Potential Future High Water Levels at Mevagissey Harbour: To inform future need for defence

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1	03/12/21	Submission – Max Bradbury
1.1	06/12/21	Internal approval, minor changes – Dr Daniel Conley
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Contents

1. Introduction

Sea level rise is the primary mechanism by which expected coastal flood risk is to change in the UK in the future. It describes the phenomenon where global temperatures rise, causing increases in the level of the world's seas and oceans through thermal expansion of seawater and addition of water through land-based ice melt. The rate at which global temperatures rise, and therefore sea level, is significantly dependant on the concentration of greenhouse gases (GHG) in the atmosphere. The rate at which GHGs are released going forward will affect the rate of sea level rise in the future[1].

In addition, there is potential for changes in the frequency and severity of future storm surge events. Whilst worldwide figures suggest extreme weather events are becoming more common, there is currently not enough data to definitively indicate how UK storm surges will change in frequency and severity, but is an area of ongoing research in institutions[2]. Storm surges are the increased water level due to low-pressure storm events, normally coinciding with spring high tides, with strong wave action further increasing the water's reach. When combined with local information on sea defences and coastline structure, sea level and storm surge projections enable vulnerability assessments along the UK coastline to be carried out.

Whist increases in astronomical sea level rise may look small in the near future; it is their combination with storm surges and wave action which will greatly increase overtopping risk to Mevagissey Harbour, with potential for associated structural damage to ageing infrastructure from these increased loads.

[1] Fung F, Palmer M, Howard T, Lowe J, Maisey P and Mitchell JFB (2018). UKCP18 Factsheet: Sea Level Rise and Storm Surge, Met Office Hadley Centre, Exeter.
[2] Palmer M, Howard T, Tinker J, Lowe J, Bricheno L, Calvert D, Edwards T, Gregory J, Harris G, Krijnen J, Pickering M, Roberts C and Wolf J (2018). UKCP18 Marine Report. Met Office, UK.

2. Past Sea Level Rise

The closest tide gauge to Mevagissey is at Newlyn, where monthly and annually averaged sea level data are available. Although it is more than 50 km from Mevagissey, they are part of the same physical tidal system, so changes in sea level over time will be similar.

Figure 1 below shows that in the last ~100 years, there has been a 25 cm rise in mean annual water levels at Newlyn. Internationally, there has been a relatively significant increase in sea level rise rate in the latter half of the 20th century[2], at Newlyn however, there was an approximate 12 cm increase from 1915-1965, compared to a 13 cm increase from 1965-2015, showing only a very slight increase in sea level rise rate in more recent history. The values on the x-axis are measured from the revised local reference; later plots will be from ordnance datum, hence different values. However, all values in this report are in metric measurements, so easily compared.

Data to generate the figure was obtained from the Permanent Service for Mean Sea Level[3] and the British Oceanographic Data Centre[4].

