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FLOOD HAZARD SENSITIVITY TO STORM SURGE-HIGH WATER CONCURRENCE IN A HYPER-TIDAL ESTUARY

Charlotte Lyddon[1], Philip Knight[1], Nicoletta Leonardi[1], Jenny Brown[2], and Andrew Plater[1]

Abstract

A web-based, geospatial decision support tool (DST) is described here as a means to assess potential flooding for low-lying coastal and estuarine areas. These areas are at risk from inundation in the future as a result of sea-level rise, coastal storms and high river flow. Flooding assessments use a 2D inundation model, LISFLOOD-FP, and utilize open source GIS. The DST enables users to explore the depth and extent of potential flooding from combinations of sea-level rise and storm surges at sites of nuclear energy assets in the Severn Estuary, South West England. LISFLOOD-FP uses a standard model setup and is forced at the boundaries using tide gauge data. Delft3D is used to assess spatial variability in extreme water levels in the Severn Estuary, with the aim of reducing uncertainty associated with the timing a storm relative to tidal high water in the boundary conditions for the DST.

Key words: Future climate change, flood hazard, numerical modelling, Decision support tool (DST)

1. Introduction

Future global mean sea-level rise is one of the more certain and damaging aspects of human-induced climate change (Anthoff *et al.*, 2010). Sea-level rise (SLR) has been observed over the period of instrumental record, since approximately 1700, and is projected to accelerate into the next century and beyond (Lowe *et al.*, 2010). Studies based on the relationship between sea level and air temperature suggest that SLR may exceed 1 m by 2100 (Grinsted *et al.*, 2015). Jevrejeva *et al.* (2014) use a probability density function to estimate there is < 5% probability that sea level will rise above 180 cm by 2100. The UK Climate Projection (UKCP09) report estimates of 0.93 m to 1.9 m SLR by 2100 in a low-probability sea-level range (H++ scenario) (Lowe *et al.*, 2010). Uncertainty surrounding future GHG emissions and the response of global ice sheets to increasing temperatures means SLR may lie outside the stated likely ranges (Jevrejeva *et al.*, 2014).

SLR will drive physical and socio-economic impacts in densely populated coastal areas (Nicholls et al., 2014). Globally, 150 million people live within 1 m of mean sea-level and 35% of global GDP is located within 10 m of mean sea-level (Hinkel *et al.*, 2014). Coastal populations are threatened by SLR because of reduced return periods and increased frequency and magnitude of coastal flooding. High tides, storm surges, waves and increased river flow present a combined flood hazard in coastal areas worldwide (Lewis *et al.*, 2011). Extreme water levels superimposed on rising sea levels will cause degradation and damage to communities and infrastructure at the coast, removal of natural defences and long-term erosion.

1.1. *ARCoES, Adaptation and Resilience of Coastal Energy Supply*

The ARCoES project identifies the challenges facing the future resilience of the UK coastal energy sector as a result of a changing climate. The project involves partners and stakeholders from academia, energy and engineering sectors, planners, the third sector and community networks to identify how coastal power stations can be adapted to future climate change impacts and thus become more resilient. One key aspect of the project is the development of a decision-support tool (DST) to illustrate vulnerability to future flooding as a result of changing storm climate and SLR as a series of maps and scenarios (Knight *et al.*, 2015). The aim is to identify how the coastal power stations, substations and distribution grid can be made more

[1]Department of Geography and Planning, University of Liverpool, Liverpool, UK, C.E.Lyddon@liverpool.ac.uk
[2]National Oceanography Centre, Liverpool, UK.

resilient to future climate change impacts by adapting and an appropriate and timely manner.

1.2. *The Severn Estuary*

Numerous nuclear energy assets (planned, existing, and decommissioned) and large communities are located on the low-lying floodplains of the Severn Estuary and Bristol Channel (Ballinger & Stojanovic, 2010). These assets are vulnerable to extreme water levels when they occur, often as a result of meteorologically-forced surges generated by North Atlantic low pressure systems (Uncles, 2010). The tidal regime is described as hypertidal: the tidal range increases from 6.2 m in the Outer Bristol Channel to 12.20 m at Avonmouth (Pye & Blott, 2010). Increasing tidal range up-estuary is a result of the funneling effect up to Avonmouth, (Dyer, 1995). Beyond this point, bottom friction acts to dampen tidal amplitude.

Extreme water levels and flooding events in the Severn Estuary are well documented. Severe flooding occurred from east of Bideford to Gloucester on 13 December 1981 due to high spring tides and a storm surge, but wave action did not significantly contribute to damage (Smith *et al.*, 2012). Analysis has shown that the surge itself was not exceptional, but its coincidence with the peak of tidal high water was crucial in producing very high water levels in the upper Bristol Channel (Proctor & Flather, 1989). A shift in the timing of the surge of only 1 hour might have led to no flooding in this instance. A larger storm surge (2.4 m) on 24 December 1977 occurred 3 hours before high water, giving no cause for concern. The timing of the passage of low atmospheric pressure systems and the peak of the storm surge relative to tidal high water is thus crucial in influencing extreme water levels in hypertidal locations (Proctor & Flather, 1989)

1.2.1. Coastal energy infrastructure located in the River Severn & Bristol Channel

Magnox operates a number of nuclear energy assets within the Severn Estuary. The Hinkley Point stations are located at 11 m OD, 8 km to the west of the River Parrett. Hinkley Point A operated from 1965 to 2000 and is now being decommissioned; Hinkley Point B began operating in 1976 and is expected to run until 2023 (EDF, 2017). Hinkley Point C is a project to construct a 3,200 MW nuclear power station at the site, expected to be operational by 2025 (Magnox, 2017a). Active erosion, wind and wave action increase the risk of erosion, however sea defences and rock outcrops at the coast currently provide protection. HAT at Hinkley Point is 7.12 m OD, MWHS is 5.93 m OD, and the maximum tidal range is 13.21 m (Nirex, 2005).

