Idealized WRF model sensitivity simulations of sea breeze types and their effects on offshore windfields: Supplementary material

Authors: C. J. Steele, S. R. Dorling, R. von Glasow and J. Bacon

Synoptic situation for idealized soundings

The Summer of 2006 produced exceptionally high temperatures over western Europe, including the UK, which resulted in a number of heat related deaths NCIC (2006). The Summer produced a number of long-lived blocking anticyclonic systems, which provided the potential for sea breeze formation. Thermodynamic profiles from Herstmonceux were selected from 00Z on each of 2nd -4th June 2006, when one of the first of these anticyclonic spells established. The flow regime begins with a blocking anticyclone centred over southern Ireland, that slowly moves eastward during the study period. Initially, a very weak anticyclonic circulation is present to the north of Herstmonceux station, transporting warm moist air over the relatively cold southern North Sea, creating low level cloud in eastern parts of the UK (Fig. S1). By 06Z on the 2nd, the circulation had travelled further east out into the North Sea. Daytime temperatures were sufficiently high to trigger convection over land and the geostrophic wind was orientated so that the establishment of a backdoor sea breeze was possible. By the 3rd June and continuing into the 4th , the large anticyclone had travelled further east, creating a sharp inversion in the observed Herstmonceux profile, which eroded slightly over time. Wind speeds were light and variable and favourable for the development of a sea breeze. By the 4th June, the inversion from the large anticyclone had eroded slightly and local winds had once again become orientated to favour development of backdoor sea breezes on the south coast.

a)

b)

c)

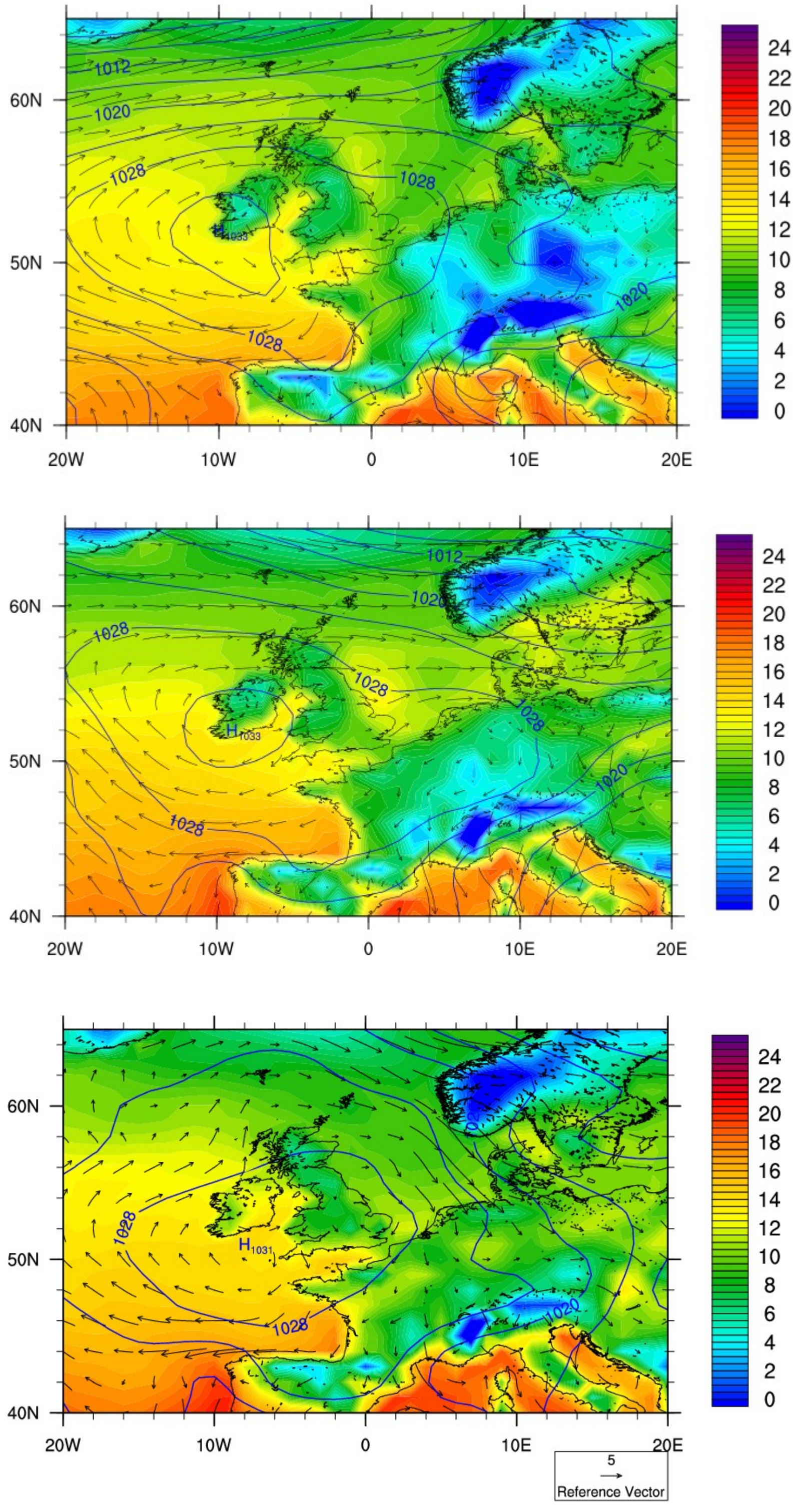


Fig. S1*: 1° GFS 00Z analysis for a) 2nd , b) 3rd and c) 4th June 2006. Filled contours denote 2m temperatures in Celsius. Blue contours represent sea level pressure in hPa and vectors depict 10m winds in ms^{-1} .*

48hr simulations

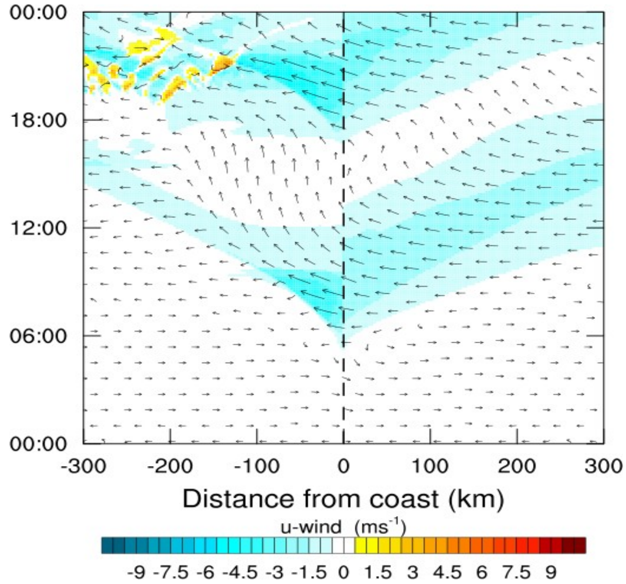
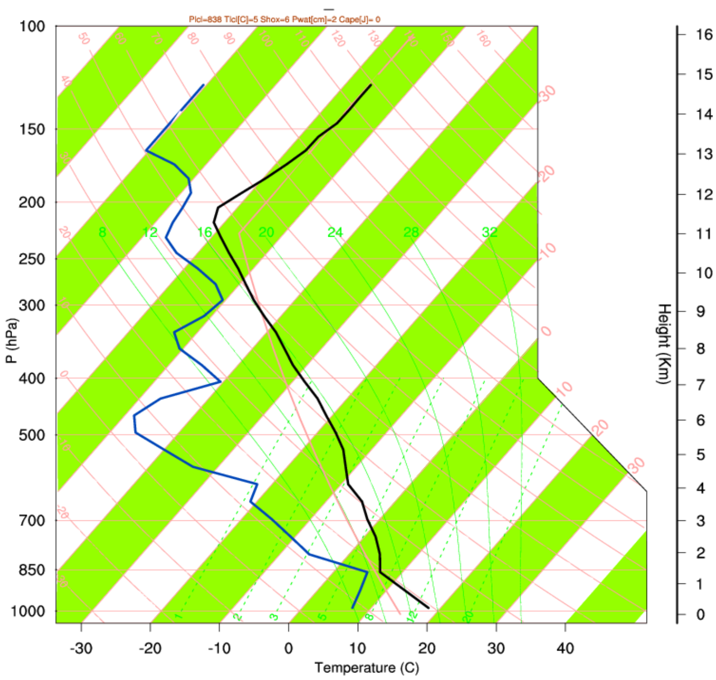


