Sea level and tides

Scottish Government
Riaghaltas na h-Alba
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Key message

Sea level changes occur due to tides and storm surges on short time scales and due to global climate change and land mass movements on longer time scales. Sea level around the Scottish coast is rising due to global warming, but the rate of increase differs regionally.

Loch Fleet National Nature Reserve © Lorne Gill, NatureScot

Background

On short time scales, sea level changes globally and locally because of the tide and the effect of storm surges. On longer time scales, sea level is affected by global climate change (ocean temperatures and the amount of land-based ice) and the vertical movement of land masses relative to the sea due to the Earth's crust rebounding following the last ice age.

Variations in sea level impact our shorelines. Tides cause sea level variability on predictable time scales in relatively short time scales, while storm surge and mean sea level rise due to climate change impact sea level extremes. Mean and extremes in sea level are important for protecting our coasts against flooding and erosion.

This assessment presents information on sea level change due to tides and long-term change in mean sea level (sea level rise). Some information on storm surge has been included.

Results

Tides

The difference between mean high and low water at spring tide, the spring tidal range, for Scottish waters from the Scottish Shelf Model (De Dominicis *et al*., 2018) shows the sea level variations due to the tides (Figure 1).

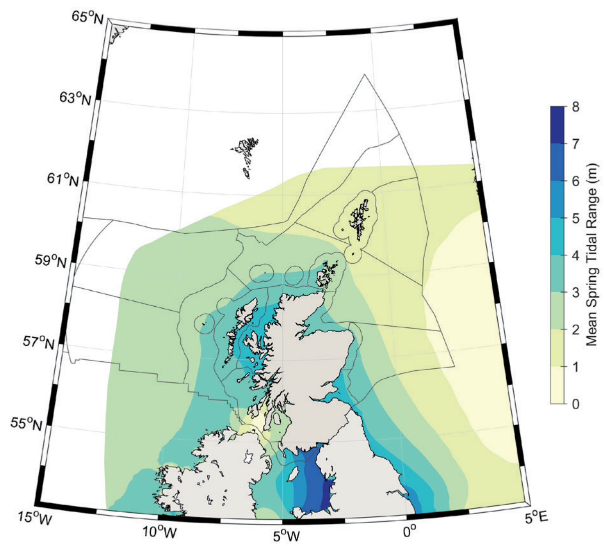

Figure 1:
Mean spring tidal range for Scottish waters from the Scottish Shelf Model.

For further information on this topic go to: https://marine.gov.scot/sma/assessment/sea-level-and-tides

The maximum tidal range (the difference between low and high water) occurs during spring tides, when tide generating forces due to the sun and moon align (i.e. new moon and full moon). At neap tides, the forces due to the sun and moon aren't aligned, and the tidal range is smaller (not shown).

The mean spring tidal range around the coast is generally between 4 and 5 m (Figure 1). The highest tidal ranges between 7 and 8 m are found in the Solway Firth. The smallest tidal ranges occur in areas known as amphidromic points. One of these occurs between Islay and the Mull of Kintyre; another is found in the north-eastern North Sea.

Tidal ranges decrease generally with distance offshore, and in the deep ocean tidal ranges are much smaller than on the shallower continental shelf.

Sea level rise

Trends in sea level vary greatly around our coasts, mainly due to different rates at which the land is moving relative to the sea.

Annual mean sea level observations from the tide gauge network show that sea level rose at all sites since records began (Table 1).

In Aberdeen, the oldest measurement site (started in 1932) trend analysis shows a 9.7 mm per decade increase from then until 2014. Estimates from around Scotland are generally in agreement with the UK and global estimates

Table 1: Sea level trends (in mm/decade) from Permanent Service for Mean Sea Level Tide Gauge Data at locations around the Scottish coast (n.s. = not significant).

Sites	Linear trend (1992-2011)	Linear trend time series	
	mm/decade	mm/decade	Time series used to calculate trend
Aberdeen	37.7	9.7	1932-2014
Kinlochbervie	35.3	31.9	1992-2019
Leith	31.1	24.0	1989-2017
Lerwick	37.4	n.s.	1957-2015
Millport	24.7	14.9	1969-2018
Stornoway	45.9	23.3	1977-2019
Tobermory	n.s.	21.0	1989-2019
Ullapool	n.s.	18.8	1983-2015
Wick	n.s.	15.7	1988-2018

of long-term sea level rise (14 mm per decade and 18 mm per decade respectively). To compare trends between sites, a common 20 year period 1992-2011 is used. These trends range between 25 and 46 mm per decade.

