Reviewer response

First of all, the authors would like to thank the reviewers for providing detailed and thought provoking responses. In addition to making changes to the paper, we have introduced some "supplementary material" in order to answer some of the reviewer questions. Supplementary material is identified by Fig. S1, S2 etc.

General comments

1. ***The importance for offshore wind energy should be described in more details with respect to: Climatological aspects (e.g. how many meteorological situations per year with sea breezes).***

   A detailed climatology of each type of sea breeze has not previously been undertaken in either the English Channel or southern North Sea as far as we are aware. However , Simpson *et al.* (1977) reported 76 *pure* sea breezes between 1962-1973 on the south coast of England, with the month of June seeing the highest frequency due to an associated maximum in land-sea thermal contrast. Our study is designed as a first step towards developing a model-based climatology given the very limited offshore observation record. To address this point, we have replaced the sentence beginning on line 23, page 6, beginning "Since sea breezes can form under moderate gradient wind speeds..." with this new paragraph (page 7, line 2):

   " Furthermore, the climatology of sea breezes forming off the east coast of England is not well known. This is especially the case for *corkscrew* and *backdoor* sea breeze types. Simpson et al. (1977) observed 76 *pure* sea breeze events on the south coast of England during the period 1962-1973 and, to date, this remains the most extensive climatology of sea breeze events in the UK. The frequency of sea breeze occurrence each year is also likely to fluctuate due to the high degree of variability in the UK wind climate (Earl *et al.*, 2012)"

2. ***Observations. There are many offshore wind farms in operation for years and the main findings of this paper should be demonstrated by selected wind farm observations.***

   Whilst we acknowledge that observations can greatly aid in the verification of a numerical simulation of a real historic event, we note that the simplifications involved in the idealized experiments used here, especially regarding coastline characteristics, mean results cannot easily be compared to observations. The idea is to test sea breeze sensitivity in very simplified cases, with our own gradient winds applied to thermodynamic profiles, in order to demonstrate the scales of sea breeze systems. We are using the results from these idealized experiments, with simplistic coastlines, as guidance for model setup in constructing a model-based sea breeze climatology for the southern North Sea, with realistic coastlines. We will present and verify the latter results against offshore observations in a subsequent paper.

Major comments

1. ***Please describe the model used in more details: Exact locations of the lower grid levels***

   The WRF model uses a terrain following hydrostatic vertical coordinate and so the precise locations of the lower levels vary. In the lower layers, η = 0.999, 0.997, 0.994, 0.987, 0.972 and 0.959, equivalent to 4, 10, 16, 40, 87 and 170m heights on average, respectively. We have added this additional information to page 8 on line 21:

   “The first five η levels in the model were 0.999, 0.997, 0.994, 0.987, 0.972 and 0.959, equivalent to representing 4, 10, 16, 40, 87 and 170m heights, on average, respectively. Model scalar variables are located on the η levels and vector quantities reside on half-levels”

2. ***What is the effect of the restriction to 24h simulation time e.g. compared to 48h...***

   Following this interesting question, several of our single coast experiments were extended to 48h, producing the following effects. Firstly, since the definition of the type of sea breeze initiated each day is strongly dependent on the orientation of the preceding gradient wind relative to the coastline, the sea breeze on the second day will likely be of a different type to that of the first (Fig. S2). Also, in a number of simulations, the profile over the land became thermodynamically unstable and produced convection ahead of the sea breeze. Sensitivity to thermodynamic profile is discussed in a new section (3.1.4) added to the article. To page 8, line 10 we have added:

   “The simulations were restricted to 24 h as the definition of sea breeze type is strongly dependant on the preceding wind direction. When the simulations were extended to 48 h, the type of sea breeze forming on the second day is a function of both the previous day's sea breeze type and the initial gradient wind forcing, as shown in the supplementary material (Fig. S2). Consequently, the sea breeze simulated on the second day is not necessarily of the same type as the initial gradient wind forcing would dictate.”

