Author's Response to Reviewer Comments

Authors comments in bold.

We would like to thank both reviewers for their constructive comments on this manuscript. We would like to address each of your comments and the changes we have made to the paper in response to your feedback.

Due to the addition of text and subsections, some of the page and section numbers given by the reviewers may now have change. Page and section numbers in the responses given by the author are for the track changed document, whereby 'No Markup' is shown.

Comments from the editors and reviewers:

Reviewer 1: Minor Comments

1	L47 – "specific research questions" – Theoretical explorations can also derive from "specific" research questions. Do you mean questions that pertain to spatially explicit problems? (Simulating a particular reach of coastline?) Suggest rethinking this paraphrasing of Murray (2007).
	L47 changed to: ***"rather than pertaining to spatially explicit research questions"***

2	L323 – clarify sentence – (see "systems", plural?)
	L376 changed to: ***"profile of the coastal system changes"***

3	L335 – Confusing paragraph (and see punctuation of "waves") – I think the authors are trying to convey what was absent from CEM but is now present in CEM2D, but the paragraph doesn't read that way to me. Sounds like it's all still "to be calculated", as though these capacities don't yet exist in CEM2D. (But they do, correct?)
	The sediment transport equations in CEM2D do not currently take into consideration the water depth, or how far from the shore the waves break. The equations used are inherited from the original CEM and these have not been updated in this version of the model. Subsequent versions of the model will include revisions of the sediment transport equations so that these variables are taken into account, but this is a significant change that will require a substantial amount of work and so has been reserved for the next iteration of the model. **L386 has been changed to make this point clearer:** ***"The longshore sediment transport equations in CEM2D are inherited from the CEM and currently do not take into consideration the water depth, or how far from the shore the waves break. Since the water depth can now be calculated within this 2D model, future developments of CEM2D will focus on a revision of the sediment transport equation and include a more suitable calculation that can take advantage of the increased complexity and added functionalities in CEM2D."***

4	Fig. 2 – more labels? alongshore/crossshore, etc., to match Fig. 4?
	Figure 2 has been updated to include more labels and to show the shoreline search technique more clearly.

5	Fig. 9a, d – x axes? It's not clear to me what's plotted here.
	Figure 9 has been updated to make the axis labels clearer.

6	Fig. 10 – Labels for land versus sea? Strange visual inversion when sideways (Fig 11 clearer)
	Figure 10 has been updated to include 'land' and 'water' labels.

7	Fig. 12 – White band? I'm missing it, I think?
	Figure 12's caption has been updated to: ***"Cross-shore profiles taken for each of the twenty-five simulations, with water level shown as a dashed line and the initial cross-shore profile as a solid red line. Labelled are the (a) beach surface, (b) dynamic shoreline and upper nearshore and (c) the lower nearshore."***

Reviewer 1: Major Comments

8	I ended up confused about how the "variable water level" advance gets presented here. This manuscript seems like exactly the opportunity to showcase everything that the inclusion of a variable water level now allows – instead of a conservative assurance that there's been no loss of benefits from CEM.
	Both of these points highlight that we do not explore the variable water level function to a great depth in this paper. The aim of this paper was to outline the technical developments of CEM2D and the advantages of these (e.g. dynamic bathymetry and variable water level), whilst retaining the original model's ability to simulate fundamental cause-effect relationships which has received much credibility. **We have carried out significant novel research using the variable water level function to look at sea level rise impacts and as such, we felt it was better placed in the follow up results paper which is currently being finalised. We do however recognise that it could be beneficial to add some additional detail into this paper about the variable water level function, given that it is one of the major developments. In light of this, the following changes have been made:** **A significant additional section (5.5 Variable Water Level) has been added to the results section:** ***"5.5 Variable Water Level*** ***Changing the water level against the dynamic topography allows CEM2D to explore how a rising water level might affect how coastal systems behave. The results demonstrate that a rising sea level causes landward recession of the shoreline and uplift of the profile (Figure 15), as is commonly held (Dickson et al., 2007; Bird, 2011). The rate of recession is broadly within two orders of magnitude the rate of sea level rise, prescribed at 2 m / 100 years in the simulations, which is in agreement with Bruun Rule estimations (Bruun, 1962). Variations in the rate of recession and morphology of the cross-shore profile are, however, observed with***

different wave climate conditions that differ in the balance of cross-shore and longshore flows (Figure 15).