UK Tide Gauge Network measurements (Figure 2) show the observed annual anomaly. To allow for comparison between sites, these have all been standardised relative to the 1992-2011 average.

UKCP18 data (climate model output) show that since 2007, most Scottish Marine Regions (SMRs) have shown an increase in mean sea level (Figure 3).

Due to climate change, sea level is expected to rise due to increased contributions of freshwater from melting of land-based ice (glaciers and

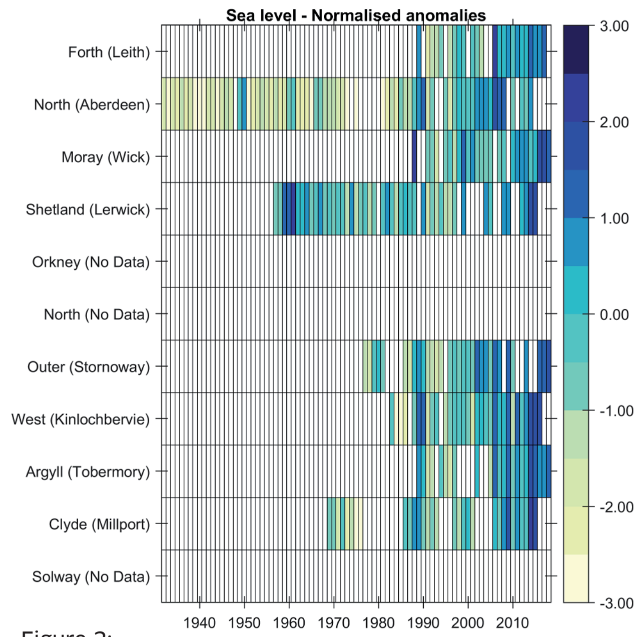

Figure 2:

Mean sea level anomaly (no units) from UK Tide Gauge Network measurement sites. Anomalies are calculated relative to the 1992 - 2011 average. Regions with no data are left white.

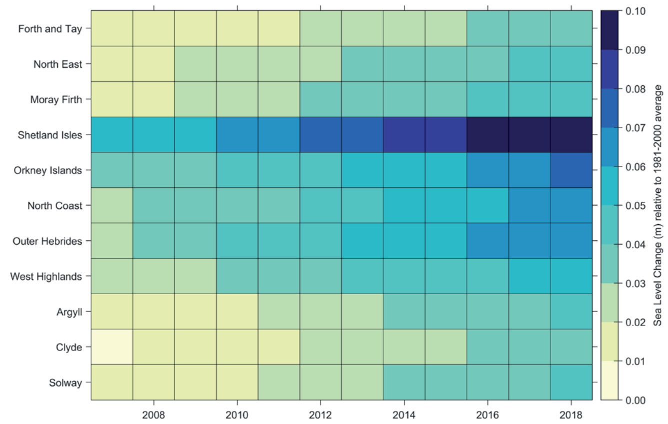

Figure 3:

Mean sea level change (m) for 2007-2018 from the UKCP18 climate model baseline scenario (RCP2.6). Change is calculated relative to the 1981 - 2010 sea level.

the polar ice caps) and due to thermal expansion (IPCC, 2019). For a low emission scenario, the sea level in Edinburgh is expected to rise by 0.08 m to 0.49 m, and for a high emission scenario 0.30 m to 0.90 m by the end of the century (when compared to 1981- 2000) (Met Office Hadley Centre, 2019).

Conclusion

Sea level varies due to tides and storm surge (over short time scales) and due to landmass and global climate change (over longer time scales). Mean sea level around the coast is increasing in all marine regions, with the largest changes in the last 30 years observed at Stornoway, Kinlochbervie and Lerwick. Sea level is expected to increase continually due to global climate change, due to both increases from the melting of land-based ice mass (glaciers, Arctic and Antarctic land ice) and due to the thermal expansion of water.

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