3. ***or how sensitive are the main findings to initial conditions?***

   We agree with both reviewers that the article lacks a sensitivity test for the initial vertical profile. We have therefore added an additional sensitivity test within our idealized experiments to deal with this issue. Two additional profiles are tested from the

Herstmonceux radiosonde station during different development stages of the same anticyclone on the 2nd and 3rd June 2006 (Fig. S1). The profiles added as Fig. 5 in the paper demonstrate, respectively, nocturnal cloud cover and a strong temperature inversion and are therefore very different to the original profile from 4th June 2006 shown in Fig. 4. The adjustments made are as follows:

Page 2, lines 18-19: "Realistic variations in sea surface skin temperature and initializing vertical thermodynamic profile for the southern North Sea do not significantly alter the resulting circulation, though the strengths of the simulated sea breezes are modulated if the effective land-sea thermal contrast is altered"

Page 9, line 7: "Additional simulations were also undertaken to test the sensitivity to two alternative initializing thermodynamic profiles (Fig. 5)"

A New section 3.1.4 entitled "Sensitivity to thermodynamic profile", has been added on page 14: "In order to test the extent to which the results of the simulations were dependant on the initial thermodynamic profile, two further profiles were used for model initialization. Both profiles were from the same period of early June 2006 but contrasted in terms of both stability and moisture availability (Fig. 5). Profile 2 is from 0000 UTC at Herstmonceux on the 2nd June 2006 when the dominance of the anticyclone first established. The profile is saturated, or close to saturation, to 750hPa with a weak temperature inversion and relatively dry air above. This is indicative of low level cloud during nocturnal cooling of the PBL. A dry layer exists between 750-700hPa, with another cloud layer to 500hPa. The second cloud layer is indicative of the remnants of a decaying frontal system to the north. This feature quickly decays and moves to the east and a sea breeze forms. Further details on the synoptic conditions are provided in the supplementary material (Fig. S1). Profile 3 was observed at Herstmonceux at 0000 UTC on the 3rd June 2006 and contains a much sharper temperature inversion at 860hPa and dryer air aloft.

The results of these baseline simulations, with no gradient wind imposed, show that only profile 2 produced any significant deviations offshore (Fig. 18) relative to those associated with the original profile shown in Fig. 4. Profile 2 formed a sea breeze with onshore winds of approximately 5ms^{-1} and was the only single coast baseline experiment to extend to the edge of the 300km offshore domain (Fig. S12a) . In contrast, profile 3 forms a sea breeze which is weaker and only extends 220km offshore, compared to profile 1 which extended 260km offshore (Fig. S12b). The presence of the initial cloud cover in profile 2 kept temperatures over land higher overnight, thereby intensified the land-sea air temperature contrast which subsequently developed during the daytime and consequently intensifying the sea breeze. Other differences occurred over land and concerned the varying strength of the sea breeze front and the degree of convection ahead of the sea breeze. These differences are associated with any thermodynamic instabilities in the profiles."

"In contrast to the baseline simulations, the pure, corkscrew and backdoor sea breeze simulations offshore all simulate a wide range of differences in wind velocities when compared to the simulations initialized with profile 1 (Figs. S13-S14). The strong inversion in profile 3 intensifies the region of divergence at the coast at approximately 0615 UTC, when the land-sea thermal air temperature difference was zero. Overall offshore, the differing profiles produce only minor differences once the sea breeze had formed, unless the initial thermodynamic profile is close to saturation at night where the land-sea thermal contrast is intensified and the sea breeze is strengthened."

Remove paragraph beginning on page 13, line 28 shown below

"Both the MYJ and MYNN PBL schemes produce different baseline states (Fig. 17b and c). At 18:00UTC both cases form pre-frontal waves of wavelength approximately 30 and 10km for the MYJ (Fig. 17b) and MYNN (Fig. 17c) cases, respectively. Prefrontal waves have both been observed and modelled elsewhere, with wavelengths of approximately 10km (Miller et al.,2003). These form in the late evening when the sea breeze interacts with a stabilizing nocturnal boundary layer inland. However, typically these dissipate quickly whereas the waves produced here traverse the model land domain. Furthermore, the MYJ scheme produces a much deeper PBL than the YSU baseline simulation, reaching 2300m, and with 2m specific humidity of 21 gkg^{-1} at 13:00UTC, 150km onshore (not shown). The MYNN scheme formed a shallower PBL than the YSU, reaching a maximum depth of 1300m, however, it also simulated the highest 2m specific humidities of 23 gkg^{-1}."

