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Clustering effects of major offshore wind developments

3rd International Conference on Energy and Meteorology, June 2015

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Introduction

In 2014, 9.3% of UK electricity was produced by wind power. This proportion is expected to increase to approximately 20% by 2020.

To achieve this growth, there is a focus on the development of large offshore wind farms.

Zone	GW
Moray Firth	~~1.5~~ 1.3
Firth of Forth	3.5
Dogger Bank	~~9~~ 7.2
Hornsea	4
East Anglia	7.2
Southern Array	0.6
West Isle of Wight	~~1.2~~ 0.9
~~Atlantic Array~~	~~1.5~~
~~Irish Sea~~	~~4.2~~

Wind farm distribution

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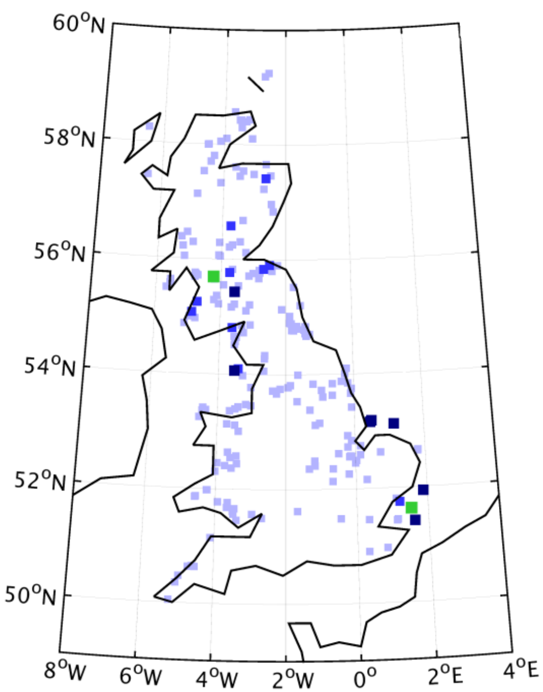
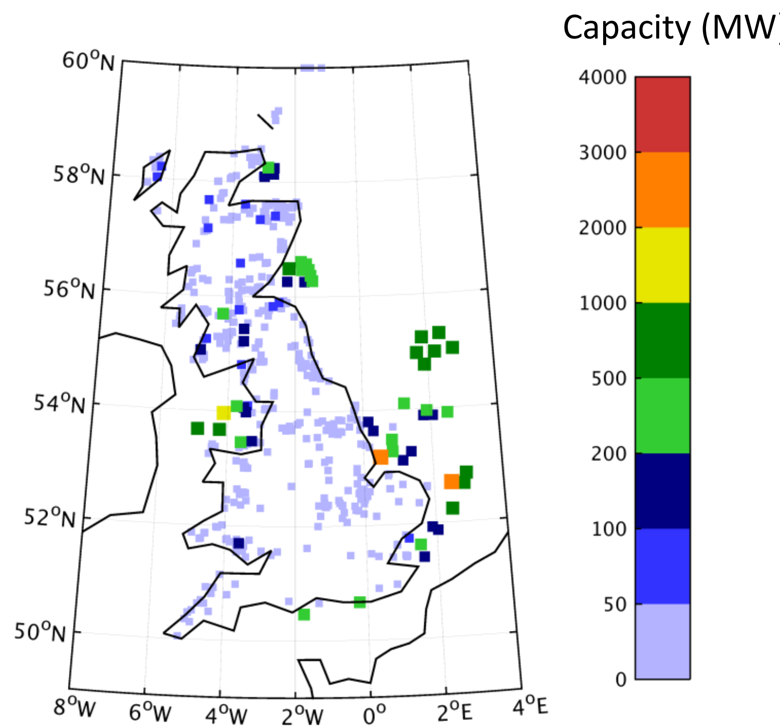
A significant change in the distribution of wind capacity is likely.

CURRENT (April 2014)
10.5 GW
3 GW offshore

FUTURE (~2025)
50 GW
37.5 GW offshore





Research questions

What is the impact of future offshore wind farms on the characteristics of the nationally aggregated wind power generation?

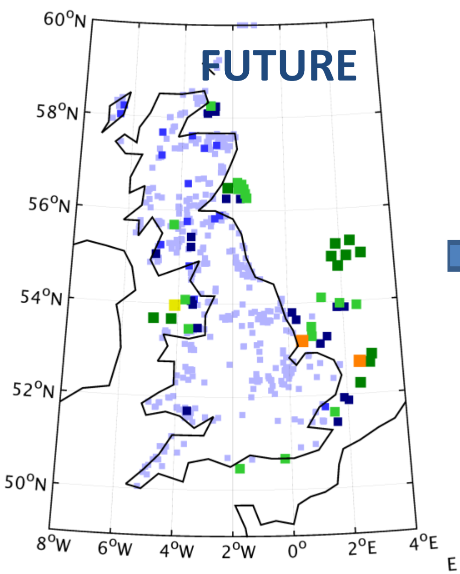
- Ramping
- Persistent low/high generation

What are the generation characteristics of a cluster of offshore wind farms?

