



Sarah Ollier, Simon Watson
s.ollier@lboro.ac.uk

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).

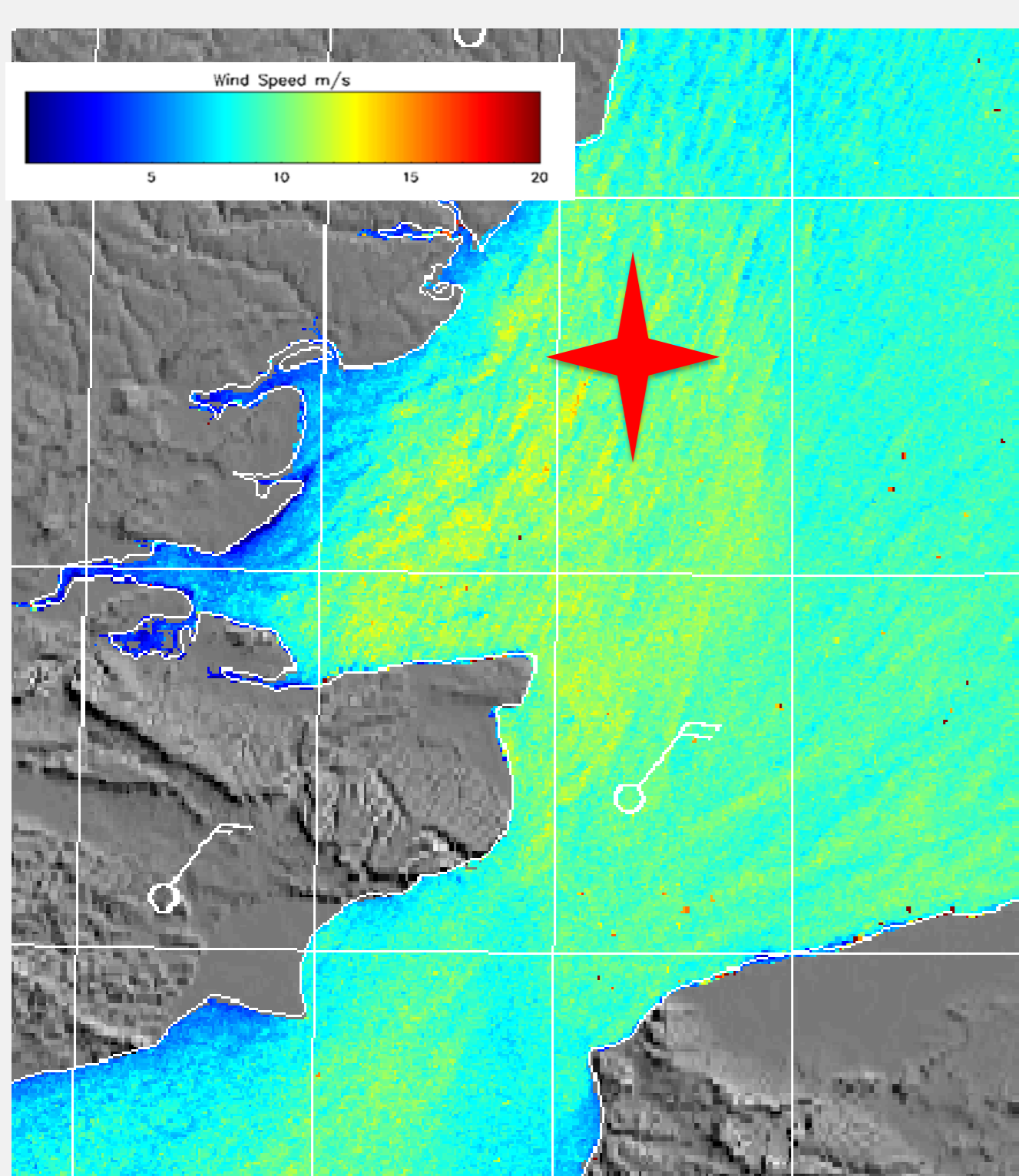


Fig.1: Roll Vortices over Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