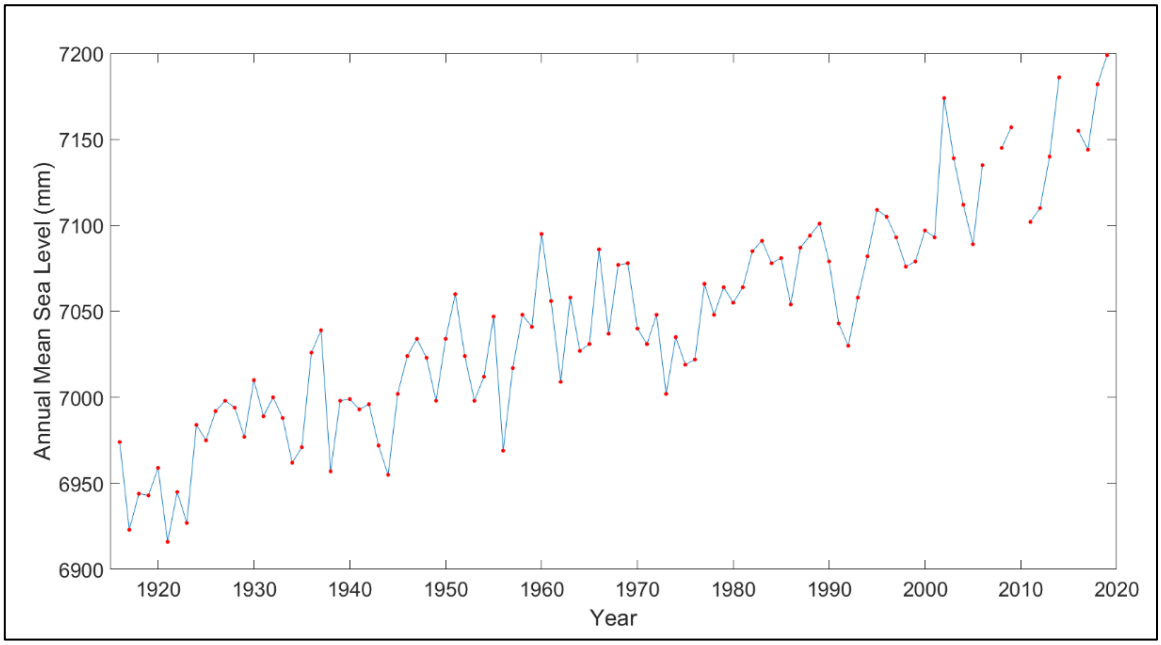

Figure 1. Annual mean sea level at Newlyn tide gauge. Generated using data from PSMSL.

The amount by which this rate of rise increases going forward will depend on future GHG emission scenarios.

[3] PSMSL. (2021). Obtaining Tide Gauge Data. https://www.psmsl.org/data/obtaining/
[4] NOC: BODC. (2021). UK Tide Gauge Network. https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/

3. Future Sea Level Rise

From this point in the report, all predictions are for Mevagissey Harbour itself, not Newlyn.

As explained earlier, the rate of sea level rise is dependent on the rate of emissions of GHGs. As it is uncertain how this rate of GHG release will change in the future, the International Panel on Climate Change (IPCC) produce multiple scenarios Representative Concentration Pathways (RCPs) of CO_2 equivalent concentrations in the atmosphere. CO_2 equivalent is a measure of how much a gas contributes to global heating, relative to CO_2, and a method of combining the heating effect of all GHGs into one metric.

Three IPCC emission scenarios were used in this report to generate plots using results of models from the Met Office[5]. These scenarios were:

1. RCP 2.6 = Very stringent pathway – emissions start declining by 2020 and zero by 2100.
2. RCP 4.5 = Intermediate and most likely – emissions peak in 2040.
3. RCP 8.5 = Unlikely – emissions increase throughout the century[6].

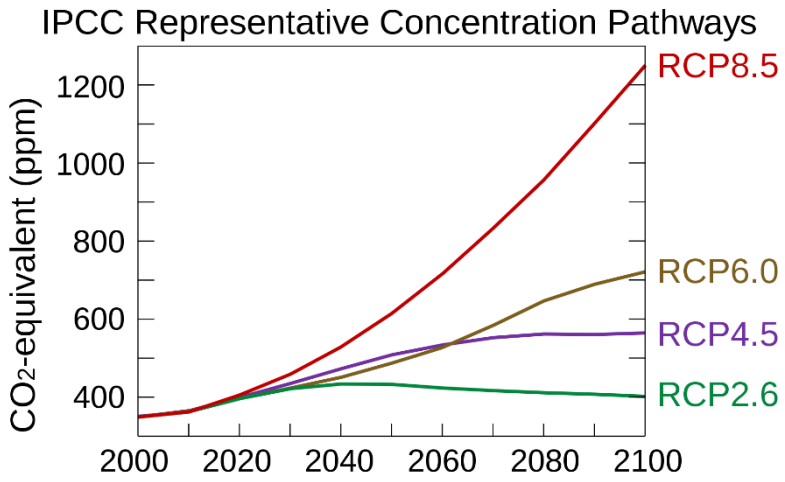

Figure 2. Atmospheric CO2-eqivalent greenhouse gas concentrations under various emission scenarios, up to 2100. Generated from IPCC.