Oldbury-on-Severn is located 35 km east of Hinkley. The surrounding area is mainly used for agriculture, and there is a decommissioned Magnox nuclear power station located 2 km north of the town. The power station ceased operation in 2012, but the decommissioning and maintenance process will extend for many decades into the future. The low-lying land is protected by sloping earth defences designed to protect against overtopping by the 1:50 year Extreme Water Level. The nuclear power station is protected by a concrete sloping wall with a minimum crest height of 9.97 m OD (Nirex, 2005).

Berkeley-on-Severn is located 45 km east of Hinkley, on low-lying land within the Vale of Berkeley. The site is situated just south of a minor estuary known as Berkeley Pill, where embankments protect the area from flooding. The shorelines is protected by an armoured rock surface, and there is evidence of erosion on the tidal flats (Uncles, 2010). MHWS can reach 7.5 m OD at Sharpness, to the north of Oldbury and Berkeley. Both power stations are at 10 m OD and are protected by embankments.

These sites of nuclear assets are designed and operated with regard to environmental conditions which can increase and exacerbate coastal flood inundation. Tidal currents which exceed 1 m s^{-1} over wide areas and for long periods and a tidal range up to 12.2 m can increase flood risk. The shoreline at Hinkley Point is subject to strong winds and substantial storm surges. Both Oldbury and Berkeley lie on low-lying land subject to inundation and both stations are threatened by erosion from the tidal River Severn. SLR poses an increasing threat to existing embankments and other defences. Therefore, operational safety cases consider how coastal power stations are likely to be affected under future climate change, and assessments are required to ensure the future resilience of coastal energy (ARCC, 2012).

2. Methods

2.1. *Coastal inundation model*

LISFLOOD-FP (Bates *et al*., 2005) has been applied as a coastal inundation model to map depth and extent of floodwaters for extreme coastal and riverine events under rising sea-levels. LISFLOOD-FP, a computationally efficient, 2D hydrodynamic inundation model is widely used to simulate floodplain inundation (Lewis *et al*., 2011). LISFLOOD-FP solves the shallow water equations, minus the law of conservation of momentum for the floodplain flow and operates over a raster grid to predict the dynamic propagation of flood waves from a user-defined boundary (Bates & De Roo, 2000). Water moves into the model domain, and flows over floodplains under the influence of gravity (Dawson *et al*., 2005). The model assumes that the flow between two cells within the domain is a function of the surface height difference of the two cells, frictional influence due to land use and gravity (Bates *et al*., 2010).

The model input data required for LISFLOOD-FP is shown in Figure 1.

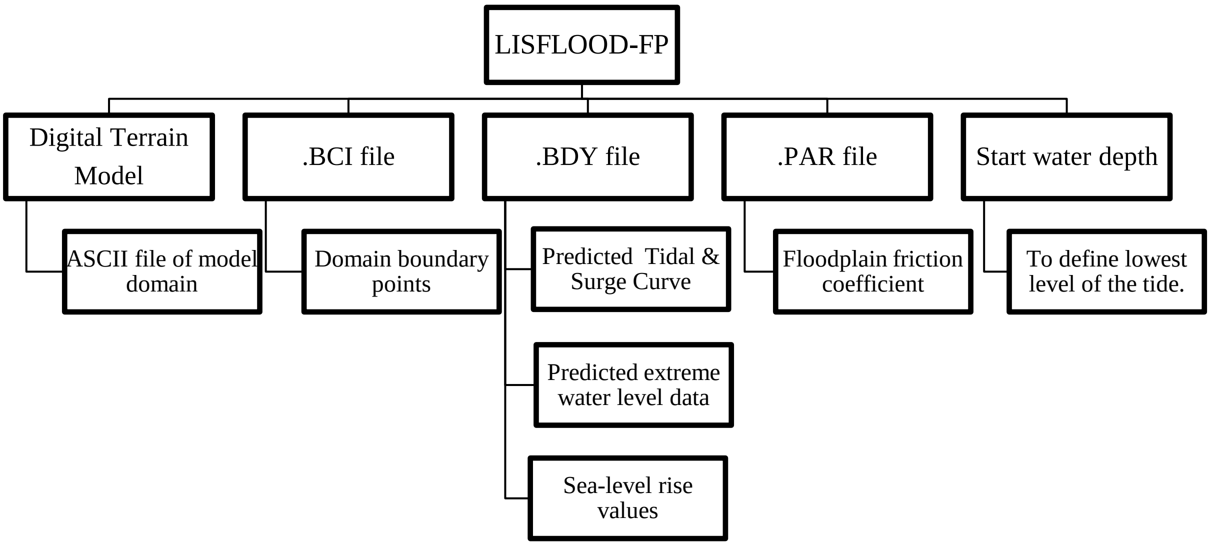

Figure 1: Files and input data required for model simulations.

2.2. ***Model inputs***

The model operates over a gridded digital elevation model (DEM), resampled to 10 m resolution to enable efficient runtime. The input data comes from the most recently available airborne laser altimetry (LiDAR) collected by the Environment Agency (EA). Sea and river defence crests were digitised into the raster to give an accurate representation of the floodplain.

Boundary conditions to force the model are described in Prime *et al.* (2015). Each scenario for Oldbury-on-Severn considers the impact of storm tides (tide+surge) and SLR, and are constant in space. The EA has generated extreme tide levels around the UK at 16 different return periods, at 2 km intervals along the UK coastline (Environment Agency, 2011). Each 10 m data point in the domain boundary is assigned an extreme water level elevation based on the closest EA data point. Return period from 1:1 to 1:10,000 year extreme water level event was used to force the model. Incremental increases in return period allow the user to explore significant changes in flood risk.