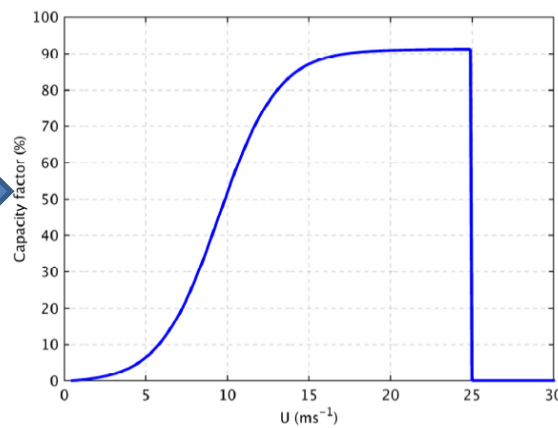
- Power output of a cluster of wind farms
- Quantify the possible local power swings

GB-aggregated wind characteristics

A 34-year reanalysis dataset (**MERRA from NASA-GMAO**) has been used to produce a synthetic hourly time series of GB-aggregated wind generation



Hub height hourly mean wind speed at each farm (MERRA)



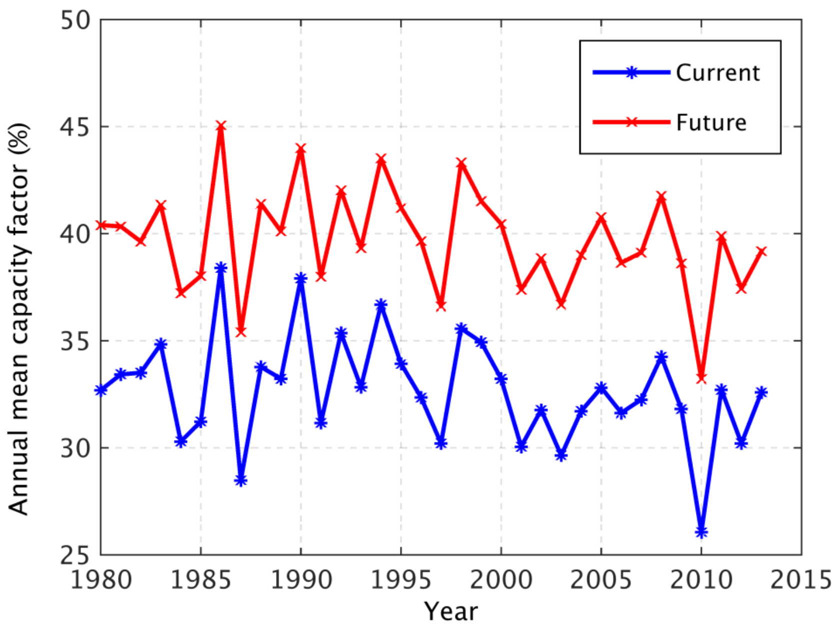
34-year hourly time series of GB-aggregated capacity factor.

Method can accurately reproduce the wind generation on spatiotemporal scales greater than around 300 km and 6 hours. See Cannon et al. poster.

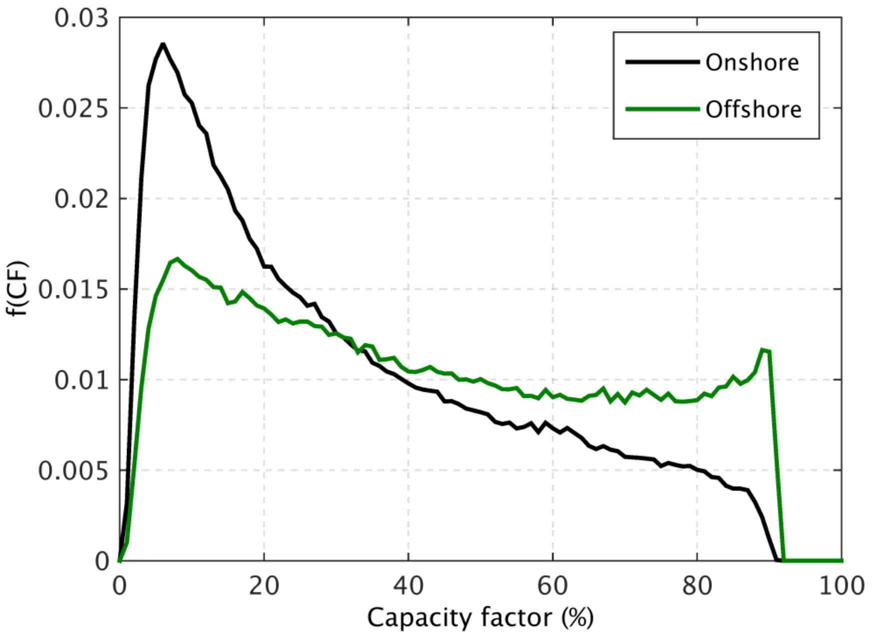
GB-aggregated wind characteristics

Hourly time series used to determine GB-aggregated wind generation characteristics.

Annual mean capacity factor determined for 34-year period.



Frequency distribution of onshore and offshore generation.



