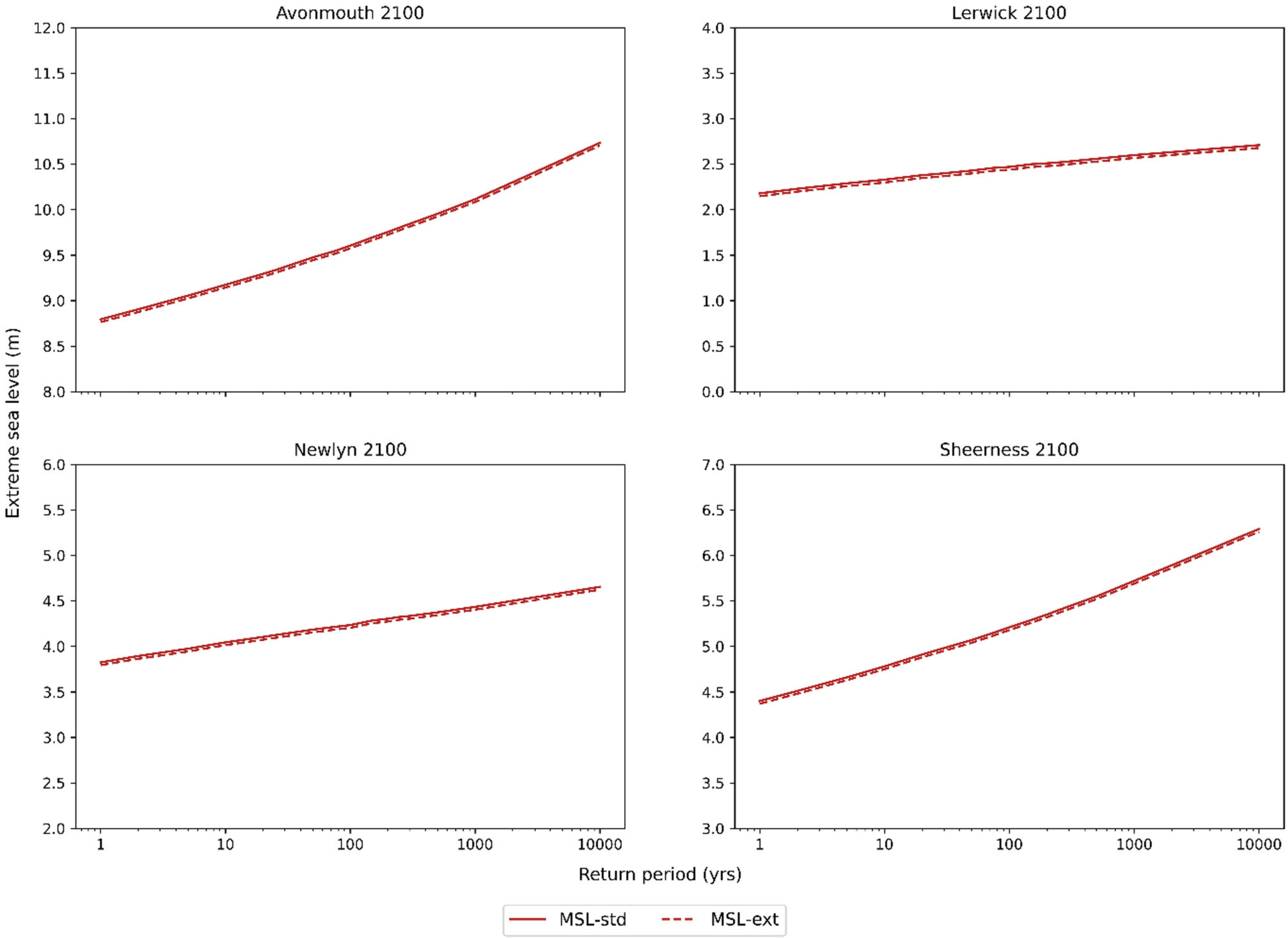

Figure 3 Projected extreme sea levels at Avonmouth, Lerwick, Newlyn and Sheerness, based on both the 21st Century time-mean sea-level projections and exploratory extended time-mean sea-level projections around the UK coastline. The red full (dashed) lines show the future return level curve under the central estimate of time-mean sea-level change from the 21st Century (exploratory extended) sea-level projections method under RCP8.5 projected to 2100. To give sensible scales and aid comparison, different Y-axis limits are applied for each site, but adjusted such that the range of each Y-axis is 4 metres.

What do you need to be aware of?

- We provide a range of values (5th to 95th percentiles) that correspond to the IPCC likely range projections for the period up to 2100. There may be a greater than 10% chance that the real-world response lies outside this range and this likelihood cannot be accurately quantified.
- We also provide values for the 70th percentile (in the shapefile datasets), which corresponds the Environment Agency's 'higher central allowance' for sea-level rise.
- Coastal Flood Boundary point locations do not exactly coincide with gauge locations and so small differences in extreme sea levels exist between gauge sites and the nearest Coastal Flood Boundary point locations due to spatial interpolation. These same differences are present in the projected extreme sea levels at Coastal Flood Boundary point locations (shapefiles) and those at UK tide gauge locations (netcdf files) however both datasets are consistent with the UKCP18 mean sea-level rise projections.