Fig. S2: *10m u-wind component for a 48 hour single coast baseline experiment using the YSU PBL scheme and a SST of 287K. 10m vector wind speeds are also shown. The dashed black line indicates the position of the coast. Distances and u-wind speeds are positive offshore.*

a)



b)

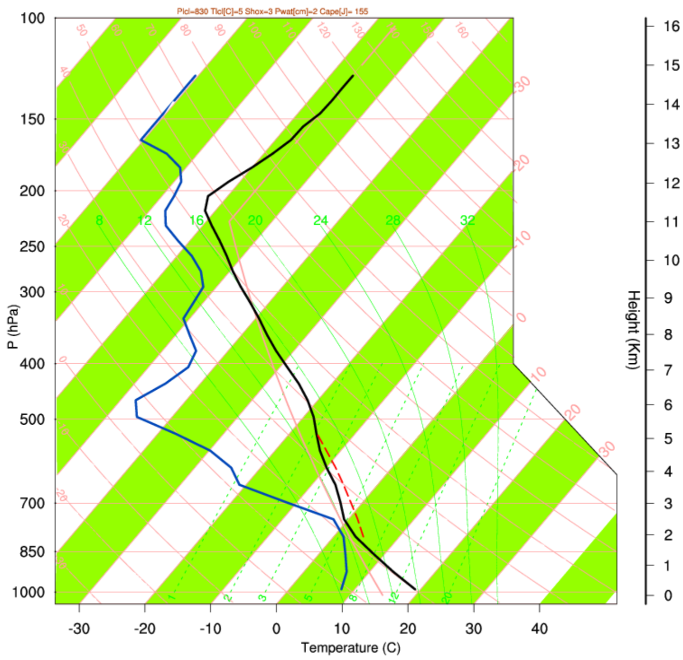


Fig S3: *Skewt vertical profiles for 1600 UTC on a) day 1 and b) day 2 of the 48hr baseline single coast simulation 150km inland. The dashed red line indicates the region of thermodynamic instability. Both the YSU PBL scheme and a SST of 287K were used.*

Baseline simulations

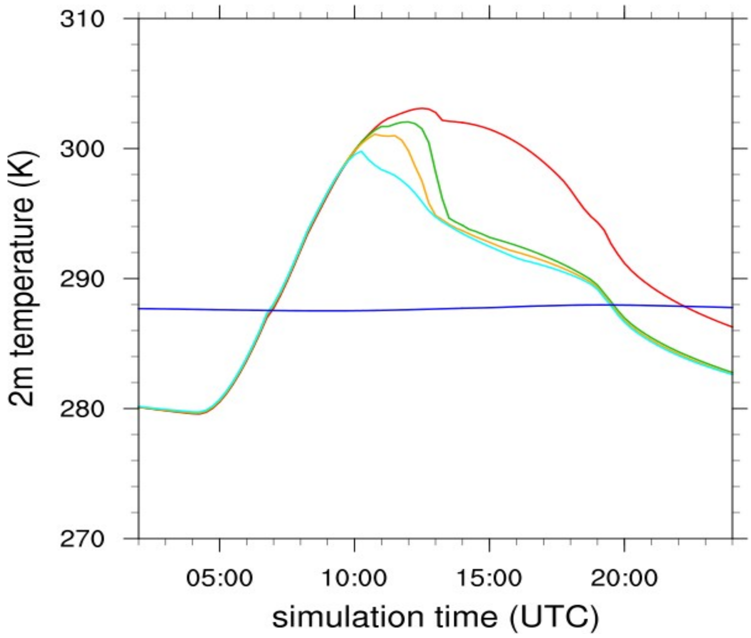


Fig. S4: *Time series of 2m temperature at 270km (red), 15km (green), 9km (orange) and 3km (cyan) onshore from the coastline. The solid blue line is the 2m temperature 60km offshore for the single coast baseline case. Based on the YSU PBL scheme and a SST of 287K.*

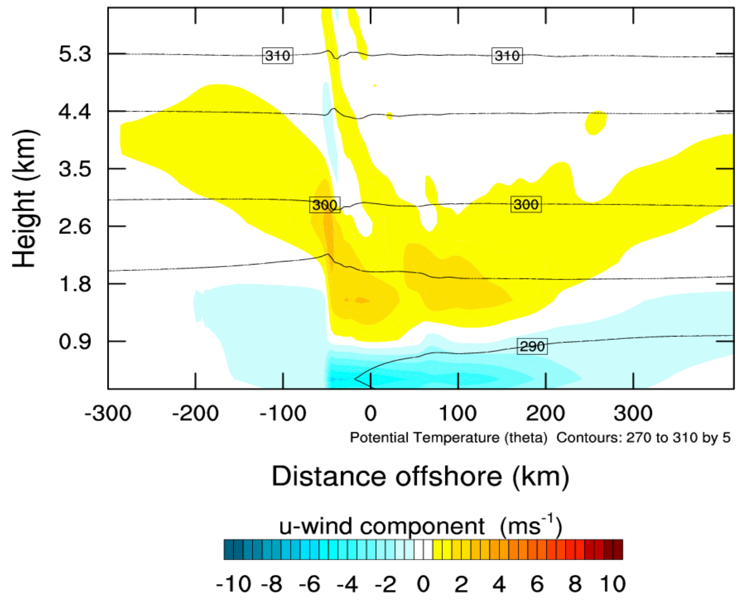


Fig. S5: *Vertical cross-section at 1900 UTC of the u-wind component for a single coast baseline simulation with no superimposed gradient winds. Distances and wind speeds are positive in the offshore direction. Solid contours denote potential temperature. Based on the YSU PBL scheme and a SST of 287K .*