Page 19, line 1 modified to: " Sensitivity tests have also been performed regarding PBL physics schemes, initial thermodynamic profile, coriolis and realistic variations in sea surface skin temperature."

4. ***Please explain the very far reaching sea breezes in nearly all simulations, eg. 250km offshore for the pure sea breeze case. To the reviewer this seems too extensive or: Do the sea breeze at UK coasts really effect the meteorology in northern France or the Netherlands?***

Sea breezes have, in the past for southern Britain, been reported by Simpson *et al.* (1977) to reach as far as 100km inland. Of the 76 cases observed by Simpson *et al.* (1977) during the 1962-1973 observation period, 6 sea breezes travelled over 100km to reach Oxford. Further afield, the sea breeze has penetrated as far inland as 200km in Australia, 150km in the southern United States and 150km in south eastern Spain (see Miller (2003) for summary of onshore extents). The extent of the land mass in the model domain and a maximum 2m land temperature of ~300K for the single coast simulations is comparable to these international studies. Simpson (1994) summarizes that the sea breeze offshore extent is similar to that of the onshore, however, Finkele (1998) reports that, with very few measurements existing for the offshore domain and with variations in definition for the sea breeze offshore extent, the offshore extent can be up to 2 or 3 times greater than the onshore. Therefore we believe the distances simulated here are plausible given the set up of the single coast model. The presence of the second coastline restricts the offshore extent to approximately 30km (Fig. S17). We are now undertaking further research with real world coastline configurations to test the implications of these simulations.

5. ***Please include results for surface temperatures in order to get an impression of the forcing for the development of the sea breezes.***

   Sensitivity to sea surface skin temperatures of 280-290K was tested, this being the range of temperatures experienced in the southern North Sea during the sea breeze season. This produced, for the single coast baseline simulations, maximum land-sea temperature differences in the range of 18.9-12.5K respectively. This contrast is reduced by increasing offshore wind speed, for example, to 12.7K and 6.4K at 280K and 290K sea surface skin temperatures respectively for a 4ms^{-1} offshore gradient wind speed. We have added this new paragraph to the last line of page 10:

   "The maximum 2m land temperature is approximately 303K, giving a maximum land-sea temperature difference 270km inland of 16K (Fig. S4). The diurnal cycle, without the influence of the sea breeze, is affected by the development of cloud at 850hPa which causes the local minimum at 1300 UTC. This is specific to the initial sounding. Regardless of the effects of the initializing vertical thermodynamic profile, the amplitude of the diurnal cycle 270km inland from sunrise at 0400 UTC to sunset at 2000 UTC is 23K."

6. ***To the reviewer it is of little use , when the authors describe phenomena without showing the results. "(not shown)" is used – to the feeling of the reviewer – too many times in the paper.***

We agree that much of the information from the simulations is in need of a supporting figure, however, we are also conscious of keeping the paper to a manageable length. We have now added all extra figures not shown in the main paper as supplementary material. The supplementary material also includes information for onshore results which are interesting but beyond the focus of the paper (eg. Figs. S7, S11, S16, S22).

7. ***Pages 4-5. While it is clear that there is a general lack of research studying the marine component of sea breezes, a detailed review of studies and findings focussed on this topic is not undertaken – authors just summarized modelling results from Arritt (1989), Finkele (1998) and Savijarvi and Alestalo (1988). I strongly recommend authors to conduct a more detailed review about theoretical and observational studies focussed on the marine component of sea breezes. For instance, a table summarizing results encountered in the literature on the main characteristics (onset, horizontal extension seaward, etc.) of sea breezes offshore should be included. Here is an example of a manuscript dealing with this topic and published recently: http://onlinelibrary.wiley.com/doi/10.1002/joc.2362/abstract***