- We recommend that you make use of multiple strands of evidence, including high-end sea-level rise scenarios (e.g, the low-likelihood high-impact storyline presented in IPCC AR6) when assessing vulnerabilities to future extreme water levels. Further information on high-end scenarios is available from Stammer et al. (2019).
- There are large year-to-year (and sub-annual) variations in sea level in UK tide gauge records. At present, observed tide gauge data can be found at the National Tide and Sea Level Facility at www.ntslf.org.
- The results are subject to any inherent limitations of the underlying CMIP5 models and assumed climate change RCP scenarios.
- Our best estimate from a synthesis of simulations based on the current generation of climate models is one of no change in the atmospheric contribution to storm surge. However, some models suggest significant change and in the UKCP18 Marine Projections report (Palmer et al, 2018), we consider one such model to illustrate the size of possible changes.
- We assume that the coastline and seabed do not change with time. We chose this experimental design to make the modelling more tractable given the grid resolution and lack of representation of changing water/land cells with changing water level. In addition, high quality coastline data and knowledge of future coastline evolution on 100- to 200-year timescales is sparse.
- The UKCP18 marine projections do not account for other non-climatic processes that may influence regional sea level such as local subsidence from groundwater extraction.

The UKCP18 21st Century time-mean sea-level projections correspond to the IPCC AR5 "likely range", as determined by their expert judgement. IPCC AR5 interpreted the 5th to 95th percentiles as having a "2/3 chance" of spanning the real-world sea-level rise for any given RCP scenario (Church et al, 2013). As noted above, we cannot rule out substantial additional sea-level rise associated primarily with dynamic ice discharge from the West Antarctic Ice Sheet. IPCC AR6 (Fox-Kemper et al, 2021) provide local projections based on a low-likelihood high-impact storyline of accelerated ice sheet mass loss to 2150 that can be used alongside the UKCP18 projections.

The exploratory extended time-mean sea-level projections have much lower confidence than the 21st Century Projections. They are designed to be used alongside the 21st Century projections for those interested in exploring post-2100 changes. These projections can be considered as sensitivity studies and should not be interpreted as showing the full range of post-2100 behaviour, or the most likely behaviour. The potential for additional sea-level rise from Antarctic dynamic ice discharge is even more uncertain on these time horizons, with some studies suggesting several additional metres of rise by 2300 under RCP8.5.

IPCC AR6 states that in the longer term, "sea level is committed to rise". The amount to which sea level will rise is dependent upon future temperature rise. If global temperature rise is limited to 1.5°C of warming, global mean sea level will rise by approximately 2-3m over the next 2000 years. However, if global temperature rise reaches 5°C of warming, global mean sea-level rise could be 19-22m, see section B.5 of the Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis (IPCC, 2021).

Further information on the caveats and limitations can be found on the website:
www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/caveats

Where can you find more information?

For further information on UKCP18:

- Find a summary of the key results from UKCP18 Projections on the website: UKCP18 key results - Met Office.
- Download the sea-level rise and storm surge data from the UKCP18 User Interface at Welcome to UKCP (metoffice.gov.uk) and the CEDA Data Catalogue at The CEDA Archive.
- Find out more on wave projections, extreme event case studies as well as the underpinning science from the UKCP18 Marine Report (Palmer et al, 2018).
- More information about this sea-level rise update can be found in the associated Technical Note: UKCP18 time-mean sea-level projections update 2023 (Palmer, 2023)

For a comparison of UKCP09 with UKCP18, see section 5 of the UKCP18 Marine Report (Palmer et al, 2018).

For general information on sea level:

- IPCC Fifth Assessment Report, Working Group 1 report The Physical Science Basis, Chapter 13 (AR5 Climate Change 2013: The Physical Science Basis — IPCC)
- IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), (Special Report on the Ocean and Cryosphere in a Changing Climate — (ipcc.ch)).
- IPCC Sixth Assessment Report, Working Group 1 report The Physical Science Basis, Chapter 9 (AR6 Climate Change 2021: The Physical Science Basis — IPCC)

For information on flood risk assessments and strategic flood risk assessments:

- Environment Agency Guidance Flood risk assessments: climate change allowances - GOV.UK (www.gov.uk)
- Environment Agency's Coastal flood boundary conditions for the UK reports, Coastal flood boundary conditions for the UK: 2018 update - GOV.UK (www.gov.uk) and data, Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) - data.gov.uk

This document is citable as Perks RJ, Howard T, Palmer M (2023). UKCP18 Factsheet: Sea-level rise and storm surge - supplementary data, Met Office.

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