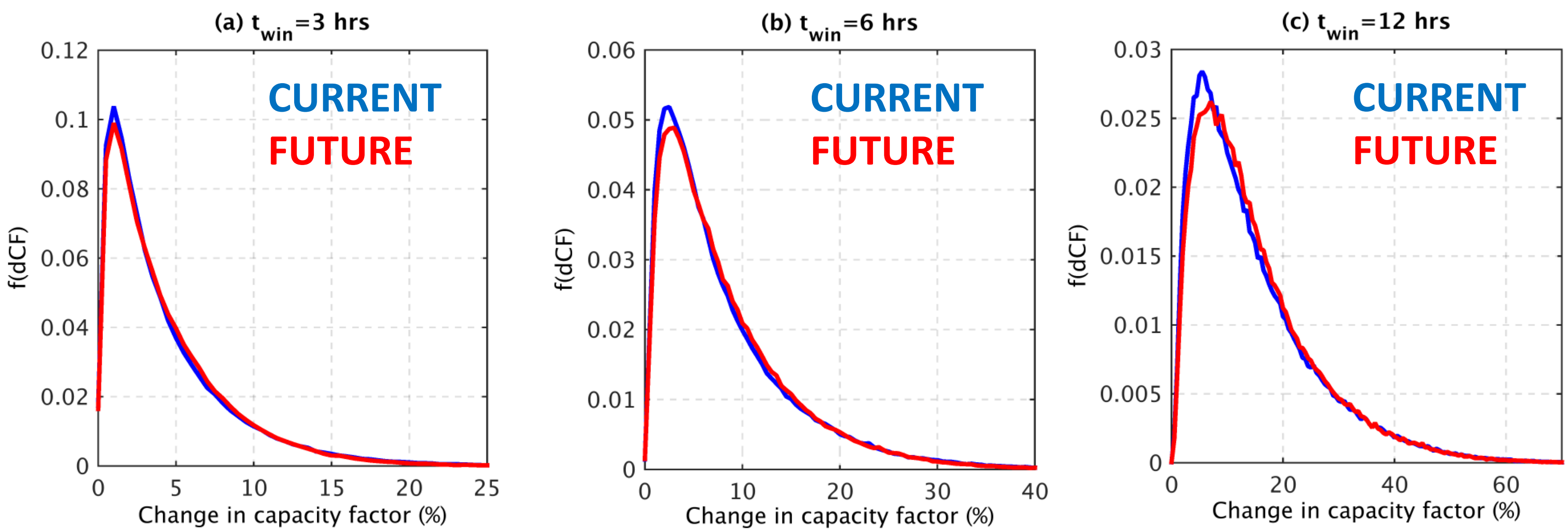
GB generation characteristics

Persistence

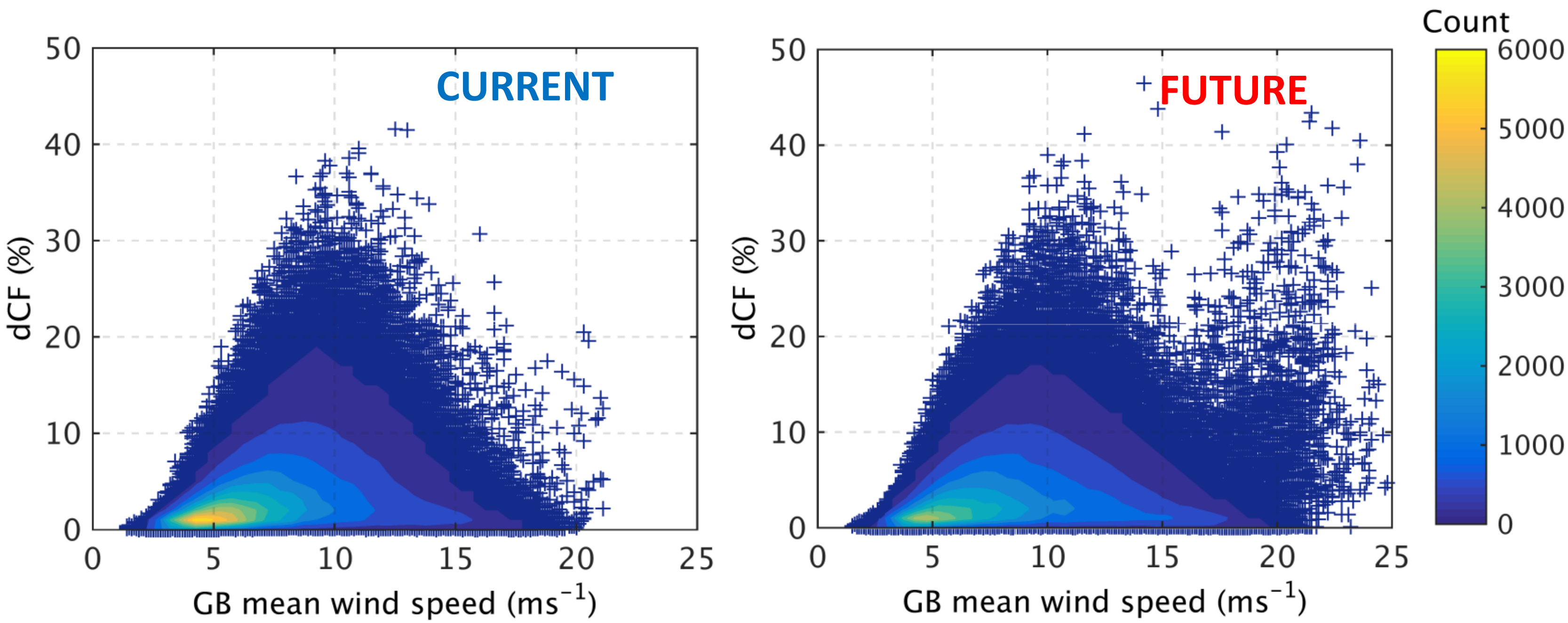
- Reduction in the number of persistent low generation events
- Increase in the number of persistent high generation events.