As in Figure 14, Figure 16 shows the change in volume of sediment across a transect (x = 30 km) every 30 simulated years, for four wave climate scenarios where (a-b) A = 0.5, U = 0.55, (c-d) A = 0.6, U = 0.6, (e-f) A = 0.7, U = 0.65 and (g-h) A = 0.8, U = 0.7. The figure shows a comparison of the results with a static water level (top) and with a rate of sea level rise of 2 m / 100 years (bottom). The spatial extend of morphological change is more diverse and widespread when the systems are subject to sea level rise. The principal active zone also tracks backwards as the water level rises and the shoreline recedes.

A rising sea level influences the evolution of shoreline features that evolve in the model, including cusps (a), sand waves (b), reconnecting spits (c) and flying spits (d) (Figure 17). As also shown in Figure 17, recession of the shoreline is observed in all four coastal systems as the water level rises regardless of the wave climate conditions (also shown in Figure 15). Where the wave climate is symmetrical, cuspate features form under a static water level but have a slight asymmetry under sea level rise conditions, where the direction bias in the model is exaggerated. The cusps extend further offshore where the bays between the headlands are eroded, increasing wave shadowing and hence, exaggerating the effects of the directional bias. A slight asymmetry in the wave climate forms sand waves along the shoreline (Figure 17b), but submergence of these features under a rising sea level leads to the formation of a lagoon in the low-lying centre of the landform. Where the wave climate is defined by A = 0.7, U =0.65 (Figure 17c), reconnecting spits form when the water level is static, but as the water level rises the pathways that reconnect the spit to the mainland are submerged. In Figure 17d, flying spits are shown to evolve with and without sea level rise, where the wave climate is highly symmetric. The difference between these two simulations is that under a rising water level, the flying spits cycle through submergence and reformation, as they are drowned by the rising water, but new features are able to form due to the high rate of longshore sediment transport. Remnants of the submerged spits remain in the nearshore and promote the development of spits in these areas due to the shallower water and also influence the unique plan-form morphology of the features."

Accordingly, the text has also been edited in Section 6 Discussion from L402:

"A key component of CEM2D is its variable water level. If we are to explore coastal evolution over the mesoscale, being able to model the effect of rising sea levels is essential. Whilst we have not exhausted the uses of this function here, we have demonstrated its development and how it is facilitated in the model. The power of this tool is vast and will be particularly useful for coastal managers who must plan for the dynamic evolution of these system over time periods that will be highly influenced by the effects of climate change. The results presented show that a rising sea level can significantly influence the evolution of coastal systems through recession and uplift of the cross-shore profile (Bruun, 1962), the types of shoreline features that form and the way in which these features evolve. Also found was the clear role of the wave climate conditions on the morphology of the shoreline and landform features behaviour, as the water level rises."

Furthermore, we have added the following text to Section 4.3, clarifying the scope of the paper:

"The primary purpose of this paper is to highlight the technical development of CEM2D and demonstrate its additional functionalities. The simulations shown focus on how the coastal

	systems evolve with an unchanging water level at 0 m elevation, but results are also given for how an increasing water level at a rate of 2 m / 100 years influences the evolution of four shoreline types: cuspate, sand wave, reconnecting spit and flying spit. This rate of rise is in line with the UK Climate Projections 2009 (UKCP09) (Jenkins et al., 2009) H++ scenario of 0.93-1.9 m sea level rise by 2100 (Jenkins et al., 2009; Lowe et al., 2009).”