The Met Office tests the accuracy of its model's ability to predict future sea levels by using tide levels from the distant past, to predict unseen, more recent past tide levels, i.e. using tide gauge records from 1915-1935, to predict tide levels from 1935-2000. They were able to accurately predict and reproduce observed sea level rise at tide gauge locations around the world over the 20th century, also capturing the acceleration of rise since the 1960s[7].

[5] Met Office. (2018). Data: Sea level anomalies for marine projects around the UK coastline, 2007-2100. https://ukclimateprojections-ui.metoffice.gov.uk/products
[6] IPCC. (2014). Future Climate Changes, Risk and Impacts. *IPCC Climate Change 2014 Synthesis Report.* IPCC, Geneva, Switzerland.
[7] Palmer M, Howard T, Tinker J, Lowe J, Bricheno L, Calvert D, Edwards T, Gregory J, Harris G, Krijnen J,

As RCP 4.5 is the most likely pathway, the short-term focus will be on this. Figure 3 shows the sea level rise and predicted rise from 2007 to 2037 at Mevagissey harbour. The shaded areas represent the percentiles of the prediction using the current scenario, which can be interpreted as – the closer to the 50th percentile, the higher the likelihood of this occurring (Each change in shading represents the 5th, 10th, 30th, 50th, 70th, 90th and 95th percentiles). Using the centre line prediction (50th percentile), between 2022 and 2037, there is estimated to be 7.5 cm sea level rise. This is 1/3 as much rise in the next 15 years, than in the previous 100 years, in the most likely emissions scenario.

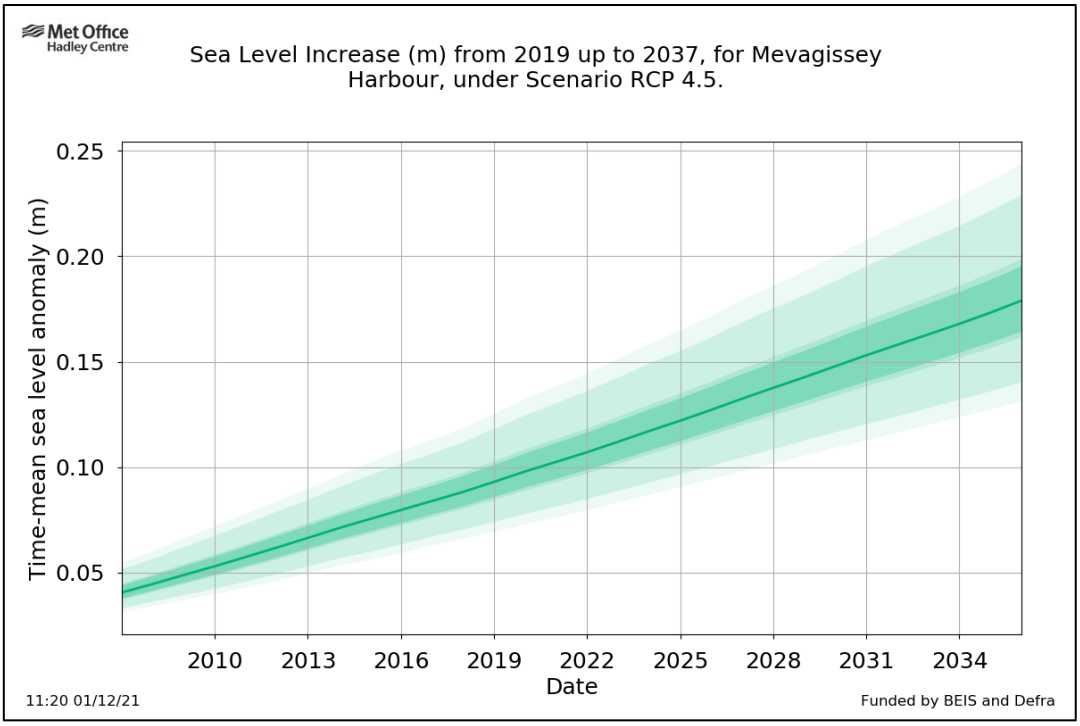

Figure 3. Estimated sea level rise at the coast of Mevagissey Harbour. From 2007 to 2037. Increase from 2000 sea level. Under emission pathway RCP 4.5. Generated from data from Met Office UKCP18 data (2018).