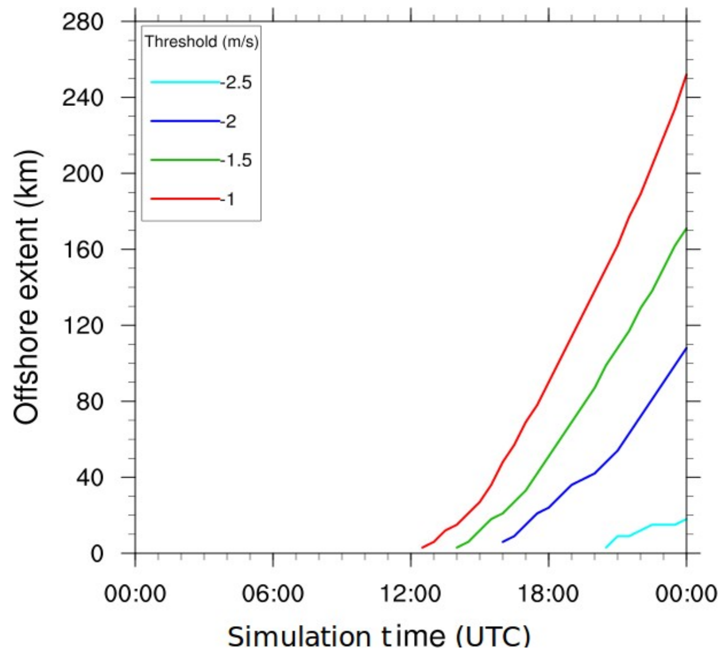


Fig. S6: *The sensitivity of the single coast baseline sea breeze offshore extent to the choice of 10m u-wind sea breeze definition threshold. Based on the YSU PBL scheme and a SST of 287K.*

Pure sea breeze experiments

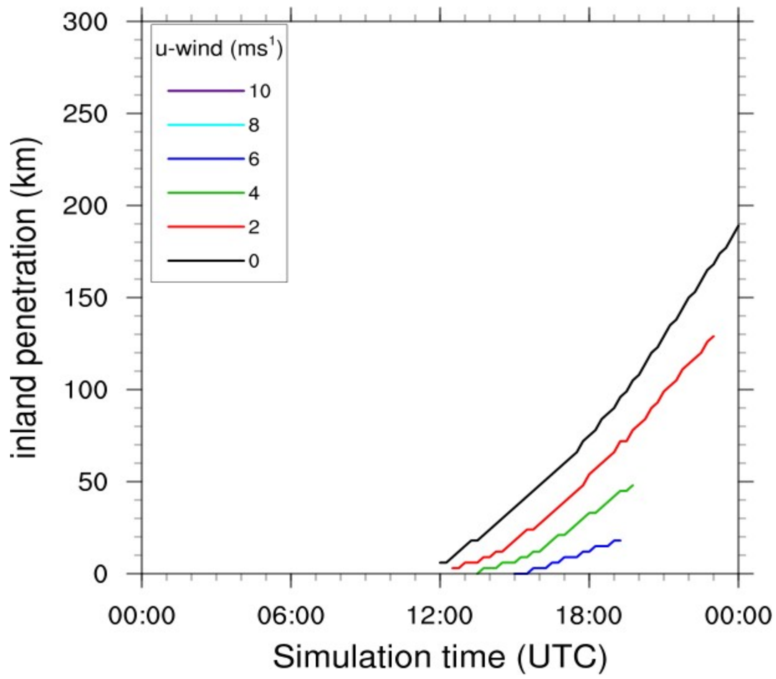


Fig S7*: Simulated onshore extents through time of pure sea breezes under various offshore gradient wind strengths. Calculation of the onshore extent is achieved following the method of Arritt (1989). Based on the YSU PBL scheme and a SST of 287K.*

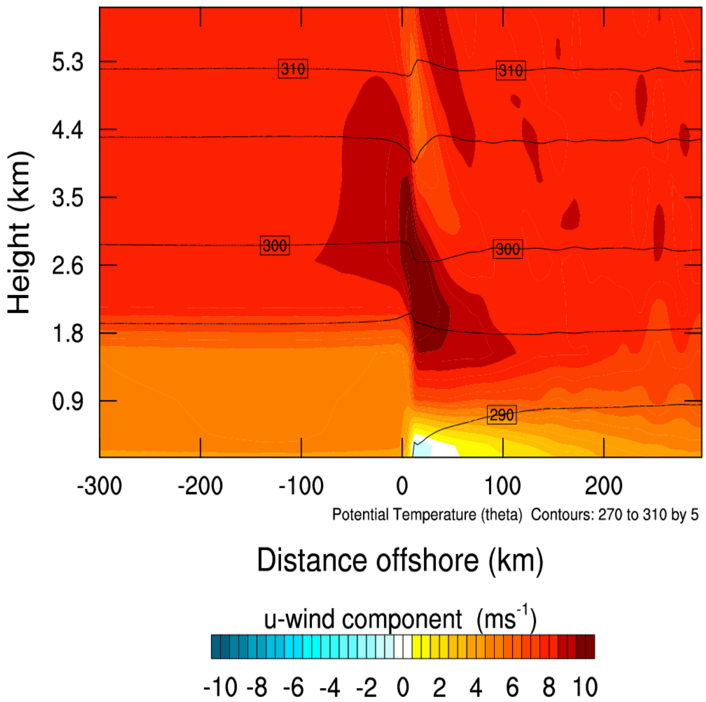


Fig. S8: *Vertical cross-section at 1600 UTC of the u-wind component for a single coast baseline simulation with an offshore gradient wind of 8ms^{-1}. Distances and wind speeds are positive in the offshore direction. Solid contours denote potential temperature. Based on the YSU PBL scheme and a SST of 287K .*

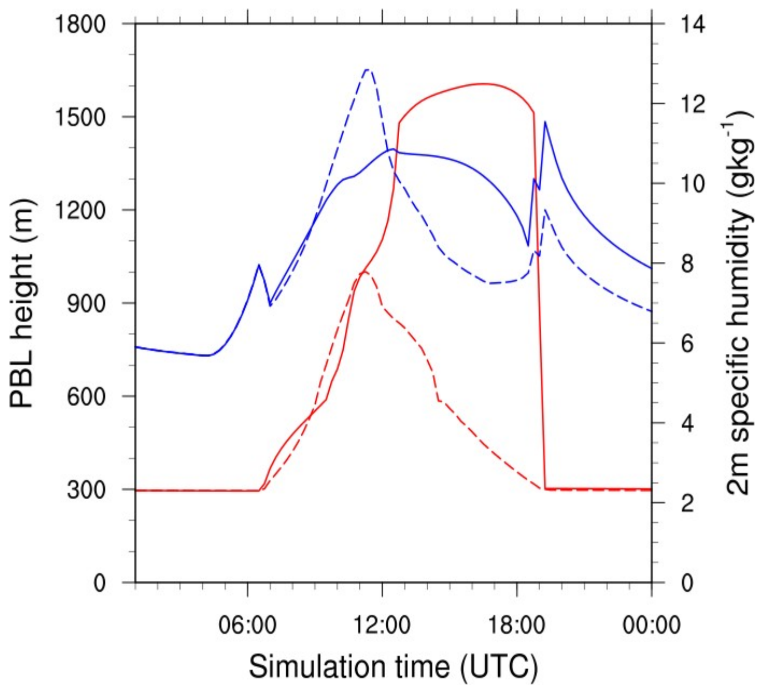


Fig. S9: *Time series of PBL height (red) and 2m specific humidity (blue) for a single coast simulation with 2ms^{-1}* offshore gradient winds. *Dashed lines represent the values at the coast and solid lines are 150km onshore. Based on the YSU PBL scheme and a SST of 287K .*