9	I would encourage the authors to show, as explicitly as they can, the difference in results yielded by CEM vs CEM2D. I see Figs. 10 & 11 – I mean some kind of quantitative demonstration of the differences in output? Here's what the old model did; and here's the amazing thing this one does. I wanted a clearer demonstration of the latter.
	There are two primary differences between CEM and CEM2D. This first is in the representation of the coastal domain, with CEM2D having a dynamic topography and bathymetry that evolves through the exchange of sediment between cells. The second development is in the ability of CEM2D to impose a variable water level in the coastal system. We have added some additional results to explore these functions more explicitly, as detailed below. **A significant additional section has been added to show some quantitative results regarding the differences in spatial scale of the features: 5.3 Spatial Scale of Shoreline Features. Within this section, it is highlighted that the differences in spatial scale of features between CEM and CEM2D are likely to occur due to the different way in which the domain is representation and sediment is distributed; as stated above, this is one of the primary developments of CEM2D. The text below is taken from this additional subsection:** ***“5.3 Spatial Scale of Shoreline Features*** ***The spatial scale of shoreline features differs between results from CEM and CEM2D. Metrics from the end of each run, as shown in Figures 10 and 11, show larger features evolve in CEM2D in six of the simulations. The larger features evolve under wave climate conditions where A = 0.6, U = 0.55-0.65 (sand waves), where A = 0.7-0.8, U = 0.7 (flying spit) and where A = 0.9, U = 0.75 (flying spit) and smaller features evolve in the remaining nineteen simulations. However, each run terminates at a different timestep and a comparison of results at the earliest termination for each pair of simulations shows that in all but one of the runs (A = 0.6, U = 0.55), the features are smaller and less developed in CEM2D than the CEM (Figure 18).*** ***The evolution of landforms is more gradual in CEM2D, likely as a result of differences in the representation of the domain and in the distribution of sediment. Rather than sediment being distributed evenly across the nearshore to the depth of closure, as in CEM, CEM2D uses the sediment distribution method to route sediment along lines of steepest descent and spreads available material across the nearshore profile. This leads to both the formation of shoreline features but also to the formation of a shallow nearshore shelf (see Section 5.4).*** ***Highlighted above are differences in results between CEM and CEM2D and in particular, the complexity of results generated in CEM2D due to the addition of a dynamically evolving profile. In nature, the features discussed evolve at different rates and to different spatial scales depending and in order to use CEM2D to investigate such systems, parameters in the model***

	including the threshold and frequency of sediment distribution should be adjusted to suit the specific environment studied and the rates at which these features form." **A significant additional section has been added to show some quantitative results regarding the influence that a rising water level has on the coastal systems: 5.5 Variable Water Level. The principal results are as follows (see response number 8 for full text):** **L358** ***"The results demonstrate that a rising sea level causes landward recession of the shoreline and uplift of the profile (Figure 15), as is commonly held (Dickson et al., 2007; Bird, 2011). The rate of recession is broadly within two orders of magnitude the rate of sea level rise, prescribed at 2 m / 100 years in the simulations"*** **L361** ***"Variations in the rate of recession and morphology of the cross-shore profile are, however, observed with different wave climate conditions"*** **L368** ***"The spatial extend of morphological change is more diverse and widespread when the systems are subject to sea level rise. The principal active zone also tracks backwards as the water level rises and the shoreline recedes."*** **L371** ***"A rising sea level influences the evolution of shoreline features that evolve in the model, including cusps (a), sand waves (b), reconnecting spits (c) and flying spits (d) (Figure 17)."*** **The text has also been edited accordingly in Section 6 Discussion from L402, as detailed in response number 8.**

10	In CEM, is it possible to impose a linear erosion rate to simulate sea-level rise? And then, in CEM2D, could the authors show the equivalent experiment with the addition of an actual landscape gradient? … we need clearer and more specific supporting evidence than Fig. 14 provides.
	We're trying to move away from the idea of imposing a linear erosion rate to simulate sea level rise, but rather in CEM2D we can increase the water level and investigate how it affects the existing erosion rate – thereby just changing sea level – rather than having to adjust the erosion rate. **We acknowledge that we need more evidence to show the variable water level function and have added results from this research into subsection 5.5 Variable Water Level. The full text from this additional section is given in response number 8 and the key findings are given below (also given in response number 9):** **L358** ***"The results demonstrate that a rising sea level causes landward recession of the shoreline and uplift of the profile (Figure 15), as is commonly held (Dickson et al., 2007; Bird, 2011). The rate of recession is broadly within two orders of magnitude the rate of sea level rise, prescribed at 2 m / 100 years in the simulations"*** **L361** ***"Variations in the rate of recession and morphology of the cross-shore profile are, however, observed with different wave climate conditions"***