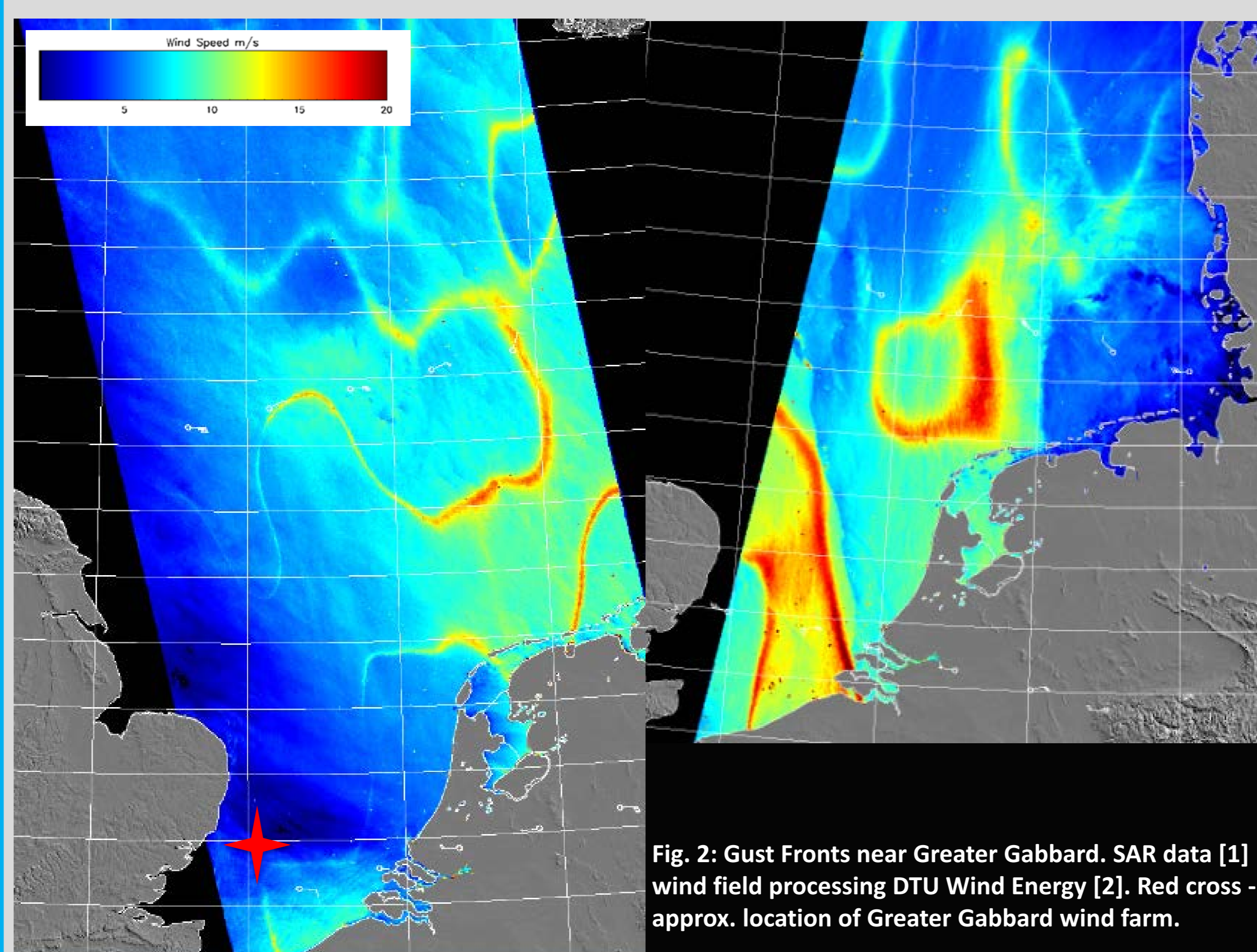


Fig. 2: Gust Fronts near Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

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.

