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SAR data [1] wind field processing DTU Wind Energy [2].

Wind Phenomena: Impacts on Power Output

1… Introduction

We investigate the impact of meteorological phenomena on wind energy using:

- Synthetic Aperture Radar (SAR) examples of phenomena Greater Gabbard wind farm, UK (fig. 1-3)(sections 1.1 – 1.4).
- Estimation of power output estimation for an individual turbine and across a wind farm during these events.

1.1. Roll Vortices (RV):

Counter-rotating turbulent rolls which form and persist. In [4] RV led to periodic turbine loading and power output variations in onshore wind farms, frequent RV are expected in stable offshore wind farm regions (fig. 1).

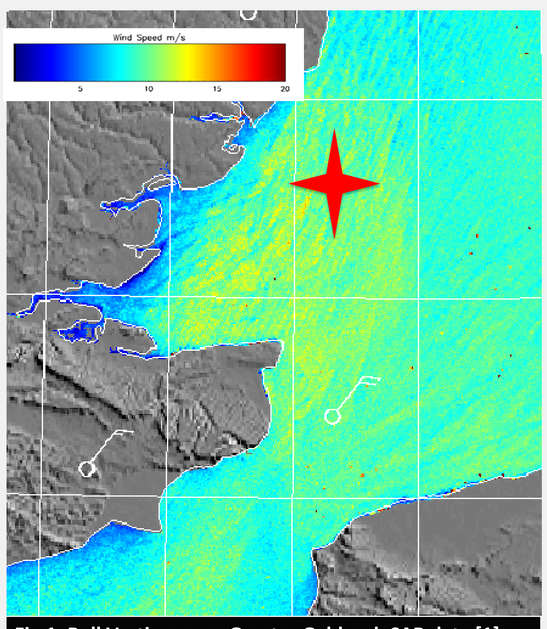

Fig.1. Roll Vortices over Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

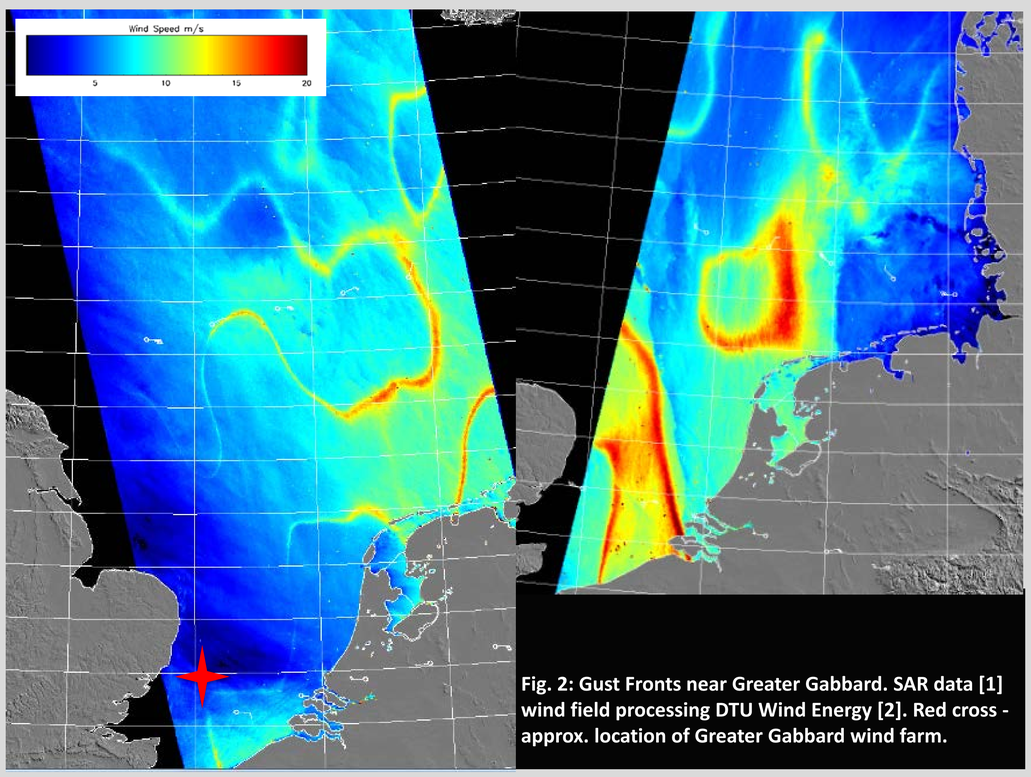

Fig. 2: Gust Fronts near Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

1.2 Mesoscale gust fronts:

localised high speed wind gusts and precipitation. In [6] gust associated increases in ocean wave height impacted turbine structures, whilst intermittent wind speeds reduced energy capture efficiency (Fig.2).

1.3 Atmospheric Gravity Waves (AGW)

Topographic obstacles displace coast-sea flow and waves persist in stable conditions. In [5] 0.6 ms^{-1} decreases in wind speed were associated with AGW across a theoretical wind farm; small AGW were created by turbines unlike the larger scale AGW in fig. 3.