	L368 ***"The spatial extend of morphological change is more diverse and widespread when the systems are subject to sea level rise. The principal active zone also tracks backwards as the water level rises and the shoreline recedes."*** **L371** ***"A rising sea level influences the evolution of shoreline features that evolve in the model, including cusps (a), sand waves (b), reconnecting spits (c) and flying spits (d) (Figure 17)."*** **The text has also been edited accordingly in Section 6 Discussion from L402, as detailed in response number 8.**

Reviewer 2: Major Comments

11	The improvements that this numerical redistribution of sediments introduces in landscape evolution over the previous model are not clear.
	We are sorry if this is not clear. In CEM the horizontal filling and emptying of cells can allow too much sediment to be added or removed from cells which then translates into the simplistic landward or seaward movement of the shoreline. This method is rather opaque in existing descriptions of the original CEM model and only really clear when analyzing the code. In CEM2D and in this description we have been very clear about the need to refine this process, especially in light of the model moving towards being two dimensional and the storage of sediment in cells being vertical as opposed to horizontal. **Importantly, the CEM2D sediment distribution method enables the model to simulate the dynamic topography of the coastal system not just the shore edge. Sediment transport is first calculated for the one-line shoreline, like the CEM, but rather than the material assumed to be distributed evenly across the nearshore profile, the sediment distribution method allows the profile to dynamically evolve. The method is based broadly on the sand pile theory and steepest descent method, which are used in other numerical models.** **To make this clearer in the manuscript, the following text has been added to L140 in Section 3:** ***"The implementation of this method in CEM2D allows the nearshore profile to evolve dynamically, rather than assuming an even distribution across the nearshore profile and forming shore-parallel contours, as is the case in CEM and other one-line models."*** **The differences observed between the CEM2D and CEM due to the implementation of this method are highlighted in Section 5.3 Spatial Scale of Shoreline Features, which has been added to the manuscript. An extract from L302 is shown below (see full text in response number 9):** **"The evolution of landforms is more gradual in CEM2D, likely as a result of differences in the representation of the domain and in the distribution of sediment. Rather than sediment being distributed evenly across the nearshore to the depth of closure, as in CEM, CEM2D uses the sediment distribution method to route sediment along lines of steepest descent and spreads available material across the nearshore profile. This leads to both the formation of shoreline features but also to the formation of a shallow nearshore shelf (see Section 5.4)."**

12	The response to changes in sea level is even not explored through the paper.
	This feedback was also given by reviewer 1 and changes have been made accordingly, through the addition of Section 5.5 Variable Water Level and additional text in Section 6 Discussion, as detailed in response number 8 above.

13	I have also got the impression comparing Figure 10 and Figure 11 that this redistribution changes the spatial scale of the features developed due to probably a reduction on the effective alongshore flux due to this sediment redistribution scheme.
	The spatial scale of features is different between CEM and CEM2D, due to the way in which sediment is distributed in both models. This has now been addressed in the manuscript, with the addition of Section 5.3 Spatial Scale of Shoreline Features (see response number 9 for full text).

14	The CEM2D model produces very different results for example for A=0.5 with any U and what seems to be a numerical instability for U=0.75, A=0.6. The authors should have examined these big differences in model behavior.
	Having spent considerable time testing the model we are confident this is not numerical instability. Where A = 0.5, directional bias is observed in the model results due to directional bias found in some of the model routines. The effect is more apparent in CEM2D due to the more complex representation of the domain and sediment distribution in two directions but can also be seen in CEM. This has been highlighted in the manuscript, at L239. **For U=0.75 and A=0.6 the instabilities the reviewer may be referring to are ponds/pooling in the CEM2D outputs. This is a reflection and good example of how the 2D representation of a coast in CEM2D allows more complex topography (that evolves over time) to be simulated, rather than the 'single line' of the 1D CEM model that just identifies a shoreline. In our simulations this is not reflective of instability but the cumulative development of the coastline over time.**