Extreme water level elevations are combined with representative surge curves for tide gauges around the UK (Environment Agency, 2011). The nearest storm surge shape for Oldbury was Avonmouth, used to represent all locations along the coastline. The peak of a representative surge curve is lined up and recombined with the peak of tidal high water. This methodology is in line with that proposed by the Environment Agency, and assumes that the peak of the tide and surge occur at the same time (McMillan *et al*., 2011). Wave and river inputs were not included due to the location within the Severn Estuary: Oldbury is largely protected from waves (Magnox, EU Stress Test Report for Oldbury, 2011).

A SLR parameter is added to all values to produce a time-varying water elevation which represents a worst case scenario. A baseline SLR parameter, 0 m, was selected to represent present-day sea-level conditions, and then increased in 10 cm increments up to 1 m. This allows the user to explore a series of extreme water level elevations, combining storm tide and SLR. Each model scenario output can be visualised and presented with symbology to represent maximum depth and extent of flood inundation and flood hazard, as a result of the variables set in LISFLOOD-FP; changing return period and SLR.

2.3. *Extreme water level modelling*

Delft3D-FLOW, which solves depth-averaged unsteady shallow-water equations across a 2D horizontal curvilinear, boundary fitted grid (Lesser *et al*., 2004), is used to simulate barotropic tide-surge-river propagation and interaction in the Severn Estuary. The Severn Estuary model domain (Figure 2) extends from Woolacombe, Devon and the Rhossili, Gower Peninsula in the West, up to Gloucester in the East. This is known to be the normal tidal limit of the Bristol Channel (Pye & Blott, 2014). The horizontal resolution varies from 3 km at the seaward boundary in the lower estuary, to less than 10 m in the upper estuary. The model domain has 2 open boundaries: a sea boundary forced by tide gauge data, and a river boundary forced by river gauge water level data from Sandhurst. Gridded bathymetry (SeaZone Solutions Ltd., 2013) was resampled from 50 m resolution to 30 m resolution to improve computational efficiency, and interpolated onto the model grid.

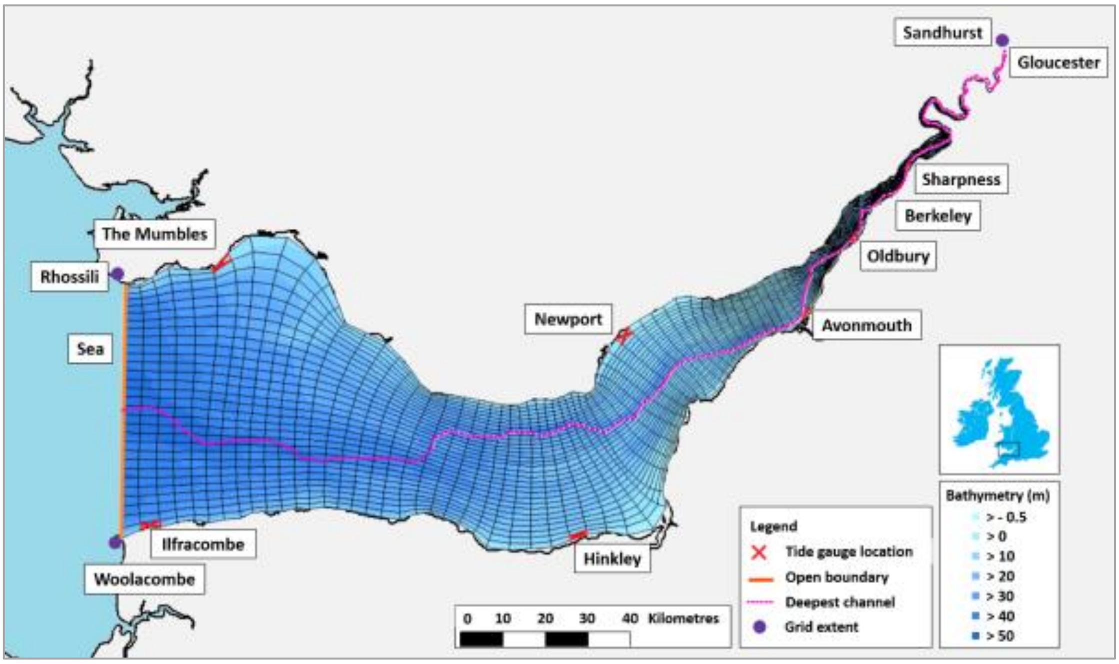

Figure 2: Severn Estuary model domain. The bathymetry is relative to chart datum at Hinkley (CD).

The project uses long-term tide gauge records from Ilfracombe and Mumbles in the Severn Estuary to generate a time series for the most extreme event on record, 07:15, 3 January 2014. A low pass, Chebyshev type II filter is applied to the storm surge component with time to remove the time-varying meteorological component and tide-surge interaction, a method previously used by Brown *et al.* (2015). The filtered surge component is recombined with the tidal curve in a number of time-shifted configurations, up to 6 hours before and 6 hours after the peak of tidal high water. This is to investigate how the timing of the peak of the surge relative to the peak of tidal high water influences locally generated tide-surge interaction and spatial-temporal variability of extreme water levels across the estuarine domain.

3. Results

3.1. *Decision Support Tool*

The DST is a tool for stakeholders to understand the vulnerability to future flooding at the coast, by exploring a series of 'what if' scenarios of SLR and storm surges. The spatial element of the DST comprises a zoom-enabled base map (Ordnance Survey or OpenStreetMap) with each flood risk scenario superimposed on top (Figure 3).