We agree that tabulating the offshore results of previous studies would be a very useful way of summarizing the research so far, providing there are sufficient studies to do so. Of the three numerical studies mentioned in the original paper, Savijarvi and Alestalo (1988) do not focus on the offshore environment, leaving only Finkele (1998) and Arritt (1989). Additionally, there are also relevant offshore studies by Gahmberg (2010) and Crosman and Horel (2012). As for observational studies, there are data in Fock and Schlünzen (2012) and scattered reports in Simpson (1994). We feel that in this case, adding additional information within the text and for each of the existing studies is unfortunately the best way forward since there aren't enough consistent metrics between studies to be able to produce a meaningful table.

Page 6, line 5, new paragraph: "More recently, Crosman and Horel (2012) performed idealized large eddy simulations of both sea and lake breezes. Sensitivity tests were performed on lakes of varying size, up to 100km. However the focus of the study was once again in the offshore environment. The effect of varying the width of the water source produced sea/lake breezes which did not conform to sea breeze scaling parameters, suggesting that lake breezes should be treated differently. For a 100km lake, however, the lake breeze characteristics matched those of a sea breeze in terms of sensitivity to heat flux and vertical stability.

The behaviour of corkscrew and backdoor sea breezes is also largely under-studied. References to the types, as described by Miller et al. (2003), are usually implicit. For example, Gahmberg et al. (2010) studied the effects of incrementally varying wind direction and found that the sea breeze is stronger for geostrophic flows 45-90° left of perpendicular from the coastline (approaching from the sea), indicative a corkscrew sea breeze."

8. ***Page. 4. "Originally from nautical origins, the types of sea breeze are know in the Northern Hemisphere as:". Please give here a reference where it was originally described these types of sea breezes.***
   Page 4 line 9 modified to read: " Defined originally from nautical origins, as described by Miller et al. (2003), the types of sea breeze are known in the Northern Hemisphere as:
   Pure - Sea breeze circulation with largest gradient wind component perpendicular to the coast and in the offshore direction (Fig. 1)....."

9. ***Page 6. In the Introduction section it is stated that "...it is entirely plausible that the power produced by these wind farms will be modulated by the sea breeze. It is therefore vital to be able to quantify this potential impact on power output". I agree with the authors that sea breezes offshore can strongly impact on wind power energy around the coast of Britain. However, I am not sure that local / mesoscale flows such as sea breezes are the main circulation influencing offshore wind power in the UK. In addition, authors quoted Simpson (1994) for referring that the most common period for observing sea breezes in UK is during June. I strongly recommend to give some statistics about the characteristics/climatology of sea breezes (occurrence, wind speed, etc.) observed in the southeastern fringe of the British Isles. If sea breezes are not the main wind circulation during the whole year, please rewritte the above statement.***
   Sea breezes are not the most common wind circulation in the UK. They can theoretically form at any time of year, however, they are most common during the Months of May to September when there can be a consistently high land-sea thermal contrast. Even so, the high degree of variability of the UK wind climate means that even during the months of May to September, the number of sea breezes can vary significantly from year to year (Earl *et al.* 2012; Simpson 2004). Please also see our response to point 1 of General comments on sea breeze frequencies.

10. ***Pages 6-7. The idealized WRF model sensitivity experiments presented in this numerical study have been initialized using vertical observations from sounding data recorded at the Herstmonceux radiosonde station (south east England) on the 3rd June 2006. Previous numerical studies to date used idealized vertical conditions, and therefore applying***

sounding observations is a strong point of the current manuscript as noted by Crosman and Horel (2010). However, a single sounding for an anticyclonic day dominated by sea breezes over coastal areas in UK is used, which is the major weakness of this study. The direction and strength of prevailing low-level boundary layer winds (large-scale synoptic flows) has been shown to be the most influential factor on sea breeze evolution (Estoque 1962). Since one of the objectives of this manuscript is to test the influence of wind speed and direction of the gradient wind, analysing three different types of this local wind (pure – large scale flows perpendicular to the coast; corkscrew and backdoor – gradient winds parallel to the coast), it is strongly recommended to chose three vertical profiles representative of each sea breeze type. For the paper being accepted, authors should rerun experiments selecting observed sounding. data for pure (perpendicular gradient winds), corkscrew and backdoor cases (parallel gradient winds) over the study area. Please see our response to point 3 in Major comments.