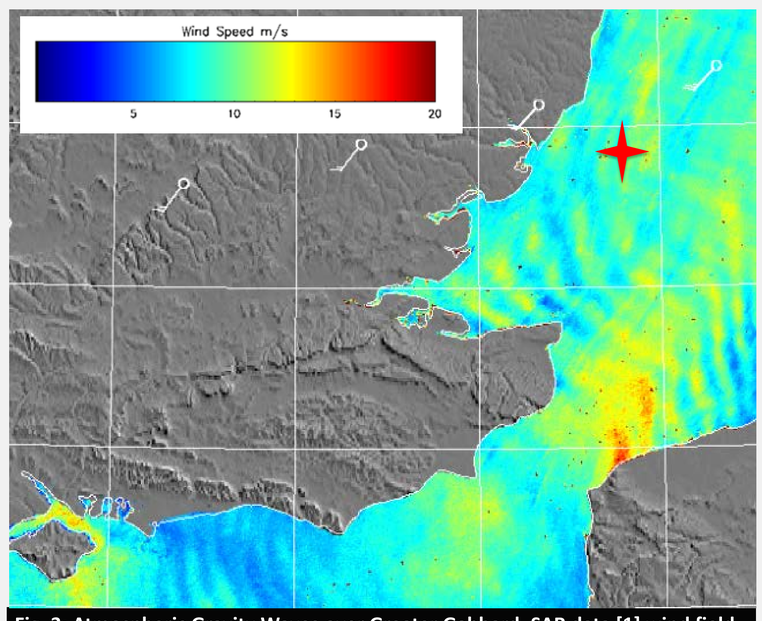

Fig. 3: Atmospheric Gravity Waves over Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

2. Gust front event, estimated single turbine diurnal power output

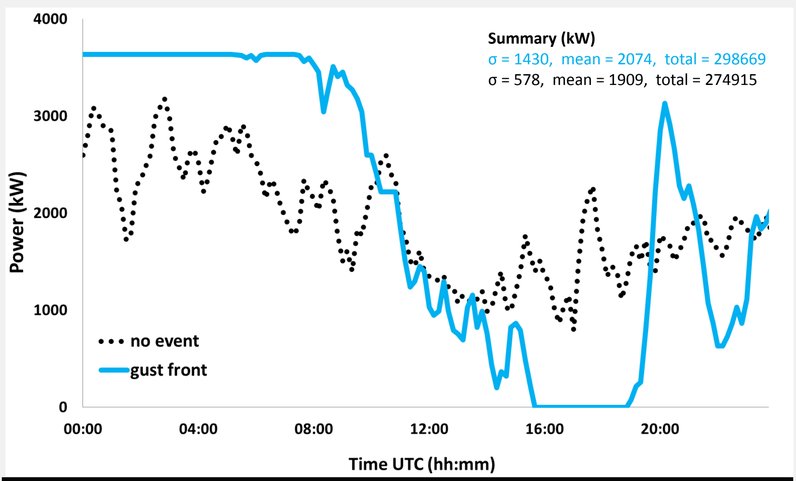

Fig. 4: Estimated power output for a single turbine at Greater Gabbard during the gust front event (fig. 2.)(blue line) compared with a day with no event (dotted line) at the same locatioh. Wind speed data inputs obtained from the Marine Data Exchange [9].

Estimated power output was calculated for a single Siemens 3.6 turbine at Greater Gabbard using meteorological mast data [9].

During the gust event power output is more variable and total power output higher than for a non-event day with a similar average wind speed (fig. 4).

3. Gravity Wave event, estimated spatial variation in power output across a theoretical wind farm

Fig. (5a) shows spatial power variation across a theoretical windfarm based on Greater Gabbard during the AGW event (fig. 3.).

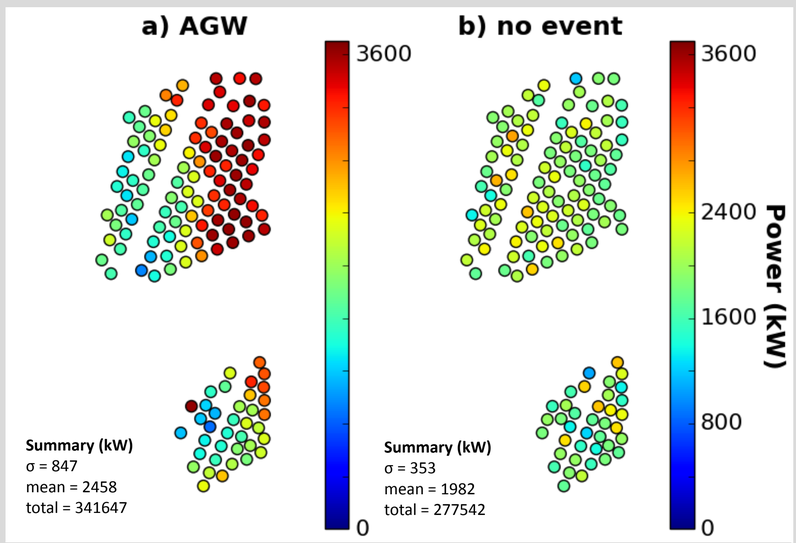

Fig. 5: Power output over theoretical wind farm, each dot represents a turbine and the colour coding represents the power output from an individual turbine. SAR data [1] wind field processing DTU Wind Energy [2].

The theoretical farm uses Greater Gabbard layout in a location clear of turbines to avoid errors in wind speed estimation from SAR introduced by scattering from the turbines.

There is considerably higher spatial variation in power output and a higher total power output for the farm compared with a non-event day with a similar average wind speed (b).

4… Future directions

- SAR and mesoscale model (WRF) based climatology of phenomena around wind farms.
- Analysis of turbine condition monitoring data (SCADA) during events.
- 3D modelling of phenomena-turbine interaction to assess fatigue loading.

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