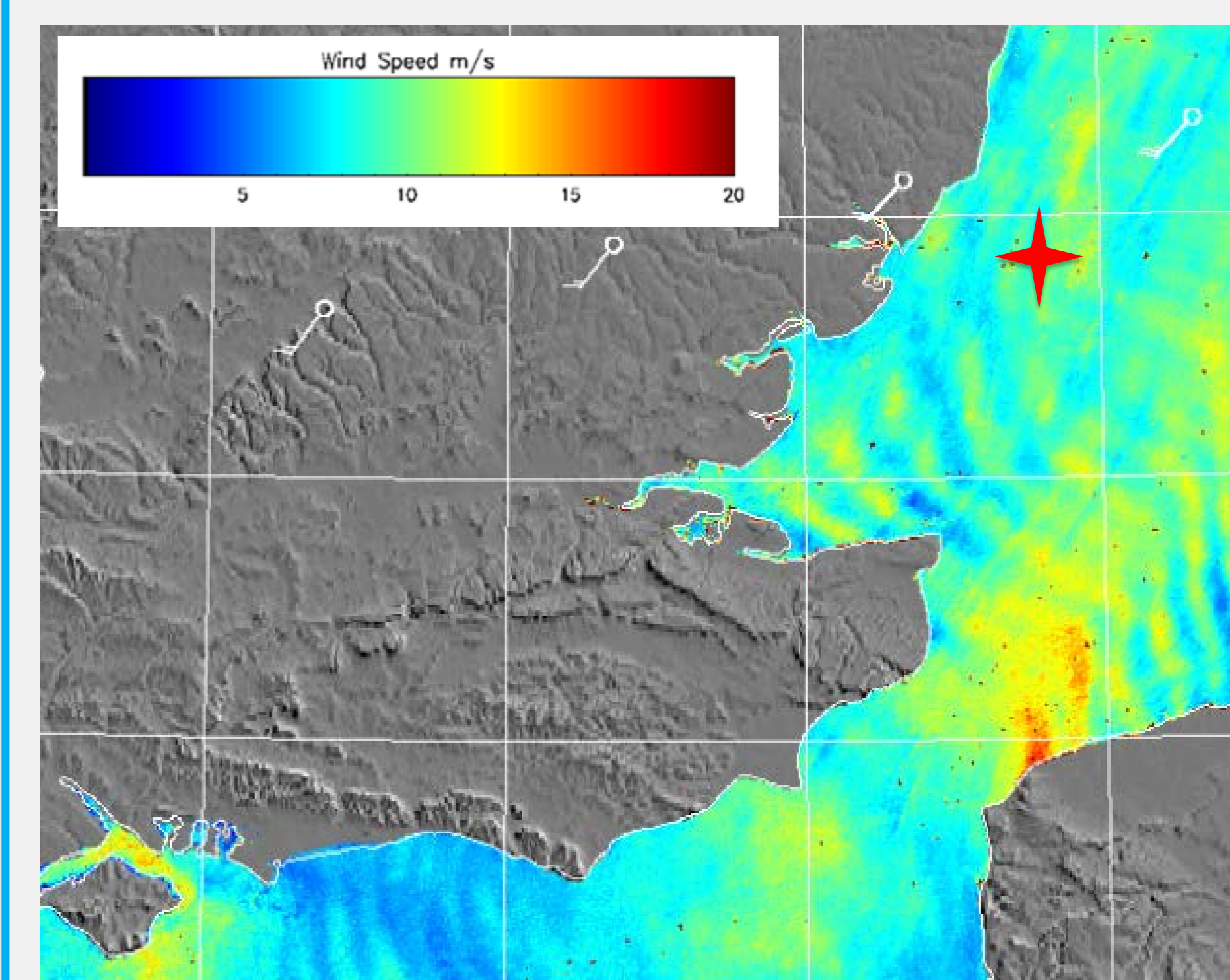


Fig. 3: Atmospheric Gravity Waves over Greater Gabbard. SAR data [1] wind field processing DTU Wind Energy [2]. Red cross - approx. location of Greater Gabbard wind farm.