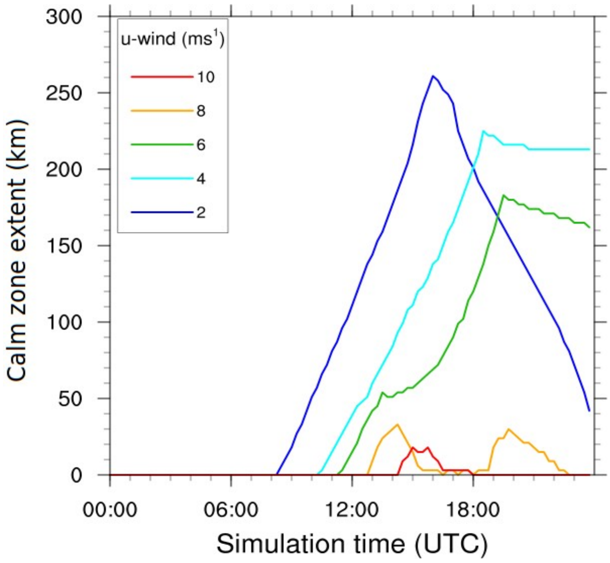


Fig. S10: *Length of the single coast calm zone (10m wind speed < 1ms^{-1}) for varying offshore gradient wind strengths. Based on the YSU PBL scheme and a SST of 287K.*

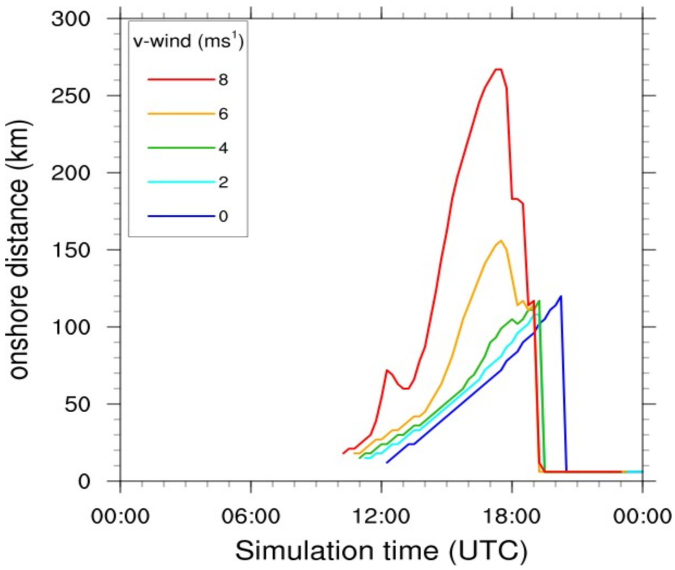


Fig. S11: *Onshore extents of single coast corkscrew sea breezes for different v-wind strengths defined using the method of Arritt (1989). Based on the YSU PBL scheme and a SST of 287K.*

Thermodynamic profile sensitivity

a)

b)

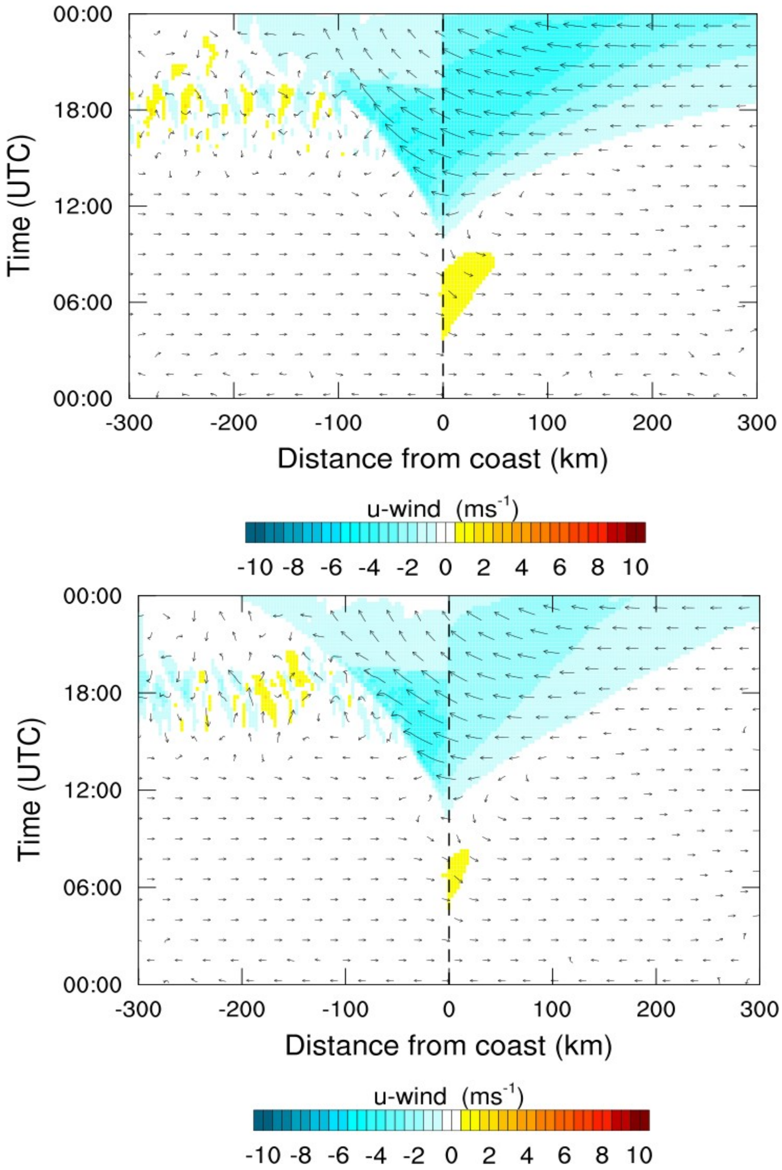
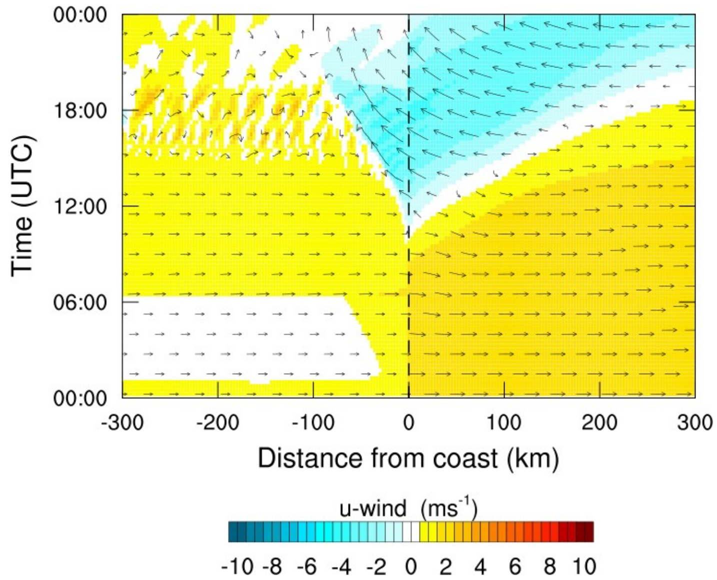