Ramping

In terms of a change in GB-aggregated capacity factor: little difference in frequency and magnitude of ramping events.



Ramping



- Due to the increase in capacity- in terms of power output, the magnitude of the ramping increases by a factor of 5.
- Increase in the number of ramping events associated with high wind speed turbine cut-out.

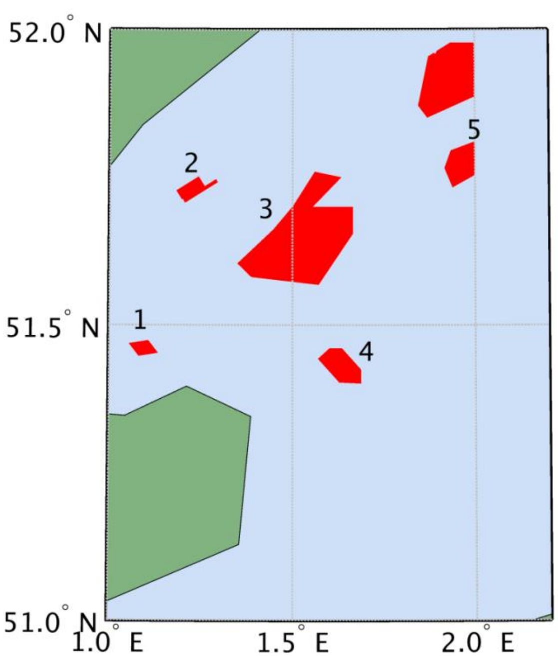
Local generation characteristics

Consider the generation characteristics of a cluster of offshore wind farms.

Future: Round 3 wind zones, approximately 1 GW per 1000 km^2.

Current: Thames estuary region 1.7 GW within approximately 800 km^2.

	Farm	Size (MW)
1	Kentish Flats	90
2	Gunfleet Sands	172
3	London Array	630
4	Thanet	300
5	Greater Gabbard	504



WRF Downscaling

An understanding of the wind resource at a high spatiotemporal resolution is required.

- Local coastal effects
- Wind farm effects

Weather Research and Forecasting (WRF) model used to downscale the large atmospheric conditions (ECMWF analysis).

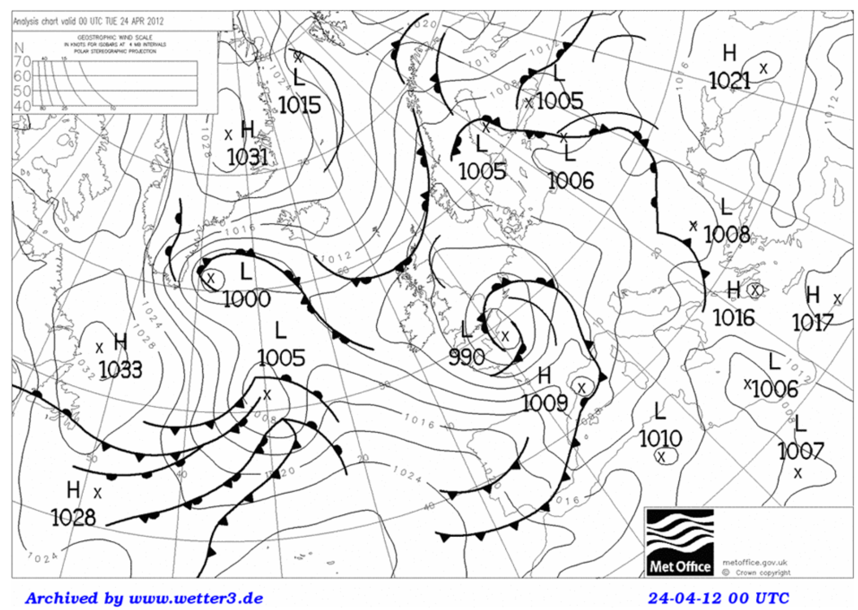
- Single domain (4 km resolution)
- 180 km x 180 km
- 100 vertical levels
- Wind farms parameterised using the Fitch method (Fitch et al., 2012)
- Thrust and power coefficients provided by turbine manufacturer
- Mellor-Yamada-Nakanishi- Niino (MYNN2.5) Boundary layer scheme

Case study: 25th April 2012

Swing in GB-aggregated capacity factor from around 5% to 80% within 24 hours.

Event caused by a deep low pressure system arriving from the North Atlantic.