Continuing along the timeline up to 2100, figures 4, 5 and 6 show the projected sea level rise in the three different scenarios. Table 1 shows a summary of the sea level rise in each RCP at key dates. Note that each graph begins at 10 cm rise in 2020 as predictions are on a baseline of the mean sea level between 1981 and 2000, so this table references rises above this 10 cm starting point.

Year/Scenario	RCP 2.6	RCP 4.5	RCP 8.5
2035	70 mm (2.8 in)	70 mm (2.8 in)	100 mm (3.9 in)
2050	150 mm (5.9 in)	170 mm (6.7 in)	210 mm (8.3 in)
2100	370 mm (14.6 in)	470 mm (18.5 in)	700 mm (27.6 in)

Table 1. Sea level rise from 2020 levels and select dates in the 21st century under RCPs 2.6, 4.5, 8.5. In mm (inches)

Pickering M, Roberts C and Wolf J (2018). UKCP18 Marine Report. Met Office, UK.

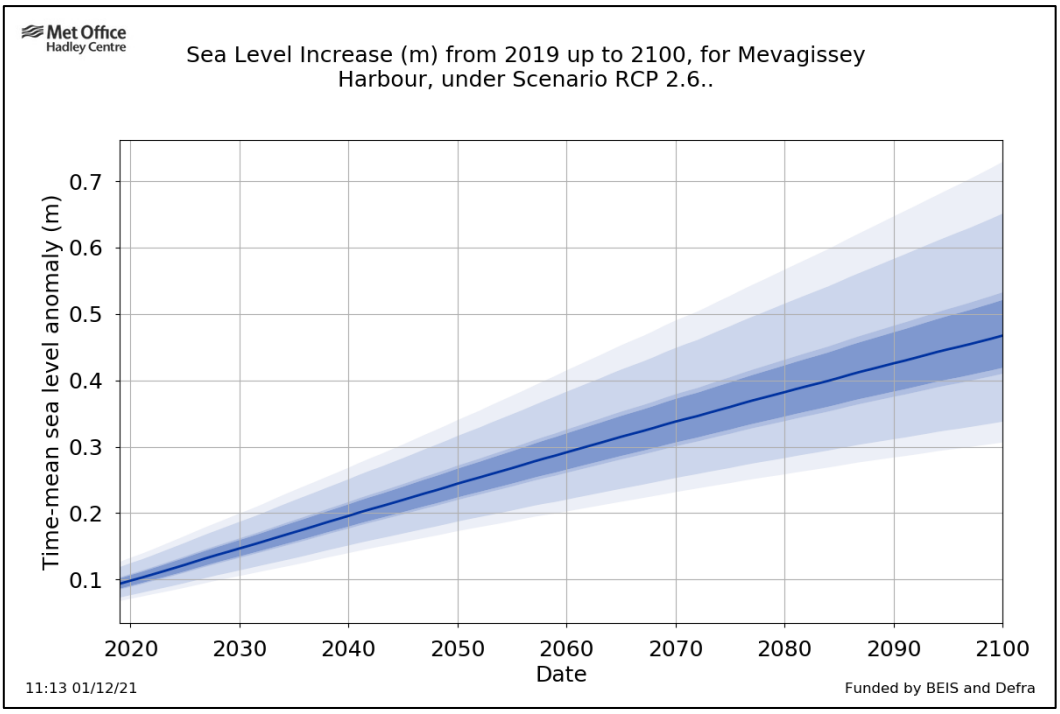

Figure 4. Estimated sea level rise at the coast of Mevagissey Harbour. From 2020 to 2100. Increase from 2000 sea level. Under emission pathway RCP 4.5. Generated from data from Met Office UKCP18 data (2018).