Fig S12: *Single coast baseline experiments using vertical profiles a) 2 and b) 3 for initialization. Filled contours denote 10m u-wind component with positive values in the offshore direction. Arrows represent 10m wind vectors. The PBL choice for both simulations was YSU and the SST set at 287K.*

a)



b)

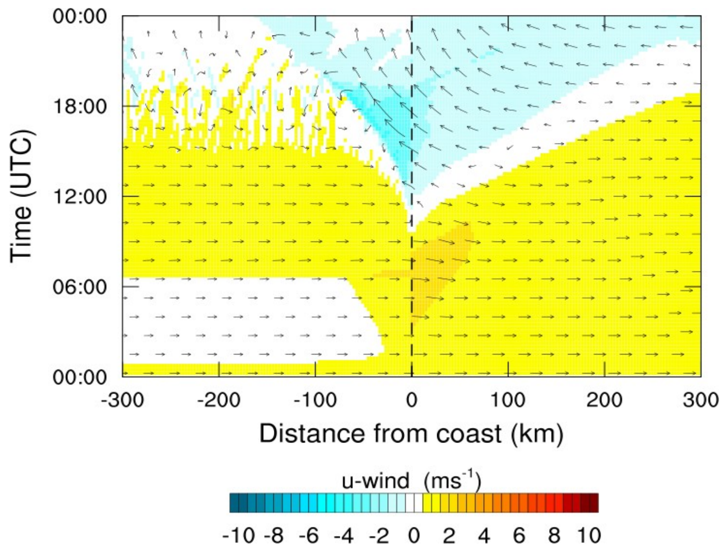
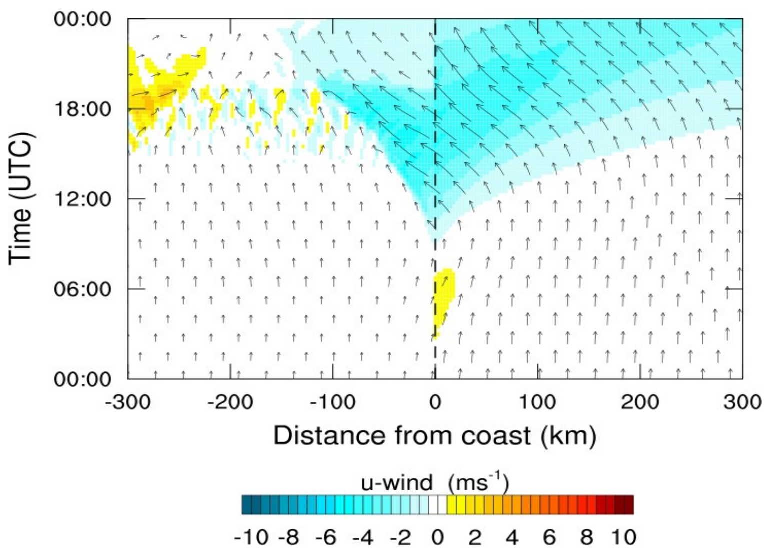


Fig S13: *Single coast simulations using vertical profiles a) 2 and b) 3 for initialization in a 2ms*$^{-1}$ *offshore gradient wind. Filled contours denote 10m u-wind component with positive values in the offshore direction. Arrows represent 10m wind vectors. The PBL scheme for both simulations was YSU and the SST set at 287K.*

a)



b)

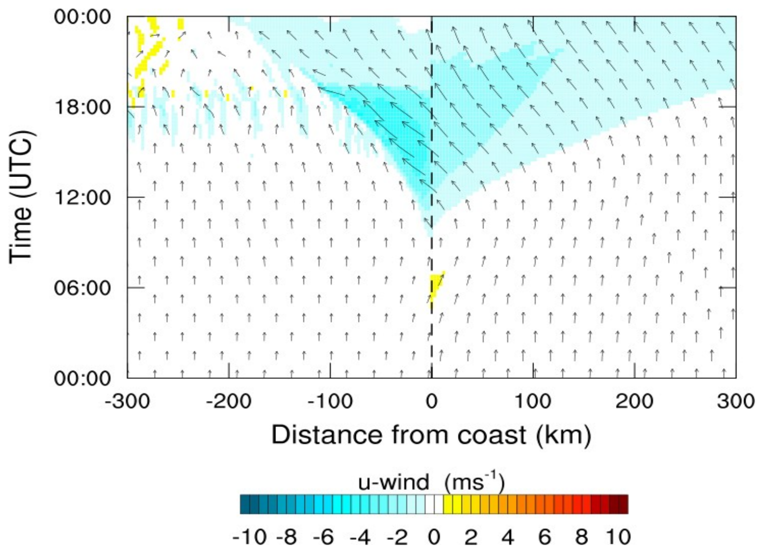


Fig S14: *Single coast simulations using vertical profiles a) 2 and b) 3 for initialization in 2ms*$^{-1}$ *shore parallel gradient wind. Filled contours denote 10m u-wind component with positive values in the offshore direction. Arrows represent 10m wind vectors. The PBL scheme for both simulations was YSU and the SST set at 287K.*