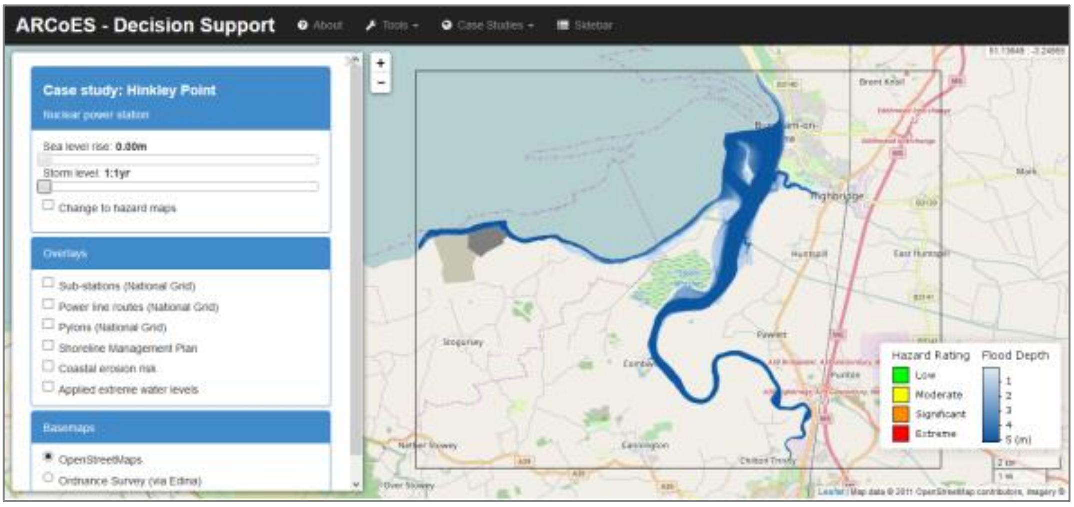

Figure 3: ARCoES Decision Support Tool with menu slider system displayed with sea-level rise (0 m) and storm level (return period) (1:1 yr). Flood depth or hazard rating can be displayed in the spatial element of the tool.

The user is able to change SLR and storm level / return period in the menu slider system and view the resulting flood inundation in the spatial flood map. Additional local power infrastructure, such as major sub-stations and electricity pylon routes can be overlaid by clicking the appropriate boxes in the menu system. This allows the user to explore a series of scenarios to for their own flood risk evaluation.

3.1.1. Hinkley Point

Animations are available online for incremental flood risk and return period at Hinkley Point (https://arcoes-dst.liverpool.ac.uk/animations/flood_scenariosSLR_Hinkley.html). Figure 4 shows the potential depth and extent of inundation at Hinkley Point, as seen in the DST, for Extreme Water Levels under a 1:100 and 1:10,000 year return period. The blanked out area near to Hinkley (shown within each scenario) is covered by existing pre-operational and operational safety cases. Under a 1:100 year event, 0 m sea-level rise, agricultural land to the south of Pawlett experiences up to 1 m inundation as does Steart Point at the mouth of the River Parrett. Under a 1:1,000 year event and 0 m SLR, much of the low-lying land to the west of Pawlett and Stretcholt experiences up to 2 m inundation. Burnham on Sea, Steart Marshes and Highbridge would also experience inundation. These results show how the DST can be used to explore a range of incremental SLR and return periods on inundation depth and extent.

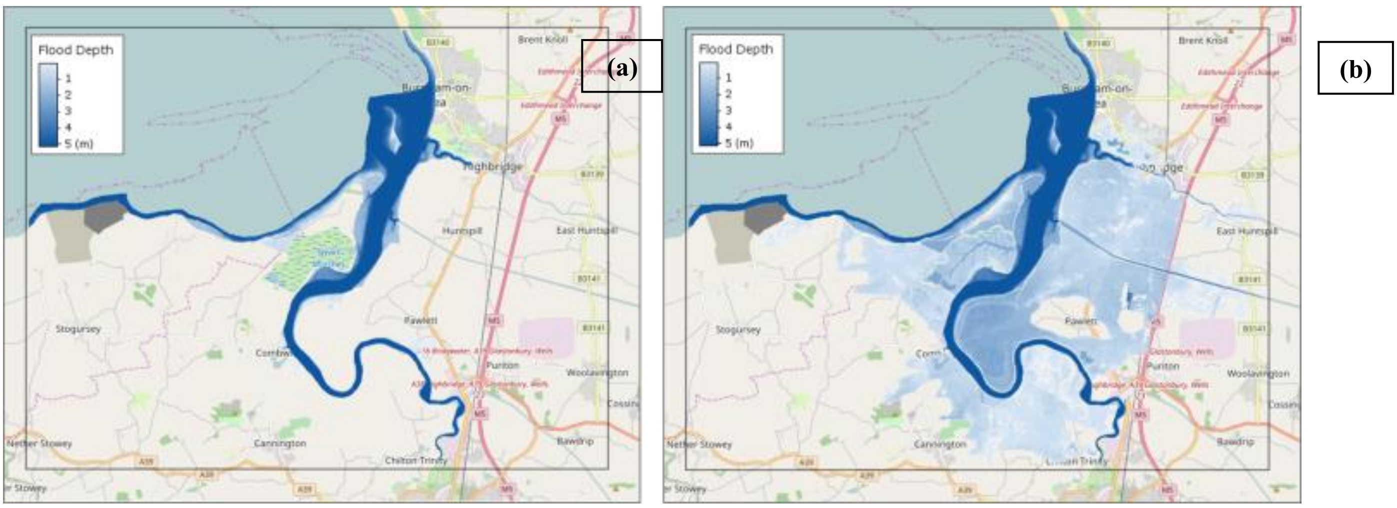

Figure 4: (a) DST screen shot of the scenario with 0.0 m sea-level rise and a 1:100 year storm level (Extreme Water Level). (b) DST screen shot of the scenario with 0.0 m sea-level rise and a 1:10,000 year storm level (Extreme Water Level).

3.1.2. Oldbury-on-Severn

Figure 5 shows screen shots from online animations showing potential flooding for the area around the nuclear energy infrastructure at Oldbury-on-Severn. The screen shots show increasing SLR and a constant 1:200 year storm level. The base map used for these images in Ordnance Survey (OS, 2014). A 1:200 year storm level under present-day sea level (no increase) would result in inundation of agricultural land of less than 1 m. A 1:200 year event, accompanied by 0.2 m SLR generates more extensive extent of inundation, but only up to 1 m in depth. Oldbury-on-Severn power station is unaffected, as well as some residential properties in the towns of Oldbury-on-Severn and Oldbury Naite to the south. A 0.6 m SLR would lead to a greater extent of inundation up to 1 m, particularly agricultural land to the south-east of the model domain. Again, Oldbury-on-Severn power station is unaffected and some small areas around Oldbury-on-Severn remain protected. 1.0 m SLR would result in widespread inundation up to 8 m depth. Transport and access routes within the area would be flooded, as well as local amenities, agricultural land and properties.