15	In general, it is important to highlight what new features are better represented in the new version and what are the implications for coastline shape simulation, and a simple comparison with the old model results is not enough.
	In our revised manuscript, we identify in several places the new features of CEM2D and what they allow the model to do as progress from CEM. These have been listed below: **a. L113 *"CEM2D contains a significant number of modifications to enable it to model the evolution of coastal features including their topographic profiles and to study the influence of a variable water level."*** **b. L115: *"However, as opposed to each cell containing a fractional horizontal fill of sediment, each cell contains values for depth of sediment to the continental shelf, elevation of sediment above the water level or depth of water (Fig. 5(b)). Having these additional values enables CEM2D to represent two-dimensional coastlines with greater topographic detail compared to the original CEM, as illustrated in Fig. 5."***

c. L116: ***"Importantly, the two-dimensional profile allows the morphology of the beach and shoreface to evolve according to the transport of sediment, across the entire model domain. It explicitly models the slope of the continental shelf and shoreface and the morphological profile of the beach and sea floor."***

d. L126 ***"Sediment transport is calculated using the same equation as CEM (Eq. 1) but because CEM2D represents sediment transport in two-dimensions, material eroded from a cell is distributed to the surrounding cells based on the slope between cells and an angle of repose (Fig. 6)."***
…L146 ***"The implementation of this method in CEM2D allows the nearshore profile to evolve dynamically, rather than assuming an even distribution across the nearshore profile and forming shore-parallel contours, as is the case in CEM and other one-line models. The ability of the simulated coast to evolve dynamically in this way provides a more realistic representation of the morphodynamic behaviour of these systems. How sediment is distributed can affect the longer-term evolution of the system and record a morphological memory of landforms which can interact with other features as they form and mature (Thomas et al., 2016)."***

e. L148 ***"CEM2D's two-dimensional structure allows the water level to be varied, but by default the water level is at 0 m elevation. There are two dynamic water level modes within the model which can be run independently or in combination that can be used to represent tidal fluctuations and long-term sea level change."***

f. L150 ***"The increased complexity of the model domain and of sediment transport processes in CEM2D compared to CEM, enable it to model complex two-dimensional coastal profiles and evolve their morphology. The features allow more complex morphodynamic processes to be explored and to investigate not only the evolution of the one-line shore, but the surrounding beach and shoreface."***

g. L153 ***"The sediment storage and handling technique allows complex landforms and features to develop and leave a morphological memory in the bathymetry as they evolve, which is not possible in the equilibrium profile of the CEM."***

h. L155 "Sea level change is an important addition to this model from the original CEM, that could be used to explore the response of coastal systems to fluctuating water levels and the influence of fundamental climate change effects such as sea level rise."

i. L252 ***"CEM2D shows a greater sensitivity to inputs variables compared to the CEM, apparent in the development of these four feature types. In CEM2D a greater distinction is made between reconnecting and flying spits due to the increased complexity of CEM2D's sediment handling and distribution methods."***

j. L278 ***"CEM2D again shows a greater sensitivity to the wave climate conditions, with more distinction made between reconnecting and flying spits due to the refinement of sediment handling techniques in the model."***

k. L282 ***"…reconnecting Long Point Spit in Lake Erie, Canada, where the wave climate is characterised by high asymmetry (A = 0.8-0.9) and high angle wave dominance (U = 0.6-0.7) (Ashton and Murray, 2006b). Under all four potential wave climate conditions, reconnecting***

spit features form in CEM (Fig. 10), whereas in CEM2D (Fig. 11) either sand waves or reconnecting spits form depending on the combination of A and U values within the given ranges. Ashton and Murray (2007) suggest that the wave climate is favoured towards an asymmetry (A) of 0.8 along the entire spit and under these conditions, reconnecting spits form in CEM2D (Fig. 11), as per the natural system."