11. ***Page 7. The experiments were initialized for 24 hours, instead of 48 hours. Please discuss in further detail the possible impact of these short simulation time on the findings presented here. It is recommended to rerun the idealized WRF model for 48 hours.*** Please Please see our response to point 2 in Major comments.

12. ***Pages 9-17. In the result section is presented many interesting findings, but please try to summarize all these results in a table in order to help readers to compare these new results with previous studies. I strongly recommend to tabulate all the characteristics of sea breezes (timing, extent, duration and strength, etc.) found for both the single and dual-coast experiments and for the different sea breeze / study cases: baseline, pure, corkscrew and backdoor.***

    We agree that tabulating results will provide a better synthesis and so we have added four additional tables to the article:

Parameter	Pure		Corkscrew		Backdoor	
Gradient wind speed (ms^{-1})	2	6	2	6	2	6
Onset time (UTC)	1300	1415	1130	1100	1200	1100
Thickness of onshore flow (m)	700	450	750	650	600	600
Maximum onshore speed (ms^{-1})	3.75	1.13	4.47	3.76	4.25	3.88
Offshore advancement (ms^{-1})	5.55	-	6.48	8.33	4.63	3.47
Onshore extent (km)	130	20	110	160	110	90
Offshore extent (km)	270	10	300	300	170	100

Table 3: *Summary characteristics of different sea breeze type characteristics using gradient wind speed of 2ms^{-1}and 6ms^{-1} orientated offshore (pure), along shore with land to the left (corkscrew) and along shore with land to the right (backdoor). All simulations are based on the YSU PBL scheme and a SST of 287K.*

Parameter	Pure								
PBL scheme	YSU			MYJ			MYNN		
Gradient wind speed	3	9	15	3	9	15	3	9	15
Detachment wspd (ms^{-1})	9			8			5		
Max. offshore extent (km)	18			15			0		
Calm zone length (km)	66	48	0	48	0	0	66	0	0
Flow retardation (%)	75	75	79	60	66	-	75	75	65
Max. onshore wspd (ms^{-1})	3.14	0.93	-	2.95	0.26	-	1.73	-	-

Table 4: *Summary of pure sea breeze dual-coast characteristics for varying offshore gradient wind speeds and PBL schemes. The detachment wind speed is the minimum offshore gradient wind speed required to prevent a sea breeze from reaching the coast. The maximum offshore extent is defined as the maximum continuous distance offshore that the u-wind component is less than -1ms^{-1} . The calm zone length is defined as a continuous region with wind speed below 1ms^{-1} . The flow retardation percentage is the percentage drop in 10m wind speed over the water surface due to the thermal contrast relative to the average value at 0300 UTC. Supporting figures can be found in the supplementary material (Figs. S15-17).*

Parameter	Corkscrew								
PBL scheme	YSU			MYJ			MYNN		
Gradient wind speed (ms^{-1})	3	9	15	3	9	15	3	9	15
Max. offshore extent (km)	80			97			97		
Flow retardation (%)	-71	0	12	-70	-27	0	-57	9	22
Max. onshore wspd (ms^{-1})	3.34	3.23	3.39	2.83	3.38	4.23	1.83	2.37	3.12

Table 5: *Summary of corkscrew sea breeze dual-coast characteristics for varying offshore gradient wind speeds and PBL schemes. The maximum offshore extent is defined as the maximum continuous distance offshore that the u-wind component is less than -1ms^{-1}. The calm zone length is defined as a continuous region with wind speed below 1ms^{-1}. The flow retardation percentage is the percentage drop in 10m wind speed over the water surface due to the thermal contrast relative to the average value at 0300 UTC. Negative values represent an increase in 10m wind speed.*