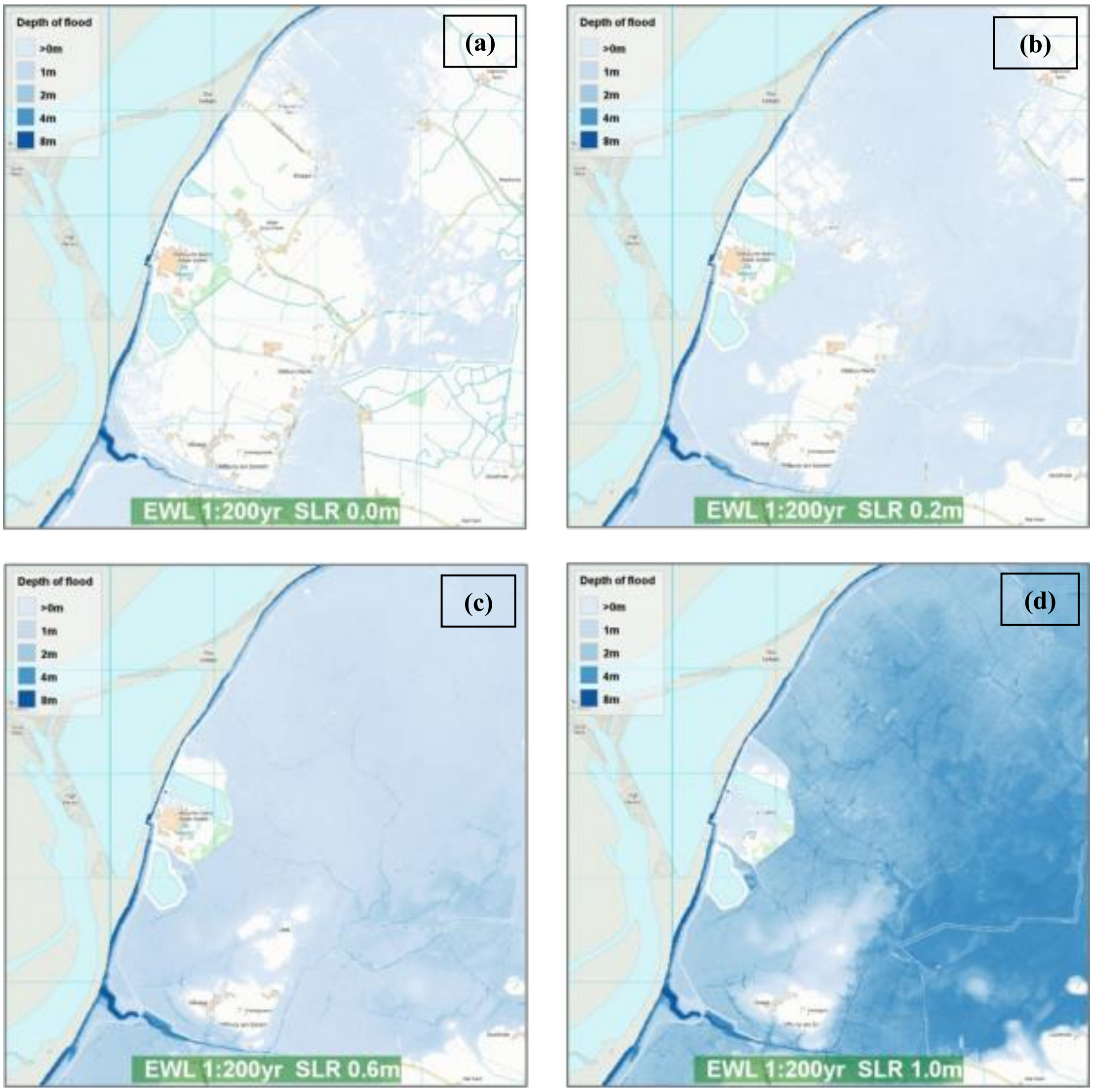

Figure 5: (a) Animation screen shot of scenario with 0.0 m sea-level rise and a 1:200 year storm level. (b) Animation screen shot of the scenario with a 0.2 m sea-level rise and a 1:200 year storm level. (c) Animation screen shot of the scenario with a 0.6 m sea-level rise and a 1:200 year storm level. (d) Animation screen shot of the scenario with a 1.0 m sea-level rise and a 1:200 year storm level.

3.1.3. Berkeley–on–Severn

Figure 6 shows screen shots from online animations showing potential flooding for the area around the nuclear energy assets at Berkeley due to SLR and increasing storm level. The base map used for these images is the Ordnance Survey data (OS, 2014). Similarly to Figure 4, and the screen shots show how incremental increases in sea-level superimposed on a 1:500 year storm event would increase the depth and extent of inundation. A 1:1 year event with 0 m SLR causes little inundation, other than at the estuary of Berkeley Pill and an area of saltmarsh in front of Berkeley Technology Centre, to the south west of the power station. A 0.2 m SLR coupled with a 1:100 year event would lead to more widespread inundation, up to the town of Berkeley, but the depth does not exceed 1 m (other than in Berkeley Pill). More significant potential inundation is reached with 0.6 m SLR superimposed on a 1:500 year event, where up to 1 m inundation depth is seen. With increasing SLR and storm surge height the depth of inundation could increase up to 8 m.