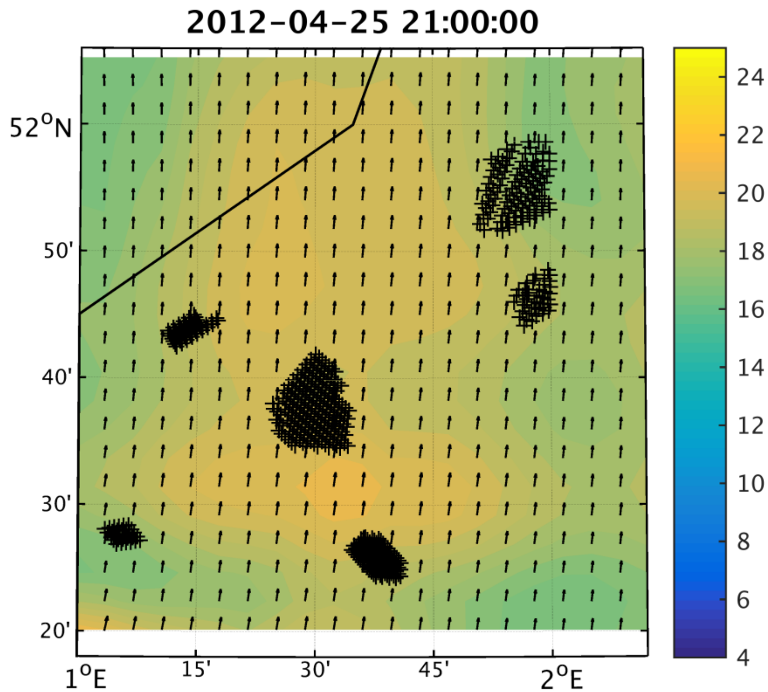
Investigate the power characteristics of the wind farms in the Thames estuary.



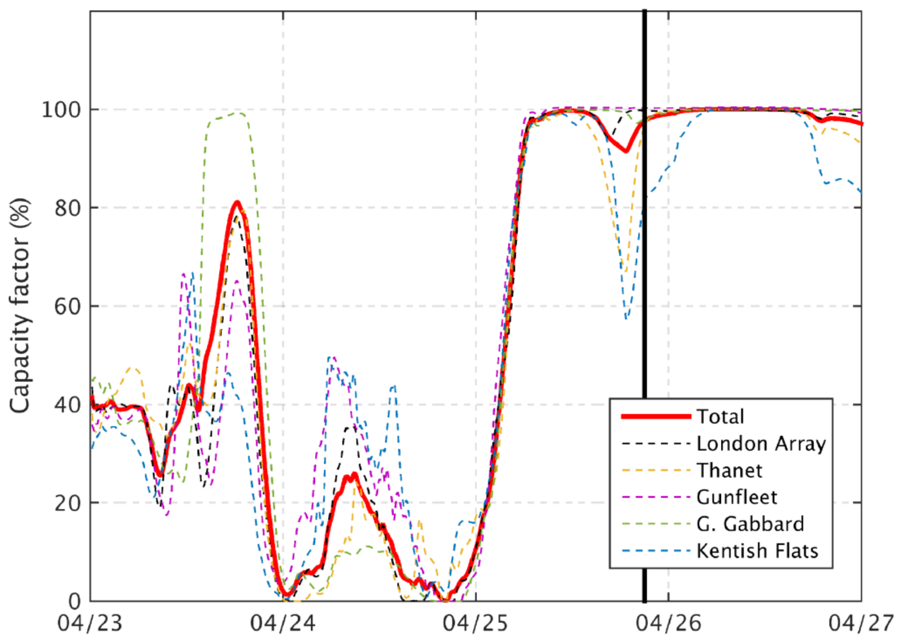
Case study: 25th April 2012

Wind speed increased from approximately 4 ms^{-1} at 00:00 to 16 ms^{-1} at 06:00.

Swing in aggregated capacity factor from around 3% to 99% within 6 hours (1.6 GW)



U at 70 m (ms^{-1})



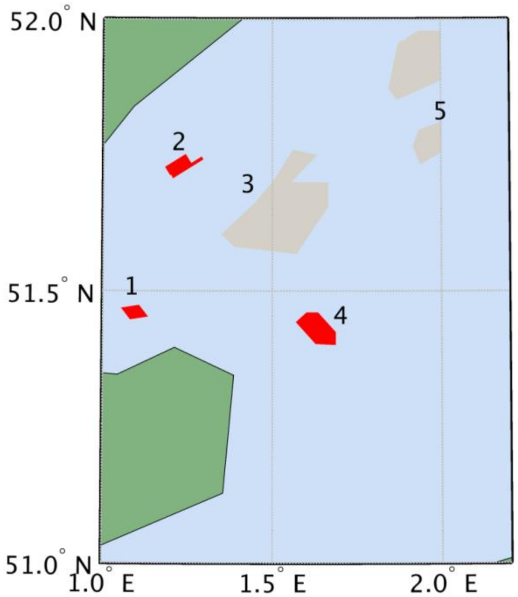
Thames estuary wind farms capacity factor