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

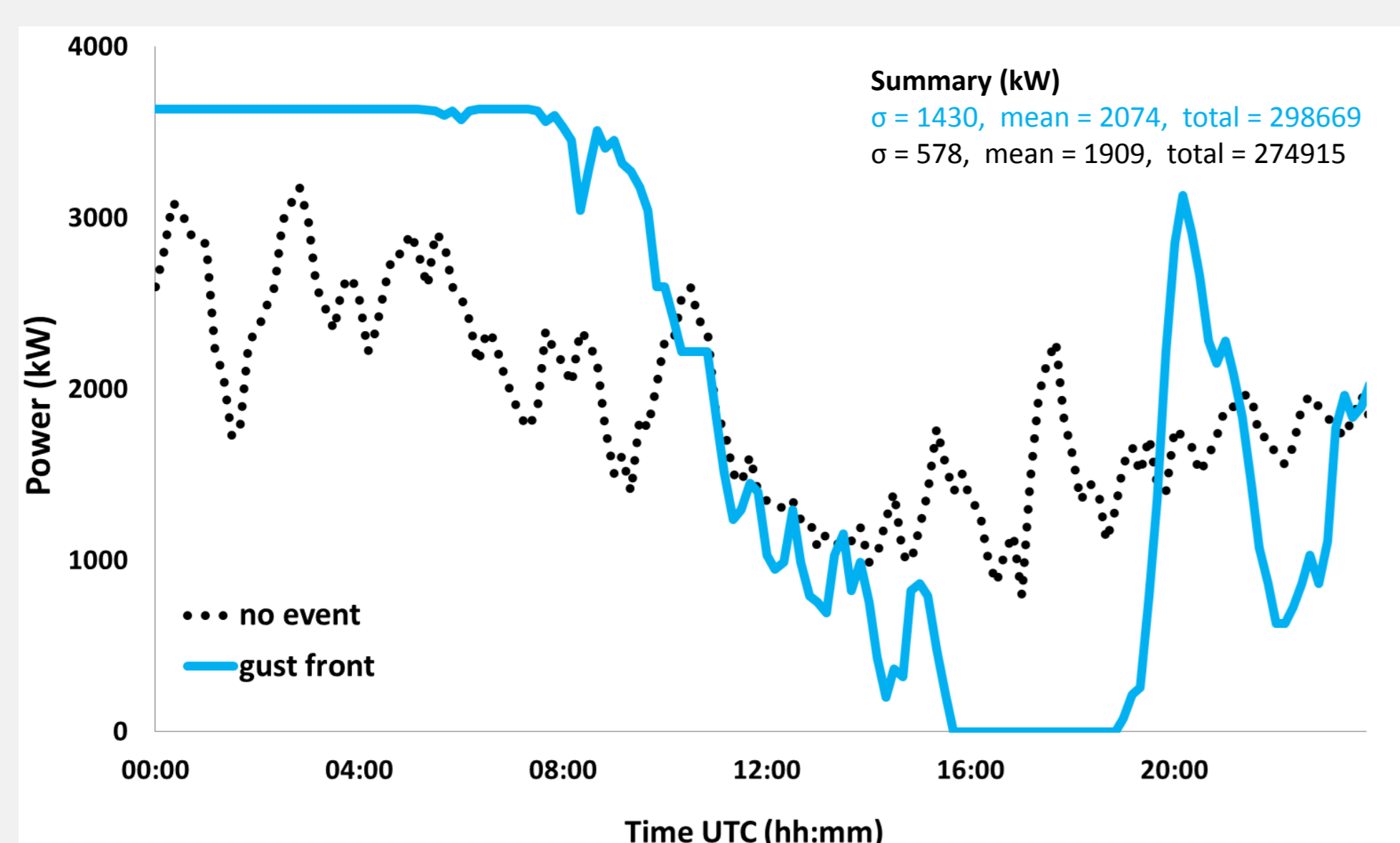


Fig. 4: Estimated power output for a single turbine at Greater Gabbard during the gust front event (fig. 2.)(blue line) compared with a day with no event (dotted line) at the same location. Wind speed data inputs obtained from the Marine Data Exchange [9].

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.).