Parameter	Backdoor								
PBL scheme	YSU			MYJ			MYNN		
Gradient wind speed	3	9	15	3	9	15	3	9	15
Cork. Dominance (ms^{1})	5			11			9		
Max. offshore extent (km)	24			27			24		
Flow retardation (%)	29	-	-	36	10	-	43	22	-
Max. onshore wspd (ms^{-1})	3.44	2.12	1.37	2.15	2.53	0.55	1.45	1.63	1.12

Table 6. *Summary of backdoor sea breeze dual-coast characteristics for varying offshore gradient wind speeds and PBL schemes. The maximum offshore extent is defined as the maximum continuous distance offshore that the u-wind component is less than -1ms^{-1}. The corkscrew dominance is defined as the wind speed where the offshore influence of the corkscrew sea breeze, formed on the opposing coastline, suppresses the backdoor sea breeze offshore. The calm zone length is defined as a continuous region with wind speed below 1ms^{-1}. The flow retardation percentage is the percentage drop in 10m wind speed over the water surface due to the thermal contrast relative to the average value at 0300 UTC.*

13. ***Page 17. Recently Tang (2012) concluded that diurnal variability of Sea Surface Temperature (SST) plays an important role in coastal area weather forecasting for the UK region, particularly for sea fog and sea breezes phenomena. Please if you found that varying SST did not have a significant effect on sea breezes offshore, present and discuss more in depth these results in the manuscript. If not, delete this subsection from the manuscript. http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-11-0253.1?journalCode=apme***

    Our original findings were that sea surface skin temperatures between 280-290K did not affect the sea breeze for baseline experiments. We have since extended this study for gradient wind speeds in the range 0-20ms^{-1} as part of our PBL sensitivity tests.
    Consequently, we have rewritten section 3.2.4 now on page 20 to read:
    "With the exception of the sea breeze front, varying the SST between 280-290K (a realistic SST range in southern North Sea temperatures for June) does not have a significant effect on the onshore environment for any type of sea breeze (Figs. 23 and S20-S23). Offshore, however, the result of increasing the sea surface skin temperature is to reduce the land-sea thermal contrast and therefore to weaken the sea breeze. In other words, the calm zone diminishes and the offshore wind speeds increase. For example, the magnitude of the increase in wind speed for sea surface skin temperatures between 280K and 290K is 1-2ms^{-1} for offshore gradient wind speeds below 4ms^{-1} (Fig. 23). At offshore gradient wind speeds above 4ms^{-1}, the change in offshore wind speed as a function of SST diminishes, as the gradient flow dominates the thermal pressure gradient."
    "For pure sea breeze circulations, the increase in SST decreases the minimum wind speed required to prevent the sea breeze circulation from reaching the land (Fig. S23; Table 7). Fundamentally, this is to be expected and indeed several sea breeze prediction methods rely on the ratio of gradient winds to land-sea thermal contrast (eg. Biggs and Graves, 1962). Without the effect of advection cooling the land surface with increasing offshore gradient wind speed, the sea breeze horizontal length scales are insensitive to the SST's simulated (Figs. S20 and S21).
    Additionally, a recent case study by Tang (2012) for an individual event has suggested that the effects of the diurnal cycle on shallow coastal water temperatures has significant impact on the sea breeze. To our knowledge, there has been no such idealized investigation into the effects of a shallow water diurnal cycle on the sea breeze. Adding such a cycle may reduce the land-sea thermal gradient and therefore lead to a weaker sea breeze."

    A new table 7 has also been added.

Parameter	Pure sea breeze SST sensitivity					
SST	280K			290K		
Gradient wspd	low	med	high	low	med	high
Detachment wspd (ms^{-1})	10			8		
Max. offshore extent (km)	15			33		
Calm zone length (km)	66	45	0	57	18	0
Flow retardation (%)	83	75	-	87	86	70
Max. onshore wspd (ms^{-1})	3.08	1.68	-	2.97	0.89	-

Table 7: *Dual-coast* **p***ure sea breeze response to varying SST. In both cases the YSU PBL scheme was selected and the simulations run with 2ms^{-1} offshore gradient winds. Supporting figures can be found in the supplementary material (Fig. S20-21).*

Minor points

1. ***Description of the model experiments in Sect. 2.1 do not match with Table 2. Please check (e.g. 2 to 10 m/s in steps of 2 vs. 0-20 m/s in steps of 1).***

   The description in section 2.1 describes the single coast experiments whereas table 2, referred to in section 2.2, describes the dual coast experiments.