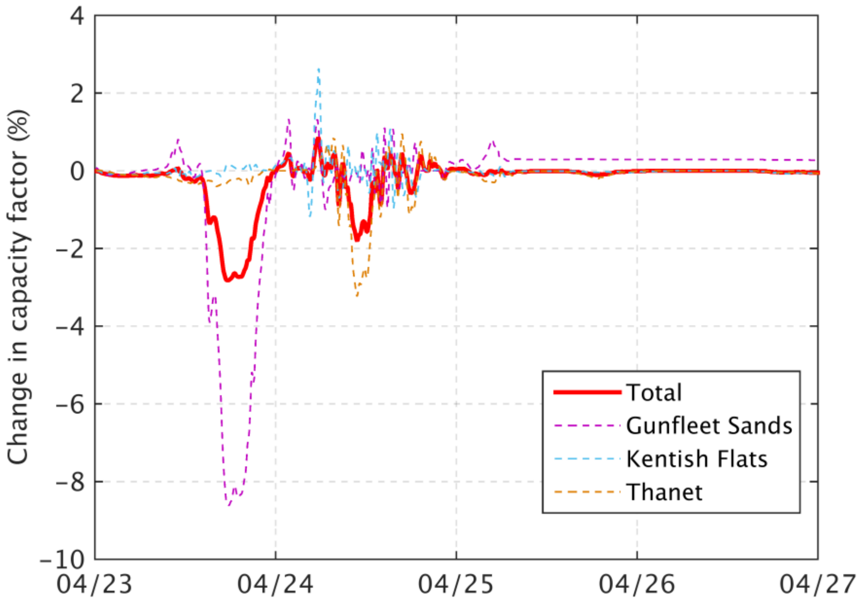
Case study: April 2012

The two largest wind farms, Greater Gabbard (5) and London Array (3), were not constructed in April 2012.

Repeated analysis without these two wind farms.

Run 1: All 5 wind farms included
Run 2: London Array and Greater Gabbard excluded





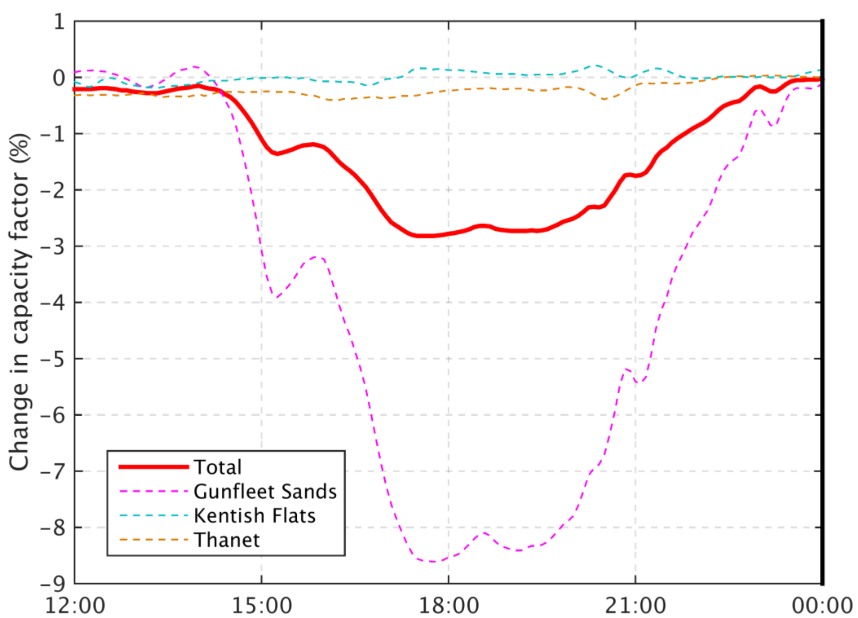
Can compare the derived capacity factor time series of the two runs to determine the impact of London Array and Greater Gabbard on neighbouring farms.

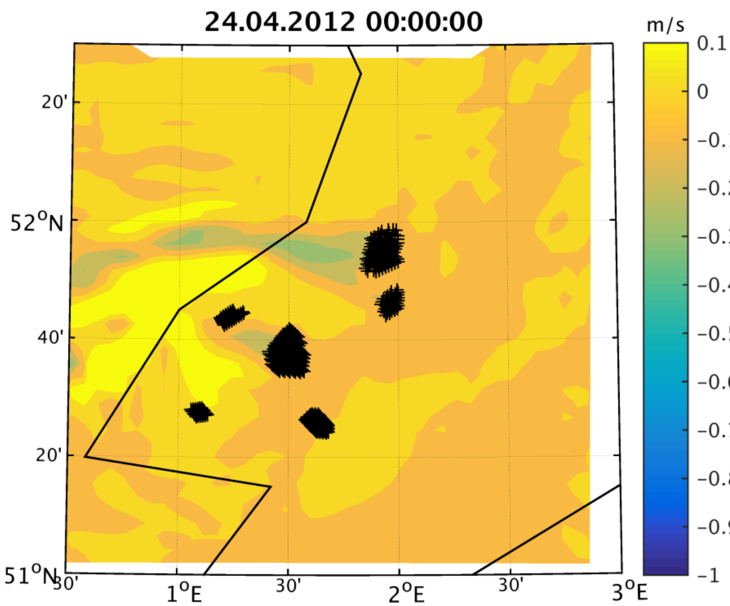
Run 1 – Run 2

Case study: 23rd April 2012

Between 15:00-21:00, region of reduced wind speed downstream of London Array reduces the output of Gunfleet Sands.