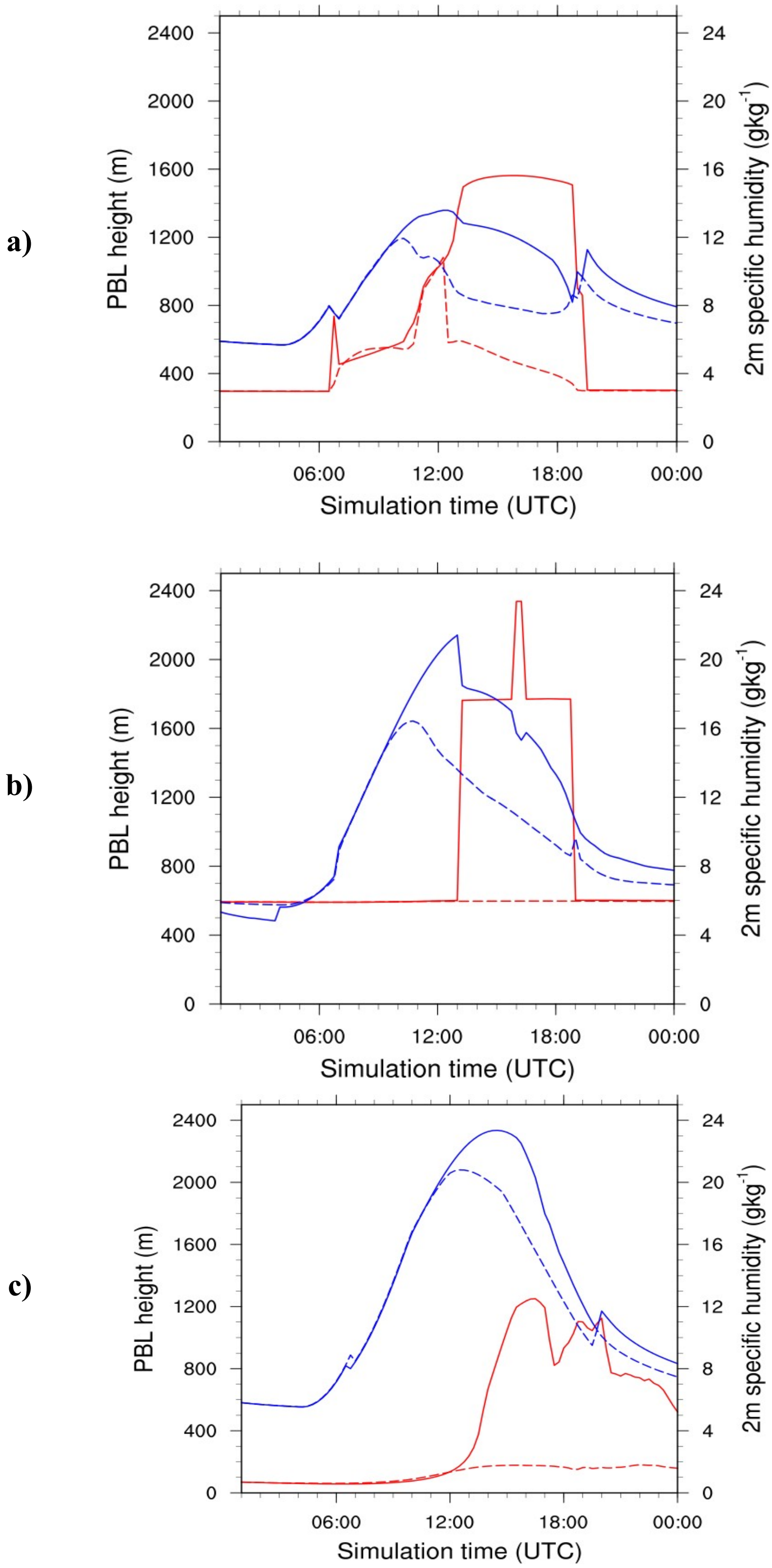


Fig. S15: *Evolution of 2m specific humidity (blue) and PBL height (red) for the baseline dual-coast simulations using a) YSU, b) MYJ and c) MYNN PBL schemes. Solid lines indicate values at 150km inland and dashed lines indicate the values at the coast. The SST in all cases was 287K.*

Dual coast pure sea breeze

a)

b)

c)

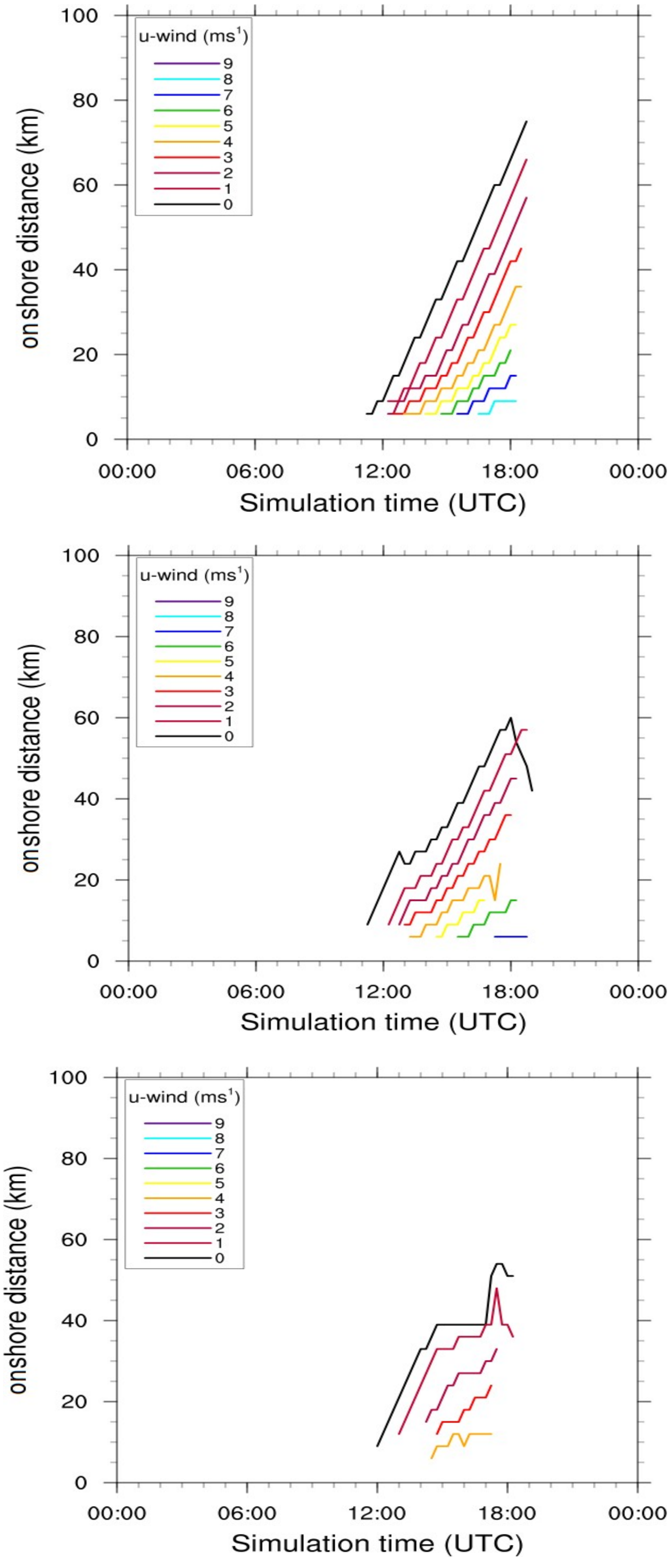
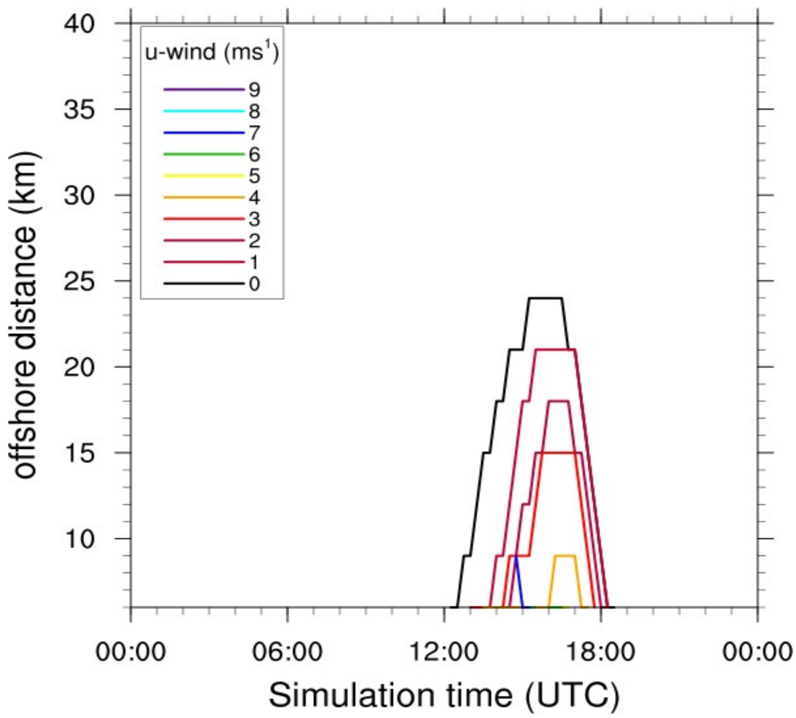


Fig. S16: *Onshore sea breeze extents using the a) YSU, b) MYJ and c) MYNN PBL schemes for a dual coast simulation using different offshore gradient wind speeds. The extent is diagnosed using the method of Arritt (1989). The SST was 287K.*

a)



b)