2. ***Sect. 3.1.1 is nightfall at 18:45? 3rd June!***

   The model simulates nightfall at 2000 UTC (2100 LST) and sunrise at 0400 UTC. We have removed "at nightfall" from page 10, line 3. The PBL in the YSU scheme is diagnosed from the Richardson number. We believe that the collapse is created when the buoyancy force becomes smaller, due to land surface cooling, making the Richardson number sub-critical. We have added the following sentence to page 11 after line 3:

   "Regardless of the effects of the initialising vertical thermodynamic profile, the amplitude of the diurnal cycle 270km inland from sunrise at 0400 UTC to sunset at 2000 UTC is 23K."

3. ***Most figures, axis labelling and legends are too small***.

   On all of the hodographs, the size of the vector wind speed labels has been increased. The text on the label bars on the Hővmuller and cross-sections plots has been doubled in size. In summary, the Figs. which have been altered are: 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19 and 20.

4. ***Table 2. A coordinate system should be included/described to define the direction of u_g. u...***

   A co-ordinate system has been described in the caption for the table and a new comment added on the last linepage 8:

   "In all simulations, the u-wind component is described as positive in the offshore direction and orientated perpendicular to the coastline. The v-wind component is orientated shore parallel and positive with the land to the left"

5. ***Fig 5 improve quality, explain sigma 1.***

   Please see our response to Major comment 1. The resolution of Fig. 5 (now Fig. 6) has been increased and the labelling of the sigma levels changed to eta levels for consistency with the description of WRF in Skamarock and Klemp (2008). Eta levels describe the terrain following vertical pressure co-ordinate system used in the WRF model. Each eta level contains the scalar variables in the model and the vector quantities lie on the dashed half levels. An additional line has been added to page 8 line 22:

   "Model scalar variables are located on the η levels and vector quantities reside on half levels"

6. ***Fig 6 mark the location of the grid levels, include sunrise and sunset.***

   We have increased the length of the time series (now Fig. 7) to show the whole day. The PBL height is a diagnostic which is determined from the Richardson number and so is interpolated between model levels. We have added the sunrise and sunset times as vertical bars on this figure and on Fig.12. The captions of both figures have been modified accordingly.

7. ***Fig 7 labels of hodograph are too small. What is the direction of u? (coordinate system).***

   The size of the hodograph labels has been doubled (now Fig. 8) and the coordinate system is defined in the main text as described in our response to minor point 4.

8. ***Fig 8 legend too small, x-wind component = u? The range of influence: 300km up to 4km onshore and 250km offshore seams to be too extensive. The doubling of the vertical extension of the onshore flow seems to be suprising to the reviewer. Please explain. Please restrict the presentation to the interesting lower part of the atmosphere (eg. 3-4km).***

We have both increased the legend size and renamed the "x-wind" component to be the u-wind. Please see our response to Major comment 4 on the spatial extent. The doubling of the vertical extent of the onshore flow ahead of the sea breeze is due to warmer temperatures inland and so there exists a greater degree of mixing. We have added fig. S5 to the supplementary material showing potential temperature and boundary layer height to demonstrate this effect. All cross-sections have now been restricted to approximately 6km height so that both the sea breeze and the vertically propagating wave can be seen (where present).

9. ***Fig 9 Please use U_g instead of V_g to be consistent with u and v. 240km in 12 hours means a propagation speed of the pure sea breeze of approx. 6m/s. Is this consistent with the presented results?***
   The gradient wind speed component shown has been changed to represent the flow direction for consistency. The propagation speed shown in Table 3 of approximately 5.5ms^{-1} is consistent with the cross-sections presented (by comparison with the extents in Fig. 10 and those estimated in Fig. 9). These are subject to definition of the offshore extent but are also consistent with Arritt (1989) where the same threshold criterion employed. The supplementary Fig. S7 also shows that the onshore propagation speed is a factor of 2-3 times lower than the offshore, in agreement with Finkele (1995).