At 00:00 the wake region is significantly shorter, therefore Gunfleet Sands is unaffected.



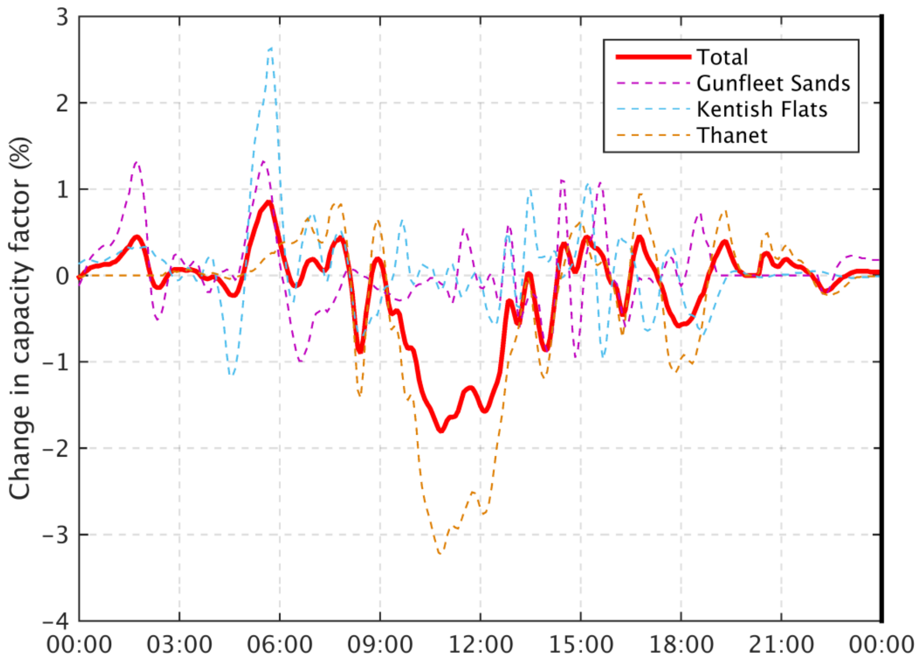


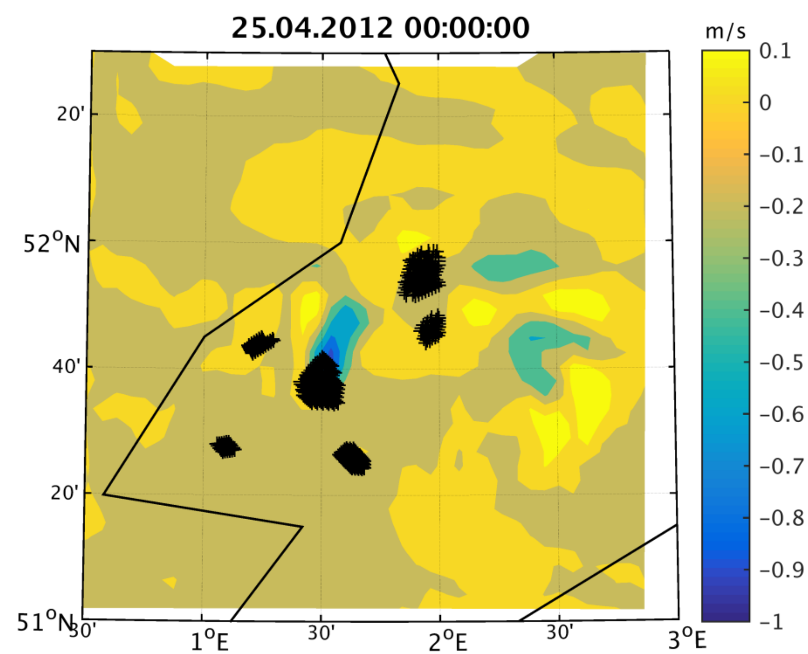
U anomaly at 70 m (ms^{-1}): Run 1 – Run 2

Case study: 24th April 2012

Between 19:00-12:00, northerly flow therefore the wake region downstream of London Array reduces the output of Thanet.

In the afternoon, wake regions have been reduced.





U anomaly at 70 m (ms^{-1}): Run 1 – Run 2

Summary

The likely change in the distribution of wind farms in Great Britain could have a significant impact on the wind generation characteristics:

- Improved performance: GB-aggregated capacity factor increases by approximately 7% relative to the current distribution.
- Greater number of persistent high wind generation events- important consideration for system integration. *See H. Bloomfield at 15:30.*
- The magnitude and frequency of ramping is largely unchanged –BUT significantly larger power swings to manage.
- Increase in the number of ramping events associated with high wind speed cut-out.