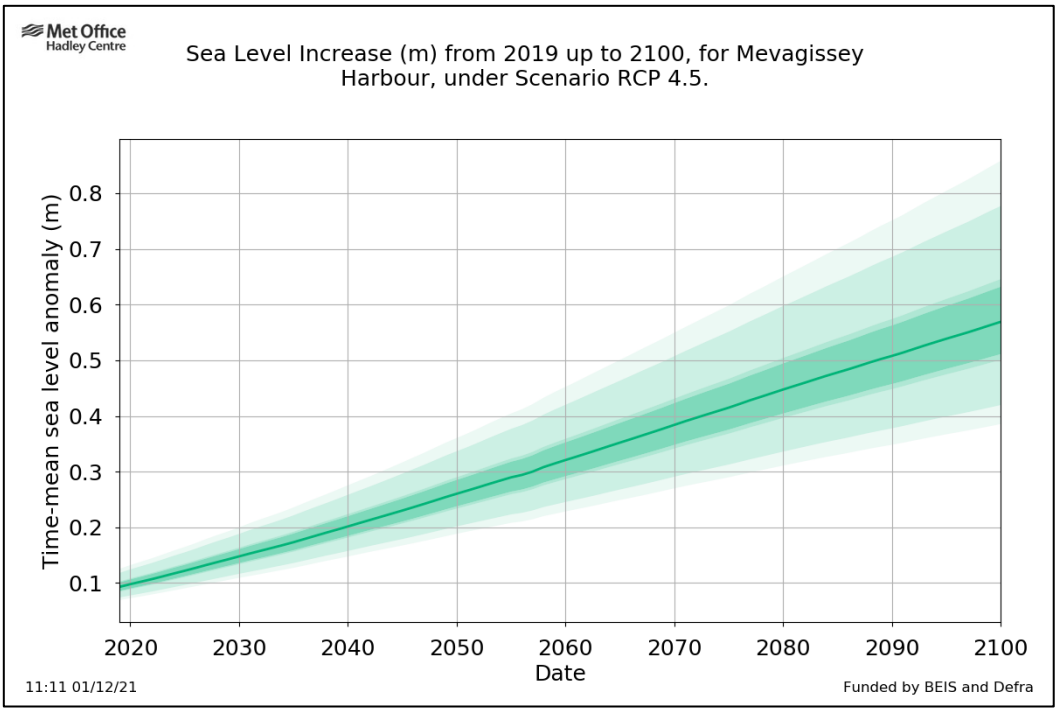

Figure 5. Estimated sea level rise at the coast of Mevagissey Harbour. From 2020 to 2100. Increase from 2000 sea level. Under emission pathway RCP 2.6. Generated from data from Met Office UKCP18 data (2018).