l. L306 ***"The evolution of landforms is more gradual in CEM2D, likely as a result of differences in the representation of the domain and in the distribution of sediment. Rather than sediment being distributed evenly across the nearshore to the depth of closure, as in CEM, CEM2D uses the sediment distribution method to route sediment along lines of steepest descent and spreads available material across the nearshore profile"***

m. L312 ***"Highlighted here are differences in results between CEM and CEM2D and the added complexity in the evolution of the coastal systems with the addition of a dynamically evolution profile in the latter model."***

n. L318 ***"The novel development of CEM2D is to simulate variations in the nearshore topography. Of particular interest are the dynamics of the upper nearshore which evolves under the influence of sediment exchange with the shoreline (Fig. 12(b)). The lower nearshore profile tends to be influenced to a lesser degree (Fig. 12(c)) and consequently, is able to store remnants of morphological features as they evolve."***

o. L346 ***"Changing the water level against the dynamic topography allows CEM2D to explore how a rising water level might affect how coastal systems behave."***

p. L360 ***"A rising sea level influences the evolution of shoreline features that evolve in the model, including cusps (a), sand waves (b), reconnecting spits (c) and flying spits (d) (Fig. 17)."***

q. L377 ***"Adding two-dimensional functionality allows the model to generally reproduce the results of the original one-line CEM (Ashton and Murray, 2006a) by simulating fundamental shoreline shapes according to the wave climate but advances the models ability to analyse how the two-dimensional profile of the systems evolve and the influence of a variable water level."***

r. L384 ***"Importantly, restructuring and increasing the dimensionality of sediment transport in the model allows us to explore how the profile of the coastal system changes with the shape of the shoreline. In many one-line models, such as the CEM, the cross-shore profile of the coastline is kept constant and it is assumed that its core geometric properties are retained over meso-spatiotemporal scales. Whilst this is a well-used concept, there are advantages to modelling the topography and bathymetry of the coastline and it is necessary if we are to model the effect of a variable water level. For example, we can see that the nearshore evolves at a greater rate compared to the lower shoreface profile, supporting the theories of Stive and de Vriend (1995). The distribution of sediment across the profile is more transient towards the shore where the greatest volume of transport occurs. However, the geometry of the entire shoreface and the geometric demand for sediment distribution means that material is moved to the lower shoreface over time, but at a relatively slower rate (Stive and de Vriend, 1995). Further, the topographic profile of coastal landforms is indicative of their formation and***

	evolution, highlighting patterns in sedimentation and drift processes. Using CEM2D to model how this profile changes over time can inform the stability and future behaviour of features." **s. L402** ***"A key component of CEM2D is its variable water level. If we are to explore coastal evolution over the mesoscale, being able to model the effect of rising sea levels is essential."*** **t. L415** ***"Using the added functionalities, we have also shown how CEM2D can be used to explore the two-dimensional behaviour and morphodynamic evolution of coastlines and depositional features, over meso-spatiotemporal scales. From the results shown here, it is apparent that the model will enable us to conduct interesting and insightful investigations to answer research questions including how coastal systems behave under changing environmental conditions and how sea level change might influence their morphodynamic behaviour"***

16	Antolinez et al. (2018) use CEM for hindcasting 150 of shoreline evolution in the Carolinas capes, but they don't account for changes in sea level, this new CEM2D model brings a great opportunity to account for this process adequately and to show what CEM is missing.
	Yes, this would be a great opportunity. Though as in answer 8 to reviewer 1, our purpose with this paper was to outline the technical developments of CEM2D. A paper detailing results from simulations investigating the influence of a variable water level on coastal evolution is currently in preparation, but we do agree that some results that showcase the variable water level function would benefit the manuscript. **An additional section (5.5 Variable Water Level) has been added, detailing some results with a variable water level. The text has also been edited accordingly in section 6 Discussion from L402, as detailed in response number 8.**