Also considering power characteristics at higher spatiotemporal resolution (e.g. clusters of offshore wind farms)

- Downscaling using WRF with Fitch wind farm parametrization

Future work

Validate output from WRF for Thames estuary wind farms:

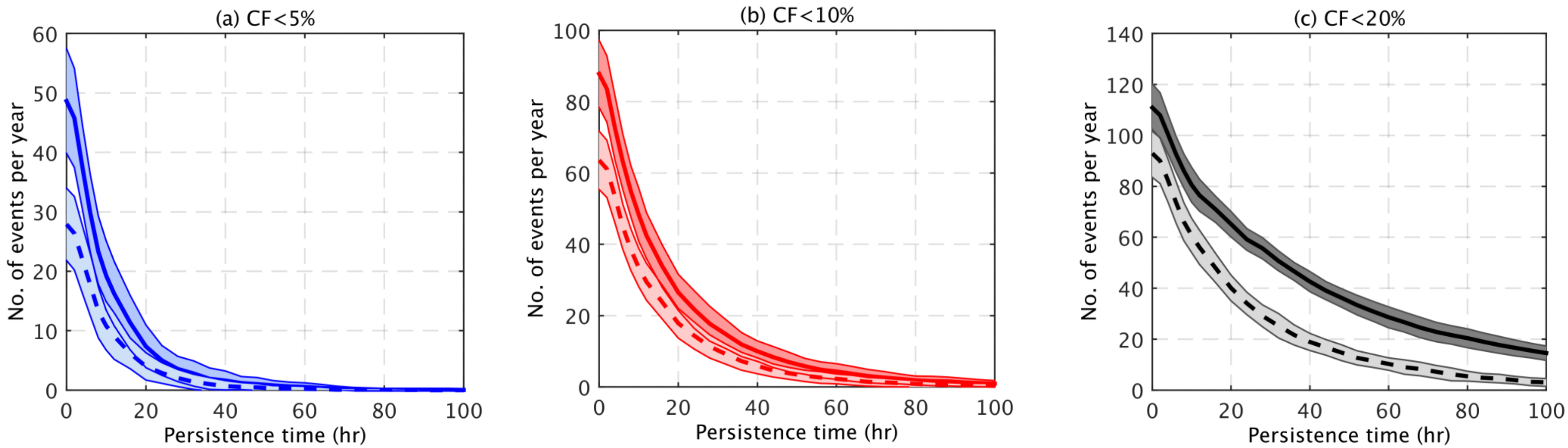
- Aggregated power output
- Satellite surface wind speed data

Consider nesting (1.5 km resolution domain) to improve effects of individual turbines and wind farms.

Investigate the performance of the planned clusters of wind farms (e.g. Dogger Bank: 7.2 GW capacity) for a series of extreme events.

Extra slides

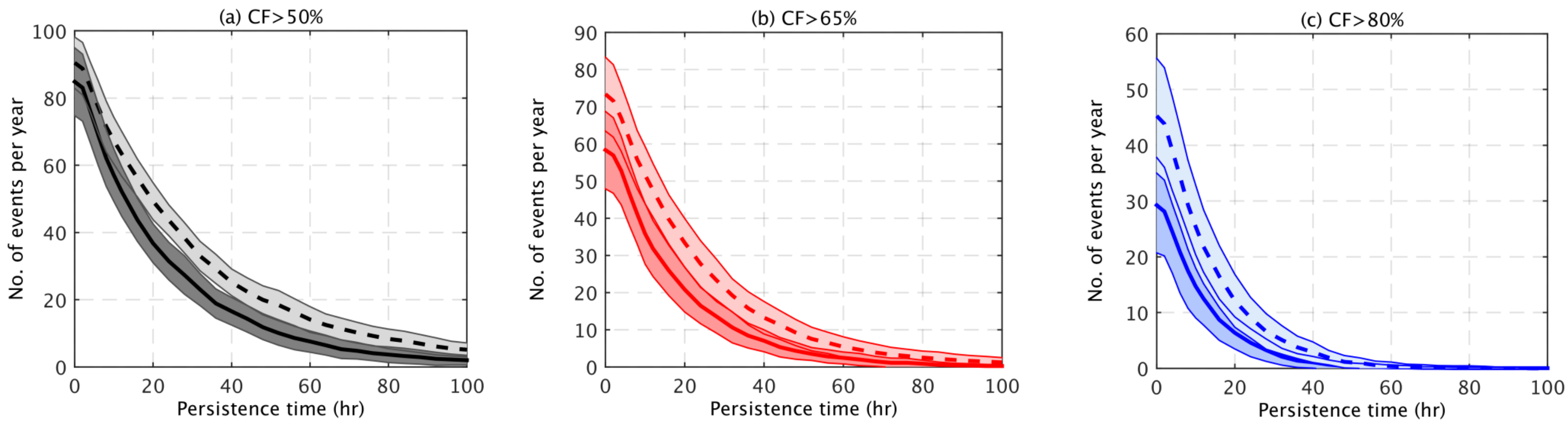
Persistent low generation events



Frequency of persistent low generation events for three capacity factor thresholds

Current (solid) Future (dashed)

Persistent high generation events



Frequency of persistent high generation events for three capacity factor thresholds

Current (solid) Future (dashed)