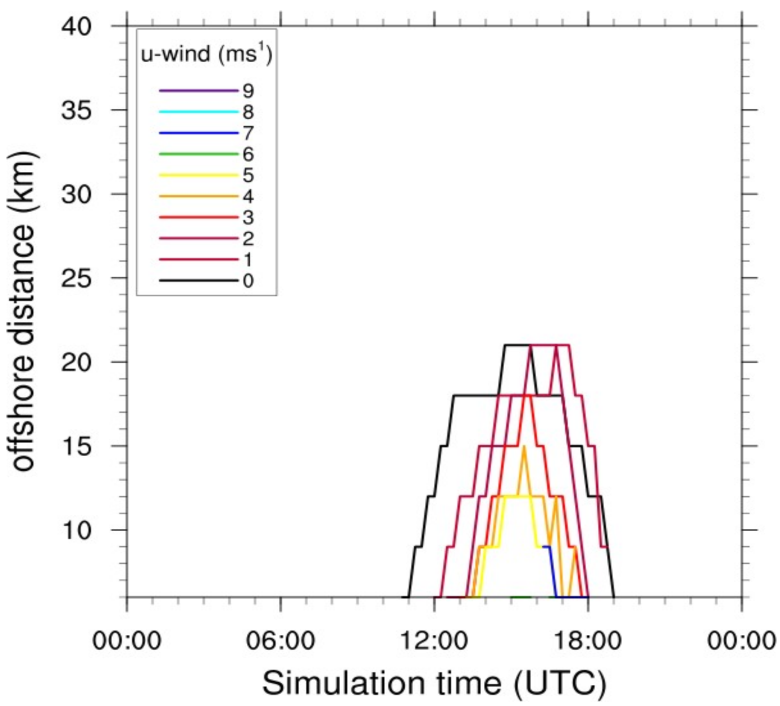


Fig. S17: *Dual-coast pure sea breeze offshore extents defined using the method of Arritt (1989) for different offshore gradient wind speeds using the a) YSU and b) MYJ PBL schemes. The SST was 287K for all simulations.*

a)

b)

c)

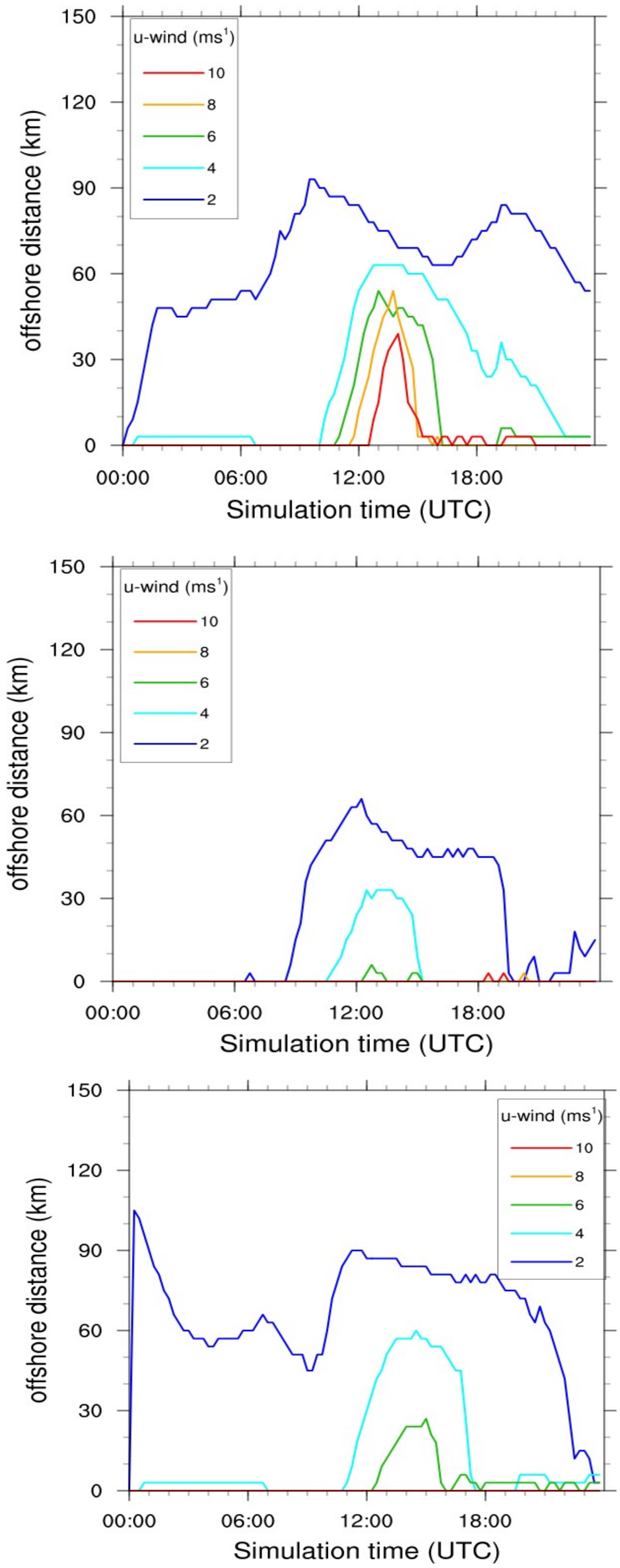


Fig. S18: *Horizontal extents of offshore calm zones (10m wind speed < 1ms^{-1}) for different offshore gradient wind strengths using a) YSU, b) MYJ and c) MYNN PBL schemes. The SST was 287K for all simulations*

Corkscrew and backdoor sea breeze simulations

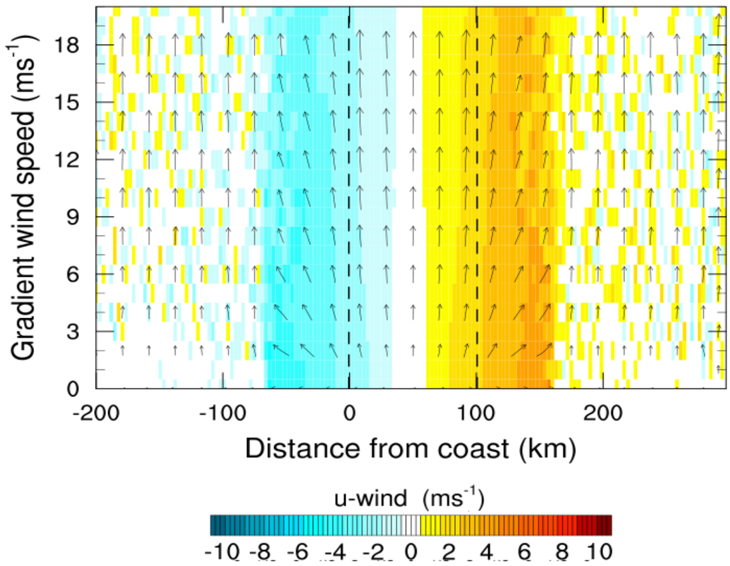


Fig. S19: *Variation of the 10m u-wind component of wind speed for dual coast simulations with increasing shore parallel gradient winds without Coriolis acceleration. Coastlines are marked as dashed black lines and the wind direction is represented as vectors. The selected PBL scheme is MYJ and SST set at 287K. Distances are measured from the western coastal boundary.*