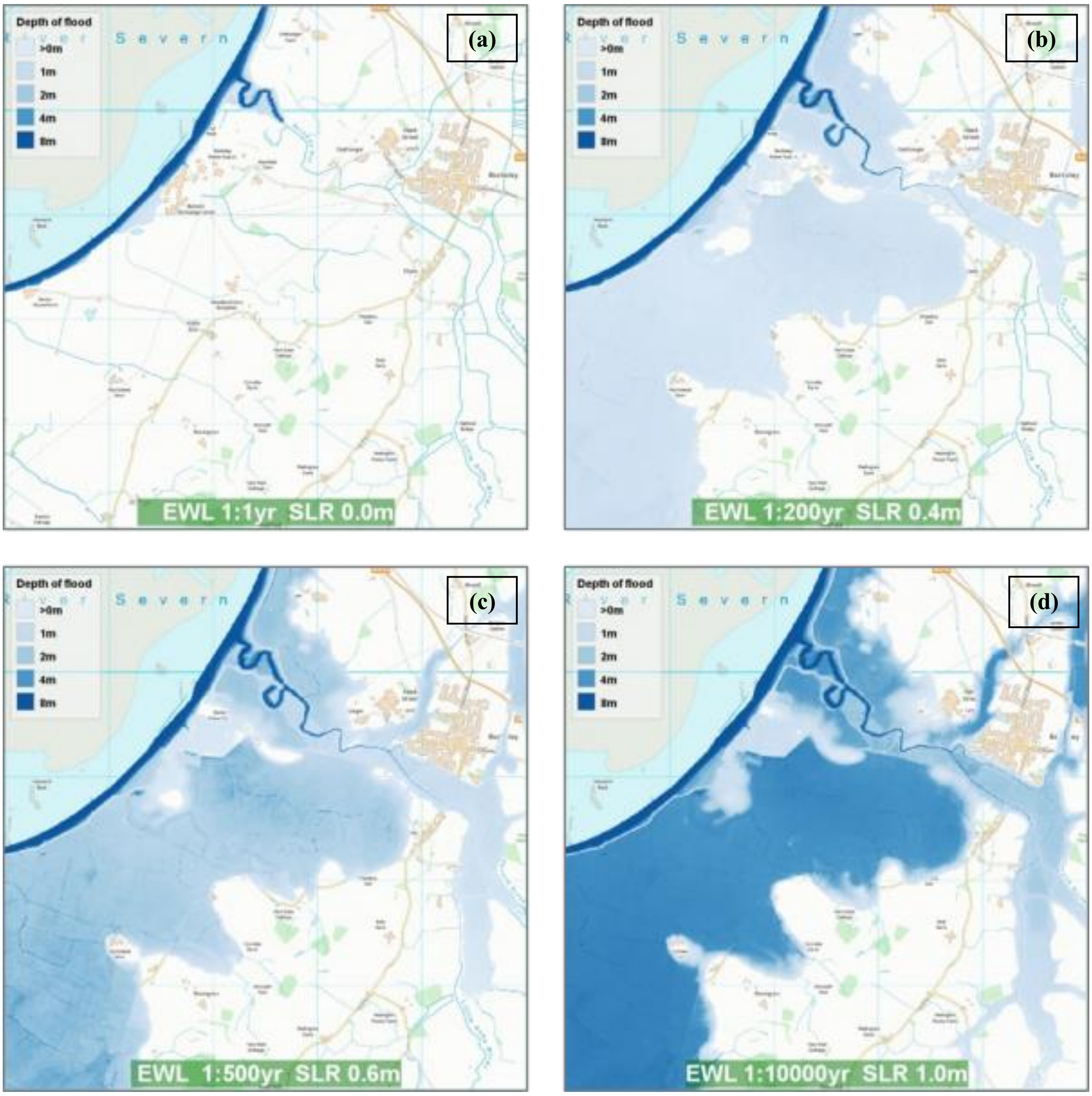

Figure 6: (a) Animation screen shot of the scenario with a 0.0 m sea-level rise and a 1:1 year storm level. (b) Animation screen shot of the scenario with a 0.4 m sea-level rise and a 1:200 year storm level. (c) Animation screen shot of the scenario with a 0.6 m sea-level rise and a 1:500 year storm level. (d) Animation screen shot of the scenario with a 1.0 m sea-level rise and a 1:10,000 year storm level.

3.2. *Extreme water level sensitivity to event timing*

The series of flood extent maps have been computed using LISFLOOD-FP coastal inundation model with a standard model setup: the time-varying boundary conditions are constant in space and use tide gauge data as the primary data source. However there are few tide gauges located near to nuclear energy assets within the Severn Estuary to provide spatially varying boundary conditions. It is important to understand the spatial variability of water level, and how water level varies within the estuary relative to tide gauges. A greater understanding of the spatial variability of extreme water levels in the Severn Estuary could then provide improved boundary conditions to the DST.

The coastal boundary of Delft3D was forced with total water level (tide + surge) data from the tide gauge data at Ilfracombe, representative of the actual timing of the event. The modelled water level at the peak of the storm tide on 3 January 2014 at each location during the total water level model run is compared to the nearest tide gauge. Figure 7 shows the percentage change in modelled water level and tide gauge data for the peak of the storm tide for sites of nuclear assets. It can be seen that there is a non-linear trend. Berkeley shows the smallest percentage change (2.23%), with the modelled water level being most closely representing the tide gauge data. Oldbury shows a 4.89% change, and Hinkley a 2.61% change.