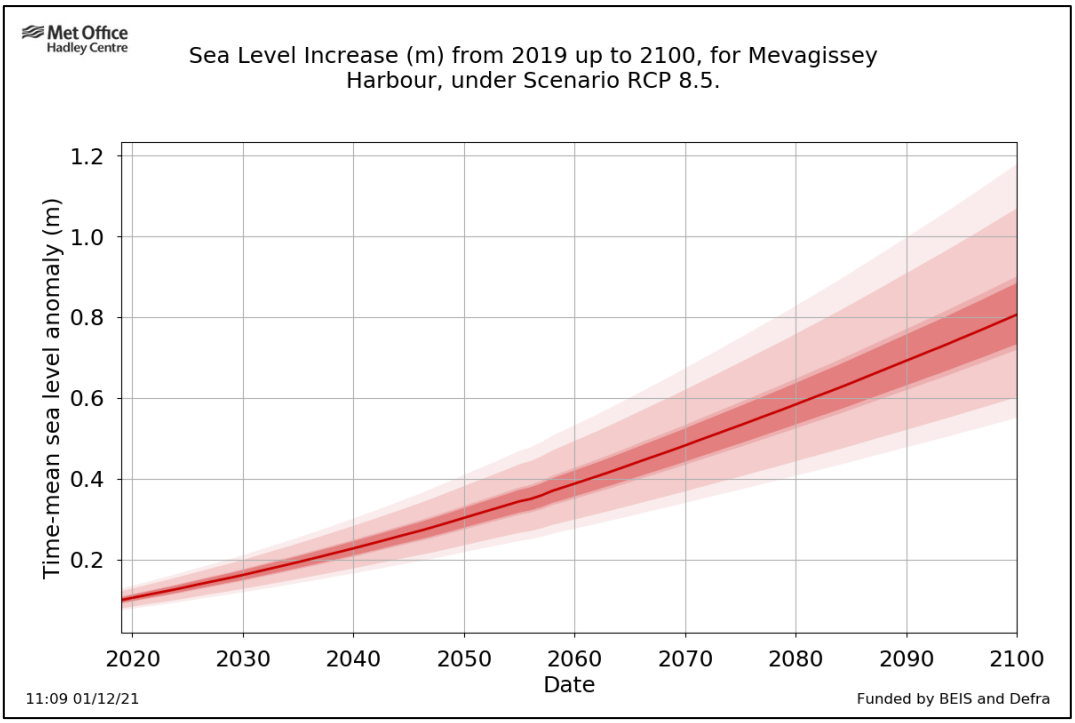

Figure 6. Estimated sea level rise at the coast of Mevagissey Harbour. From 2020 to 2100. Increase from 2000 sea level. Under emission pathway RCP 8.5. Generated from data from Met Office UKCP18 data (2018).

The table and plots show that the mean prediction of sea level rise under all emission scenarios is 7 cm by 2035 as global temperatures are already locked to a trajectory on this short timescale based on current emissions. In 29 years, 2050, sea level at Mevagissey is likely to have risen somewhere between 15 and 21 cm. Using the 95th percentile for RCP 8.5 and the 5th percentile for RCP 2.6, in 79 years, sea levels could have risen by between 21 cm and 1.1 m, but most likely ~47 cm based on the most likely emission scenario.

4. Storm Surges

This report so far has only considered thermal expansion and ice melt caused sea level rise under the influence of astronomical tides. The combination of sea level rise, spring-high tides and low pressure storm events will create significantly higher water levels, with storm waves further increasing the water's reach. It is currently unconfirmed if the intensity and frequency of storm surges are going to change in response to global warming in the UK, yet even if the current intensity is maintained; the combination with future sea level rise will result in higher waters during lower pressure events.

The intensity of storm surges are often measured in relation to their return period, e.g. where a storm surge return period of 1 in 1 year means you can expect a surge of a certain strength once per year, or a return period of 1 in 10 years means a storm of a certain strength is likely to occur once every 10 years. Predictions for the high water levels caused by future storm surges was produced using the Environment Agency's Coastal Design Sea Levels GIS application[8]. Table 2 shows the current highest astronomical tide (HAT) under average metrological conditions, the mean high water spring tide (MHWS) at Mevagissey in 2018, along with a comparison of the water level during storm surges of various return periods under 2018 sea level and predicted sea level in 2050 under RCP 4.5.

	2018		**2050**	
	Sea Level (m)	**Storm surge water level above HAT (m)**	**Sea Level (m) RCP 4.5**	**Storm surge water level above HAT (m)**
HAT	2.79		2.96	
MHWS	2.36		2.53	
Return Period and Height of Storm Surge				
1 in 1yr	2.93	0.57	3.10	0.53
1 in 2yr	3.00	0.64	3.17	0.60
1 in 5yr	3.09	0.73	3.26	0.69
1 in 10yr	3.16	0.80	3.33	0.80
1 in 20yr	3.23	0.87	3.40	0.87
1 in 50yr	3.32	0.96	3.49	0.96
1 in 75yr	3.36	1.00	3.53	1.00
1 in 100yr	3.39	1.03	3.56	1.03
1 in 200yr	3.49	1.13	3.66	1.13

Table 2. 2018 astronomical high water levels at Mevagissey, along with water levels under various storm events. Compared to high astronomical water levels and storm surge levels in 2050 under RCP 4.5.