10. ***Fig.11 too small. Large differences between approx. 0 UTC and 24 UTC are evident. Discuss the effects of e.g. a 48h simulation on the results. At 8 m/s the offshore extent of the sea breeze is limited (see Fig. 9). Could you please explain why X=-300 km u(06Z) < u(12Z) and X=+300km u(06Z) > u(12Z) ?***
    Please see our response to point 2 in Major comments. The figure has been enlarged. At X = 300km, despite a failure to produce a sea breeze, the gradient wind speed is still reduced by a land-sea temperature contrast and so at 12Z the gradient wind is less than at 6Z. Similarly, for X = -300km the temperature gradient is reversed and so, the offshore gradient wind speed is higher at 06Z than at 12Z.

11. ***Fig.13 To the reviewer it is confusing, since here we see not the real extent of the sea breeze, but the specific definition used here in combination with a superimposed wind with an offshore component. The extent for ug=0 at 24 UTC is approx.. 240 km which is not consistent with the 260km in Fig.9.***
    The issue with the inconsistent offshore extents of the two baseline simulations has now

been resolved between Figs. 9 and 13 (now Figs. 10 and 14). The offshore extent can be a subjective measure as definitions may vary. Over time, coriolis acts to increase the offshore component of wind speed. This would counteract the effect of the sea breeze during the day and so the sea breeze would not appear to advance since the definition is bounded by a u-wind component less than $-1ms^{-1}$

12. ***Fig 14 see comments fig 8.***
The figure has been increased in size and the description of the speed changed to "u-wind component". The label bar numbers have been doubled in size.

13. ***Fig.16 Again: Would the authors expect the same results for e.g. a 48h simulation? Why the results show a decrease of 10m wind between 9-13 UTC (16b) although sea breeze and superimposed wind components are in the same direction. 14a is consistent with the expectations of the reviewer since superimposed wind and sea breeze are directed against each other.***
Please see our response to point 2 in Major comments. We agree that the original Fig.16a is consistent with the sea breeze definition and superimposed gradient winds acting in the same direction. Fig. 16b shows a corkscrew case . The reduction in wind speed is the result of the increasing thermal contrast between the land and sea reducing the total wind speed.

14. ***Fig.17 title of legend is different to e.g. Fig.15; please harmonize. What is the reason for the non-symmetric wind pattern in 17c ("c" is missing in the Figure)***
The legend title has been harmonized and the issue with the non-symmetric pattern has been resolved.

15. ***Fig.19 Figure too small. At the inflow boundary at x=-300 km only for u=18 m/s from west the expected surface wind from WSW is evident. For all other superimposed winds a left turn instead of the Coriolis forced right turn is shown. Please explain.***
The figure has been enlarged. Please clarify the meaning of the above comment. As far as we can see the winds in these plots have been rotated to the right, with the exception of the $18ms^{-1}$ simulation. These were re-run and the figure replicated.

16. ***Page 4 Third paragraph. Please replace "...the p rimary focus" with ...the primary focus***.
The typing error has been corrected.

17. ***Page 19 Please replace "Tijim" with "Tijm".***
 The spelling error has been corrected.

18. ***Page 20 "Cleantech..." reference is not shown in the main text.***
 The reference is used in Fig. 3 from which the map was adapted. The citation has been added to page 6, line 22:
 "Such is the scale of the industry that, by 2020, it is planned that offshore wind power will account for 17% of the total electrical power output of the UK (RenewableUK, 2012; Cleantech, 2010)."

19. ***Pages 19-21 Please indicate the access date for the electronic references.*** The last access date has been included.

20. ***Page 21 please replace "tokyo" with "Tokyo".***
 The typing error has been corrected.

21. ***Page 30 Wind hodograph shown in fig. 7 should have an arrow indicating the daily evolution of the wind speed and direction of sea breezes. The same for fig 10.***
 The figures (now Figs. 8 and 11) have been modified accordingly.