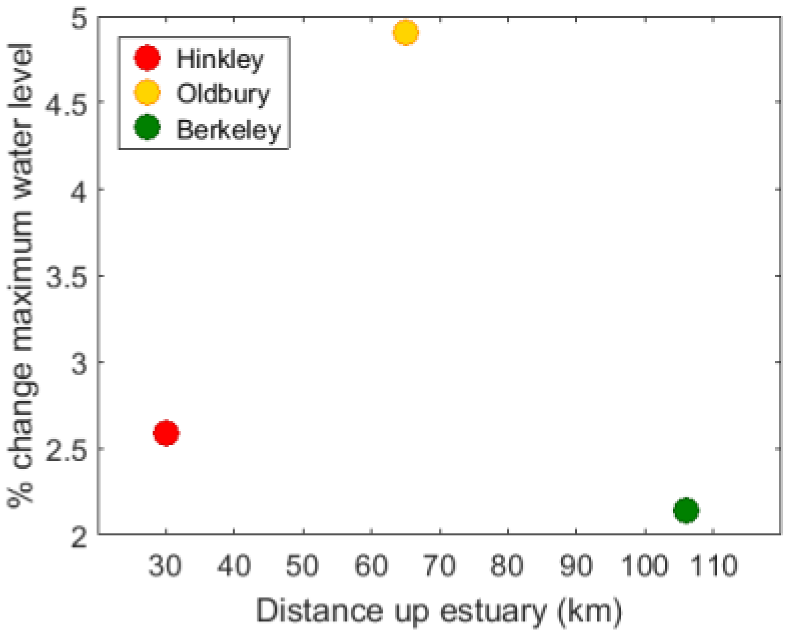

Figure 7: Percentage change in maximum water level at the peak of the storm tide on 3 January 2014 between observational data to the nearest tide gauge, against distance up estuary and modelled water level (tide+surge) with realistic timing of event.

The influence of the change in timing of the peak of the surge relative to high water is analysed for each location within the DST. Figure 8a shows percentage change in total maximum water level between Delft3D model results for each time shifted configuration, and tide gauge data at Hinkley. There is a symmetrical shape to these results, with the smallest percentage change occurring when the peak of the surge is close to the peak of tidal high water. There is up to a -1.5% change when the peak of the surge occurs 6 hours after the peak of tidal high water. The modelled results show high water to be 7.53 m when the peak of the surge occurs 6 hours after tidal high water, and 7.62 m when the peak of the surge and tide coincide. This 9 cm difference is comparatively small when considered against the 8–9 m tidal range at this location in the estuary.

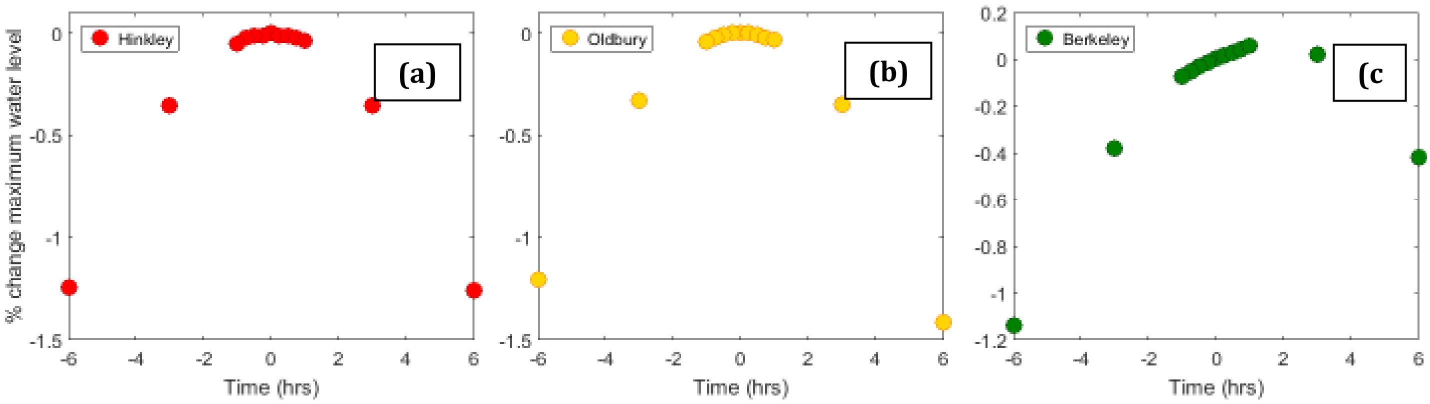

Figure 8: Percentage change in maximum total water level between observational data from (a) Hinkley (b) Oldbury and (c) Berkeley tide gauge data and model runs with the peak of the surge changed in time relative to the peak of tidal high water.

Figure 8b shows percentage change in total maximum water level between Delft3D model results for each time shifted configuration, and tide gauge data at Oldbury-on-Severn, upstream of Hinkley. As seen in the results at Hinkley, there is also a symmetrical shape to the results at Oldbury-on-Severn: the smallest percentage change occurs when the peak of the surge and the peak of tidal high water coincide. The greatest % change is seen when the peak of the surge occurs 6 hours after the peak of high water (9.02 m). Total water level is greater when the peak of the surge coincides with tidal high water (9.13 m).

Figure 8c shows percentage change in total maximum water level between Delft3D model results for each time shifted configuration, and tide gauge data at Berkeley, upstream of Oldbury-on-Severn. It can be seen that the percentage change between total maximum water level when the peak of the surge and tide coincide and maximum water level for each time shifted configuration is asymmetrical in shape. The greatest, positive percentage change is seen when the peak of the surge occurs 1 hour after tidal high water (10.84 m) compared to the model run when the peak of the surge and tide coincide (10.82 m). This is a very small difference when compared against the tidal range at this point, 11–12 m. Berkeley is located at a point in the Severn Estuary where the channel begins to significantly narrow, which results in a very large tidal range here due to the funnelling effect. The greatest negative percentage change is when the peak of the surge occurs 6 hours before the peak of high water (10.70 m).