SST sensitivity

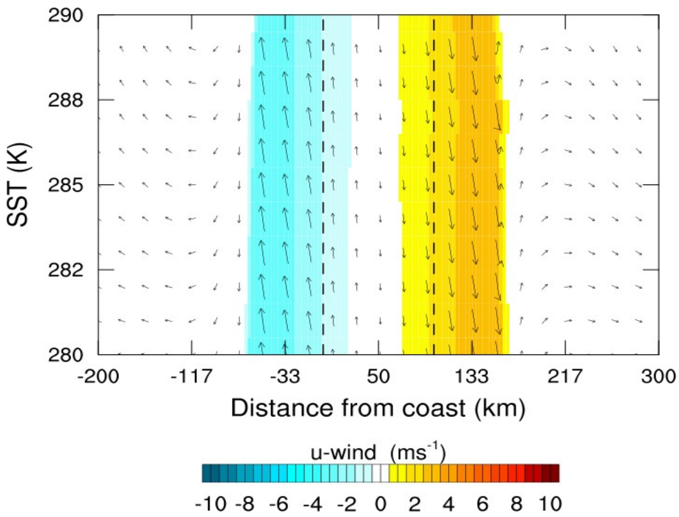


Fig. S20: *Sensitivity of the 10m u-wind component of wind speed (color) of the baseline (no gradient wind) dual coast simulations to SST using the YSU PBL scheme. Distances are positive offshore from the western coast. 10m wind speed vectors are shown by the arrows.*

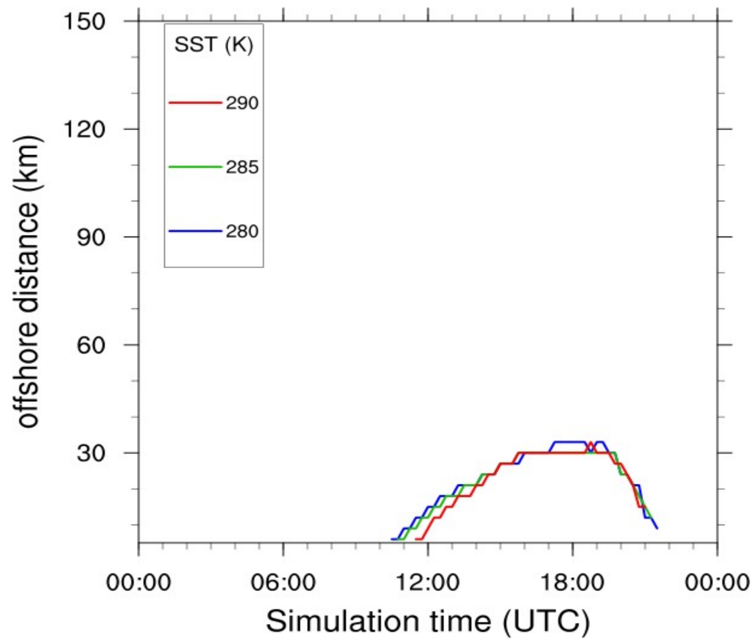


Fig S21: *Sensitivity of offshore extent to SST for dual-coast simulations using the YSU PBL scheme.*

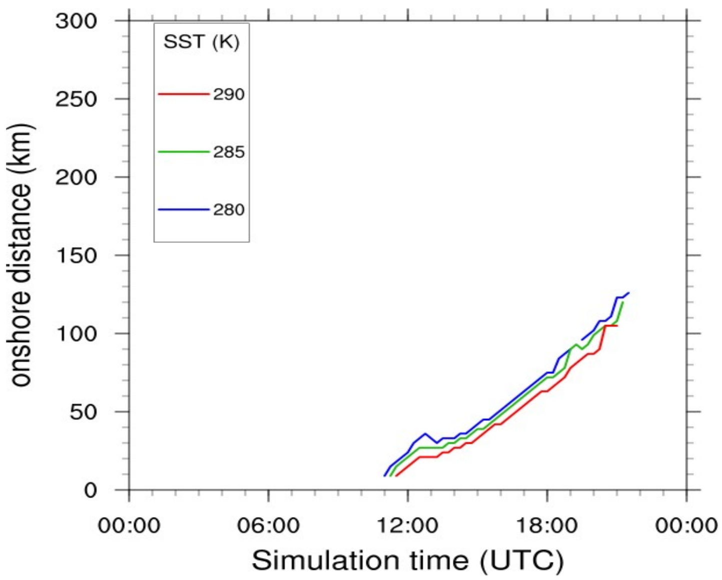
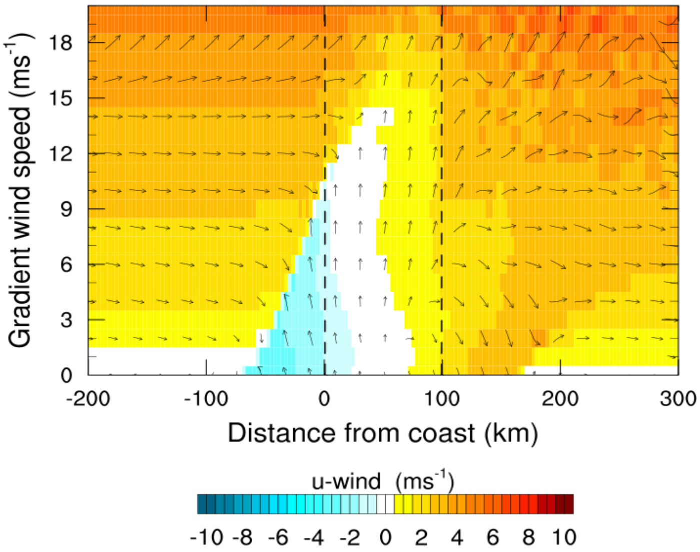


Fig S22: *Sensitivity of onshore extent to SST for dual-coast simulations using the YSU PBL scheme.*

a)



b)

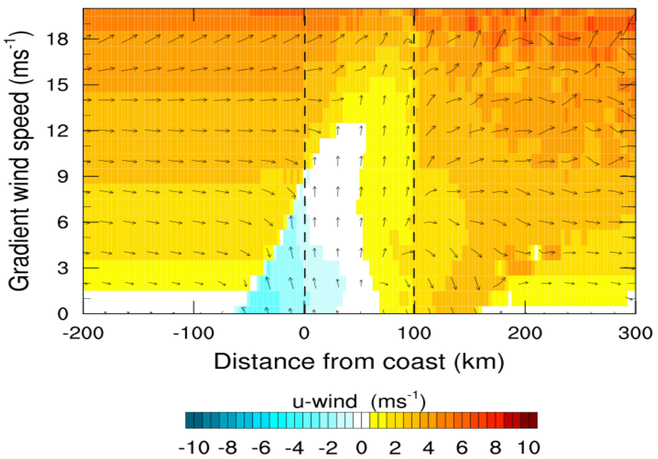


Fig. S23: *Effect of varying offshore gradient wind speed for SST's of a) 280K and b) 290K on the 10m u-wind component. Equivalent 10m wind speed vectors are also shown. The YSU PBL scheme was used for both cases. Distances and u-wind values are positive offshore from the western coastline. Both coastlines are shown as the dashed lines.*