The numbers show that in combination with sea level rise, by 2050, the strongest storm surge each decade will bring sea levels just shy of 1 m higher than the MHWS or the 10-year storm will bring a surge 0.40 meters higher than the strongest 2018 yearly storm. In the next 100 years, Mevagissey may experience a surge 1.2 m higher that the current MHWS or a 0.63 m higher than the strongest 2018 yearly storm. These higher water levels are just the mean sea level under storm conditions, the addition of large storm waves will further increase the likelihood of overtopping the harbour walls, bringing potential for structural damage to ageing infrastructure.

[8] Environmental Agency. (2018). Coastal Design Sea Levels – Coastal Flood Boundary Extreme Sea Levels.

5. Met Office Summary

The Met Office produced a summary document for its modelling of sea level rise using the best available data and predictions in 2018[9], which will be summarised here:

- Global sea level has risen over the 20th century and will continue to rise over the coming centuries.
- UK tide gauge records show substantial year-to-year changes in costal water levels (typically multiple centimetres per year).
- In their latest model predictions, the Met Office predicts larger sea level increases under the same emissions scenarios compared to the last time they ran the models in 2009 due to improved data quantity and quality.
- Amount of sea level rise depends on the location in the country. Figure 7 shows sea level rise surrounding the UK under RCP 4.5. The South West is predicted to experience some of the highest sea level rise in the country, almost twice as much as southern Scotland. (Figure shows 0.55 – 0.60 cm increase by 2100, starting from 2000, which explains the ~10 cm difference from the 47 cm increase prediction in table 1 of this report).

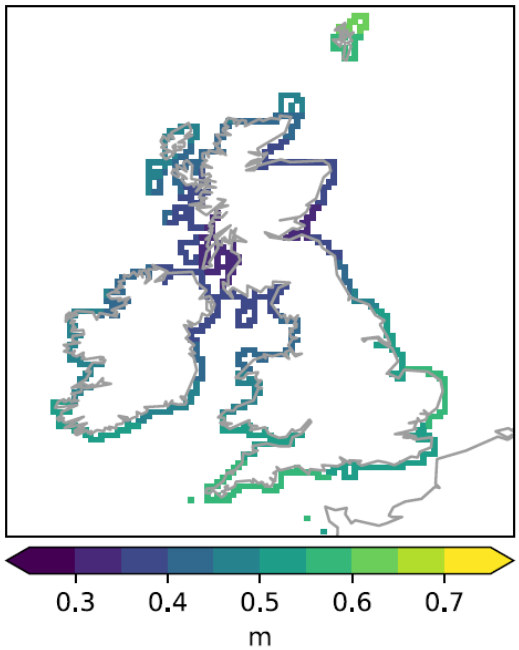

Figure 7. Regional sea level rise around the UK and Ireland coastline in 2100, under RCP 4.5 (Palmer, 2018).

- There is currently not enough data to determine future change in storm surges; continued research is needed in this area – however, storm sea levels will increase anyway due to the rise in mean sea level.
- Substantial additional sea level rise cannot be ruled out due to the uncertainty of ice discharge from the West Antarctic ice sheet.

[9] Met Office. (2018). UKCP18 Factsheet: Sea level rise and storm surge. Met Office, Hadley Centre, Exeter, UK.

6. Conclusion

It is shown that the sea level at Mevagissey has risen 25 cm over the last century, and will continue to rise over the next. The exact magnitude is difficult to predict based on unknown climate policy action, unforeseen changes and further improvements to computational modelling and climate understanding.

However, the most likely scenario is that sea levels without storm surges at Mevagissey are likely to rise 7 cm, 17 cm and 47 cm in the next 15, 29 and 79 years respectively. The combination of these with storm surges make overtopping the harbour wall at Mevagissey more likely, as well as increased structural loads causing damage to ageing infrastructure – a 1 in 10 year storm could see water levels 0.4 m higher than the average 1 per year storm today.