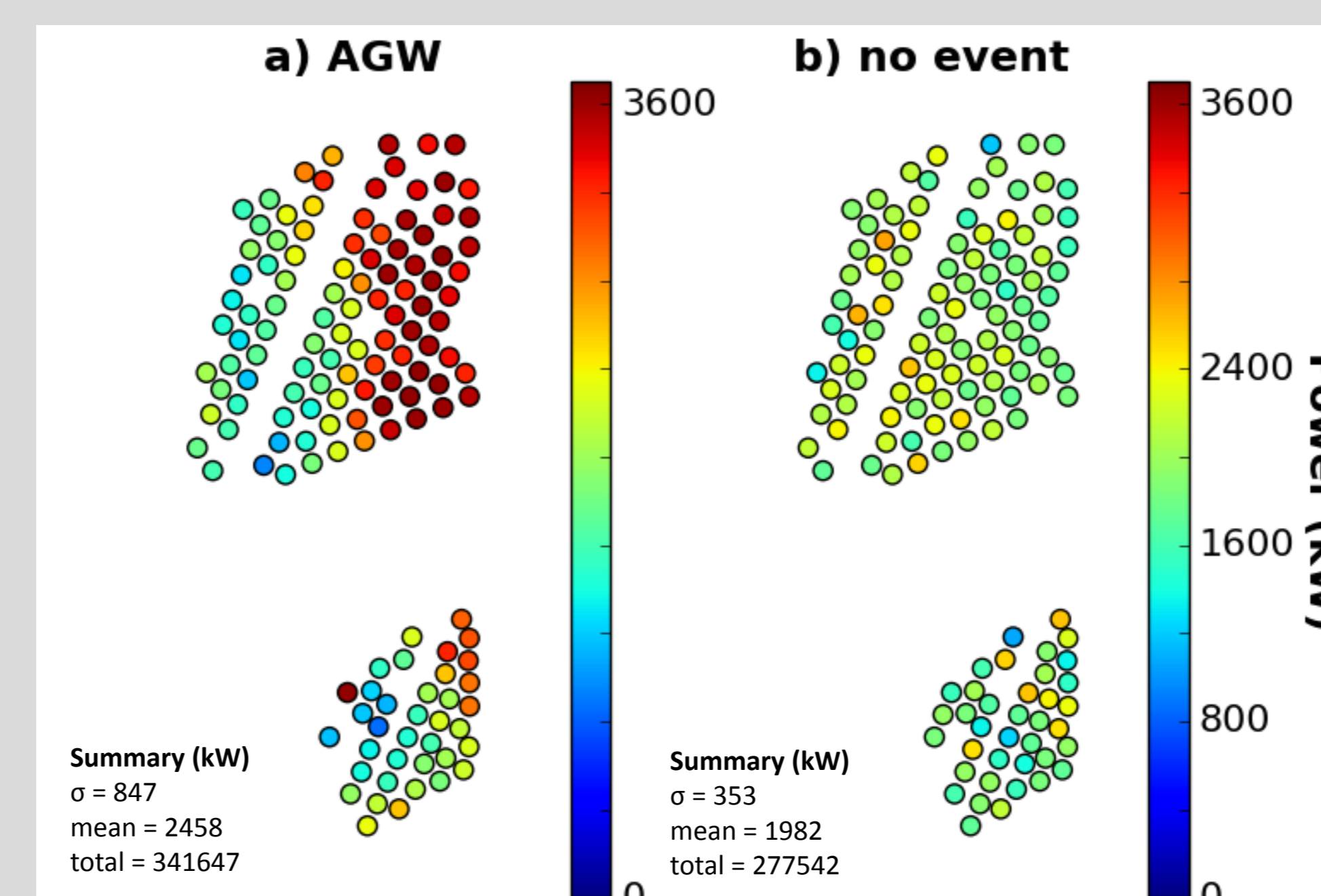


Fig. 5: Power output over theoretical wind farm, each dot represents a turbine and the colour coding represents the power output from an individual turbine. SAR data [1] wind field processing DTU Wind Energy [2].

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.

[1] ESA, "What is Sentinel-1," 2016. [Online]. Available: <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/sentinel-1>.
 [2] DTU-WE, "ENVI-SAR surface wind field processing," Danish Technical University (DTU) Department of Wind Energy, 2016.
 [3] W. Gutierrez, et al., "Structural impact assessment of low level jets over wind turbines," 2016.
 [4] A. Smedman, "Occurrence of roll circulations in a shallow boundary layer," *Boundary-Layer Meteorol.*, vol. 57, no. 4, pp. 343-358, 1991.
 [5] R. B. Smith, "Gravity wave effects on wind farm efficiency," *Wind Energy*, vol. 13, no. 5, pp. 449-458, 2010.
 [6] S. Bruschi, et al., "Synergetic Use of Radar and Optical Satellite Images to Support Severe Storm Prediction for Offshore Wind Farming," 2008.
 [7] K.-F. Dagestad, et al., "Wind retrieval from synthetic aperture radar - an overview," 2013. [8] ESA, "What is Envisat?," European Space Agency, 2016.
 [9] Marine Data Exchange, Greater Gabbard Offshore Windfarm Ltd, Meteorological Mast Data (IGMM2) <http://www.marinedataexchange.co.uk/>