17	The authors claim this new model is a 2D model, however the model is still a single process model, alongshore sediment transport, with numerical diffusion in 2D using a stability slope condition. The model would not work in waves perpendicular to the coast. In my opinion, it is not consistent to claim a 2D model that is only solving alongshore sediment transport with an integrated semi-empirical formula, why the authors don't solve sediment transport at cell level? How is this integrated transport redistributed in the cross-shore? Or is it all taken from the adjacent cell to the shoreline position? If the last, I have the impression that the model would create spurious shoreline change behavior as it has the possibility to remove a lot of sand from the adjacent cell to the shoreline in alongshore direction and later on the need to redistribute sediment in the cross-shore direction due to the slope criteria, when in nature sediment would have been taken gradually from several cells in cross-shore direction; your slope condition is changing the cross-shore profile shape in the upper-shoreface in time, could you validate this?
	As authors, we discussed the use of the term 2D and concluded that it was suitable for this model since it distributes sediment longshore and cross-shore and also allows the elevation of cells to change according to the volume of sediment they contain. We can change this to quasi-2D or part 2D if the editor thinks this is appropriate.

For the second point, as described in Section 3 of the paper, sediment transport is calculated for each shoreline cells and is moved alongshore accordingly, as in CEM. At a defined frequency, calculated according to when a sufficient amount of sediment has built up in these shoreline cells, the sediment will get redistributed. The frequency and threshold for the sediment distribution method is calculated so that enough sediment is moved to be within the threshold of a given slope angle, but not so much that large volumes of sediment are moved and make the system unstable. As a result, sediment is gradually redistributed from as many cells as meet the threshold criteria on each timestep that the method is employed.

We appreciate this may not be completely clear in the manuscript so have modified Section 3 from L123, to make this clearer:

"In CEM2D the elevation of each cell relative to the water level is used to classify cells as either wet or dry on each model iteration. The boundary between wet and dry is used to locate the shoreline, using the same shoreline search technique as CEM (Fig. 2). As per CEM, Linear Wave Theory is used to transform the offshore wave climate and the CERC formula to calculate sediment flux between shoreline cells (Equation 1). Longshore sediment transport is calculated using the same equation as CEM (Eq. 1) but is then redistributed from the shoreline cells across the model domain using a sediment distribution method which is induced when the slope angle between cells reaches a critical threshold (Fig. 6). This method is based on the relationship between the properties of coastal material (e.g. sand, gravel) and slope angle as shown by McLean and Kirk (1969). We can assume that in general, coastal profiles will maintain an average slope angle consistent with the grain size of beach material although there are a range of factors that can cause steepening or shallowing (McLean and Kirk, 1969).

To carry out the sediment redistribution procedure, at user-defined time-step intervals an algorithm sweeps the entire model domain and identifies where a given threshold angle has been reached between a cell and its neighbour. The material is redistributed, taking account of the elevation of the orthogonal surrounding cells (Fig. 6). The sediment metrics are then updated accordingly, including the total volume of material and the cell's elevation above a reference point. The rules defining the sediment redistribution are important parameters that can significantly alter the model outcomes and have therefore been thoroughly tested. The two most critical components are (1) the threshold angle between cells that instigates the redistribution method and (2) the frequency that the domain is analysed for these thresholds. Whilst the longshore sediment transport method is carried out along the shoreline on every timestep, activating the sediment distribution method at this frequency causes instability in the model and it is therefore activated less frequently. The threshold and frequency parameter values should be calibrated to allow sediment to be distributed without inducing sediment pilling or deep depressions forming in the domain. Similar techniques are widely implemented in landscape evolution models, such as SIBERIA (Willgoose et al., 1991) and GOLEM (Tucker and Slingerland, 1994) (Coulthard, 2001)."

We agree that validation of the cross-shore distribution of sediment across the nearshore profile would be advantageous. However, for this we would need field data and field examples of which we do not have.

18	I also miss a lot of discussion and review of recent existing models accounting for alongshore and cross-shore responses and accounting for changes in sea level, for example, Larson et al. (2016), Vitousek et al. (2017), Robinet et al. (2018), and Antolinez et al. (2019).

Thank you for your suggestions and for the list of references at the end of your response. We have edited the text in Section 1 starting at L51 that details some of the existing models and added these authors to the review. We recognize that this list is not exhaustive but contains some of the key models and texts relevant to the paper.