4. Discussion

With future SLR, communities and infrastructure located at the coast will face increasing vulnerability to flooding as a result of varying combinations of tides, storm surges, waves and river flow superimposed on the underlying rise in sea level. The Intergovernmental Panel for Climate Change (IPCC) estimate up to 0.98 m sea-level rise by 2100 for the 95th percentile (Church et al., 2013), which would result in greater frequency and magnitude of severe flooding events in the Severn Estuary. However there is uncertainty surrounding future SLR and storm surge climate. For example, the UKCP09 provides an industry standard in the UK for probabilistic assessment of SLR around the UK coastline, with up to 0.53 m by 2095 in Cardiff for the 95th percentile (Lowe *et al.*, 2010). The uncertainty in future SLR and storm surge climate means communities face an array of options to approach probabilistic risk assessment, each linked to different emissions scenarios, climate responses and drivers. There is a need for tools to allow coastal decision makers and stakeholders the opportunity to explore a range of SLR in a simple and approachable manner which then forms the basis of discussion around adaptation and mitigations options and strategies and when these might need to be enacted (cf. Knight *et al.*, 2015).

The Decision Support Tool presented here provide users with the opportunity to explore potential coastal flooding caused by various combinations of storm surges (from 1 in 1 to 1 in 10000 year events) and incremental SLR up to 5.5 m (in 0.1 m increments from 0.0 to 2.0 m and in 0.25 m increments from 2.0 to 5.5 m), providing considerable detail on areas, assets and access routes that are vulnerable to future flooding. In this sense, it is a tool for examining future threats to coastal lowland infrastructure and communities, the degree of SLR required to cause a substantial change in flood risk, where to avoid building future energy infrastructure, and where to implement measures that might mitigate the risk.

Importantly, it does not incorporate any physical changes to the coast or measures to reduce vulnerability future flooding but highlights where attention needs to be focussed and the SLR that would be something of a 'tipping point' in our current management and occupation of the coast. The DST therefore provides users with the opportunity to visualise where strategic planning needs to focus for ensuring future resilience to SLR.

Operationally, the DST can also be used by flood managers and first responders to assess whether forecasted extreme water levels may be close to or likely to overwhelm sea defences. This then supports the effective deployment of resources during the course of an extreme event and prevents any unforeseen problems regarding access.

The DST is designed to offer the basis for discussion and inclusive decision making. In steering clear of specific SLR scenarios it then encourages users to explore when a given amount would be likely, and thus transfers responsibility to the user to gain understanding of sea level projection. Additional resources available on the DST website provide important signposts in this respect. Similarly, in providing examples of interventions for mitigating vulnerability to future flooding – their characteristics and relative advantages/shortcomings – the website also enables users to build their knowledge of the natural behaviour of coastal environments, and how this behaviour can be promoted to mitigate future flood risk.

The case studies presented for the DST here focus on small areas, which allows LISFLOOD-FP to operate efficiently at a much finer spatial resolution (10 m grid). This enables smaller features within the DEM to be considered in the model e.g. earth banks. This allows for more accurate calculations of depth and extent of flood inundation. The DST described here uses a standard model setup; Extreme Water Level statistics to force the LISFLOOD-FP coastal inundation model boundaries are computed using data from the nearest tide gauge. However, the locations of interest presented here (Hinkley Point, Oldbury-on-Severn, Berkeley-on-Severn) are not necessarily located close to a tide gauge. Therefore the boundary conditions may not be entirely representative of the conditions each location experiences. In this respect, extreme water level modelling can provide more accurate boundary conditions for LISFLOOD-FP to be forced with. The modelled water level results from Delft3D at each nuclear site shows how the water level varies from the water level recorded at each corresponding tide gauge. No clear trend is observed in respect to how the observed water level at the tide gauge is different compared to water level at each power station moving up estuary. These results show that caution must be taken when applying observational data from a distant tide gauge to a model boundary. Forcing LISFLOOD-FP with tide gauge data originating far from the area of interest could lead to over or underestimation of flood depth and extent for each scenario. Model results from Delft3D provide a tidal time-series at each grid point, which then forces the boundaries of the LISFLOOD-FP modelling.

Modelled water level results from Delft3D also show how the timing of the peak of the surge relative to tidal high water is an important factor to consider when assessing extreme water levels. Hinkley Point experiences greatest change in maximum water level when the peak of the tide and surge occur within 30 minutes of each other, compared to when the peaks coincide. However literature suggests that the peak of the tide and surge are unlikely to occur due to non-linear tide-surge interactions. Further up-estuary at Berkeley there is a clear asymmetry in the change in maximum water level. The greatest percentage change compared with when the peak of the surge and tide coincides is when the peak of the surge occurs 1 hour after tidal high water. These results can be used in a forecasting and operational context. If a surge is likely to occur at a certain time relative to tidal high water, it is then possible to infer where the impact may be felt the most.

Changes in the timing of the peak of the surge relative to high water could be an additional menu slider system within the DST. The timing of the peak of the surge has been seen to influence the maximum water level, which in turn will influence the depth, extent and duration of high water. This would allow users the opportunity to explore a greater range of scenarios likely to occur within these areas. However this could have the opposite effect of over-complicating an already effective tool.

5. Conclusions

A web based, geospatial decision support tool has been developed for specialist and non-specialist users to explore potential future flooding from combinations of sea-level rise and storms. Outputs from LISFLOOD-FP are presented in the geospatial DST alongside a menu-slider system to explore different scenarios.

The Hinkley Point, Oldbury-on-Severn and Berkeley-on-Severn case studies highlight how the DST operates as well as the vulnerability of low-lying coastal land. These case studies highlight the future vulnerability of important electricity supply infrastructure and the surrounding low-lying rural areas to coastal flooding. These case studies also illustrate how the DST functions as the basis for dialogue regarding future coastal resilience and resource allocation with respect to flood risk mitigation.

Extreme water level analysis using Delft3D shows how modelled water levels at Hinkley Point, Berkeley and Oldbury can vary from the observed tide gauge data. Results from Delft3D could be used to force the model boundaries of LISFLOOD-FP to improve confidence in depth and extent of flood inundation. Analysis into changes in maximum water level when the peak of the surge changes relative to the peak of high water shows locations further up-estuary, in particular Berkeley, are more sensitive to the timing of the peak of the surge relative to high water.

6. Acknowledgements

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7. References

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