L51: ***"In the field of coastal modelling, there is a gap for a two-dimensional coastal model that can simulate features such as spits, bars and beach migration along with a dynamic nearshore bathymetry and a variable water level but is parsimonious enough to enable short run times allowing us to answer research questions about coastal evolution at meso-spatiotemporal scales. Existing models with such scope, such as CEM, COVE and GENESIS (Hanson and Kraus, 1989; Ashton et al., 2001; Hurst et al., 2014), are limited to transporting sediment in one-dimension and represent the coastline simply as a line with little accommodation for the nearshore shape or bathymetry. This means the models are parsimonious and fast, but are limited in their application, for example, to investigate the effects of sea level rise on costal geomorphology. Hybrid shoreline change models such as COCOONED (Antolínez et al., 2019) and CoSMoS-COAST (Vitousek et al., 2017) calculate sediment transport in cross-shore and long-shore directions and can varying the water level in model but are transect based and do not include a dynamically evolving bathymetry. The LX-Shore model (Robinet et al., 2018) is cellular-based with longshore and cross-shore sediment transport calculations but has an equilibrium beach profile as in models such as CEM and COVE. In contrast to these longer-term models, finer scale models such as Delft3D (Lesser et al., 2004) can simulate coastal hydrodynamics and sediment transport processes in two- or three-dimensions, but their complexity and long model run times means investigating sea level rise responses over meso-timescales is presently impracticable."***

19	In the abstract the authors explain the model is suitable for evolving morphological features in time scales from 10 to 100 years, but any analysis is performed in these timescales.

The models were run over a simulated period of 3,000 years, to allow time for the model to spin-up, to reduce the potential influence of initial conditions, to allow sufficient time for the coastal systems to evolve to a state of relative stability and to generate a sufficient amount of data to analyse the behavior of the systems (see L172). Whilst this is the case, the results are applicable to timescales of 10 to 100 years and we agree that this should be better expressed in the paper. The following text has been edited at L176:

> ***"The models were run over a simulated period of 3,000 years, to allow time for the model to spin-up, to reduce the potential influence of initial conditions, to allow sufficient time for the coastal systems to evolve and to generate sufficient data from which quantitative and qualitative analysis could be completed. Whilst this is the case, the results are applicable to timescales of 10 to 100 years."***

20	I support the idea of changing the bathymetry, but what is the added value if wave transformations are still assuming parallel contours to the shoreline as in CEM? other models such as Robinet et al., 2018 already account for a scheme propagating waves in complex bathymetry and studies such as the one presented in Limber et al. (2017) proofs its importance.

	This is a great point. With CEM2D we have made the topography 2D but retained a 1D approach to waves. This really comes down to the scope and parsimony of the model. Adding in wave transformations according to the changing bathymetry/topography would be a great addition and something we have thought about. However, the complexity and associated numerical overhead associated with this then restricts the spatial and temporal scope over which the model can be applied. Simply, we have chosen or line of simplification to be with a simple wave approach. CEM2D is not, nor intended to be a complete solution but by including a dynamically evolving topography and bathymetry, the model can be used to analyse how the profile of the coastal system evolves over time, the morphology of shoreline features and the existence of remnant features that are stored in the bathymetry. It was also necessary in order to account for a variable water level. **The advantage of having a dynamically evolving bathymetry also means that we can continue to increase the complexity of the model through the additional of processes that use metrics of the bathymetry, such as wave transformations.**

21	I can read several times through the text the authors acknowledge certain model limitations and they propose to incorporate improvements in coming versions, why do not incorporate them now? (for example, lines 238-240)
	We acknowledge that there are several limitations of the model highlighted in the manuscript. These have been included, as it is important to understand how the model works and what the limitations are. Model development is an ongoing process and we discuss these limitations, as areas we feel are important to focus on for future developments, that will require a significant amount of research to address.

22	Certain Figures are not properly presented, for example Figure 10 and Figure 11 cut the model domain and shoreline shapes are not complete, Figure 9 has different color markers in the legend than in the subplots.
	Figure 9 has been updated with the correct markers. **Figure 10 and 11 have been reduced along the x-axis so that the entire matrix of results can be viewed on a single page. They have been reduced by cropping the periodic boundaries from the model domain, which are repeats of the central portion of the domain (shown). Removing these Sections, therefore, do not impeded the results.**