

## Contribution of EO data to offshore wind energy planning

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**Energy is one of the  
GEOSS societal benefit  
areas.**

DTU Wind Energy is one of the founding members of the Wind Energy Community of Practice (WECP) group. It started in year 2005.

Offshore wind energy has had exponential growth during the last 10 years. See Figure 1 for the existing and planned wind farms in the North Sea.

The wind resource is of great importance for planning each wind farm. Satellite remote sensing contributes information of high relevance for the wind industry.

## Wind resource based on satellite SAR

The Aegean Sea is an area with promising wind potential for offshore wind farms. The Greek authorities therefore have focus on this. Figure 2 shows the far future locations.

Envisat Advanced Synthetic Aperture Radar (ASAR) scenes from 10 years have been retrieved, calibrated and processed using the geophysical model function CMOD5.N. Wind direction from a global atmospheric model is used to retrieve wind fields at around 1 km resolution. The 10-m wind mean wind speed map based on SAR is shown in Figure 3.

The extrapolation from 10 m to 100 m is based on atmospheric stability from the Weather Research and Forecasting (WRF) model . The method is described in Badger *et al.* (in review). The 100 m level is chosen because offshore wind turbines will operate at this level. The spatial resolution of the SAR based wind resource map is  $0.02^\circ$  latitude and longitude (Figure 4).

The wind resource offshore in Iceland has been estimated from Envisat ASAR and the results at 10 m are shown in Figure 5 (Hasager *et al.* 2015a).

Scatterometer winds from QuikSCAT has been used in the North Sea for characterizing the offshore wind climate (Karagali *et al.* 2014). Scatterometer wind data has lower spatial resolution but much higher temporal resolution than SAR. The scatterometer data has been combined with satellite SAR data (Hasager *et al.* 2015b). Figure 6 shows a map on the wind energy density in the North Sea combined from QuikSCAT, ASCAT and Envisat ASAR.

## Wind farm wake observed from satellite SAR

Wind farms offshore are large and closely spaced. This is to ensure good use of electrical grid infrastructure and at the same time have large capacity. In this way much electricity is delivered from the wind farm clusters to consumers.

The wind farm wake (shadow effects) between wind farms is investigated from satellite SAR. Wind farm wakes several kilometers long are observed, see Figure 7. The comparison to wake models is published in Hasager *et al.* (2015c).

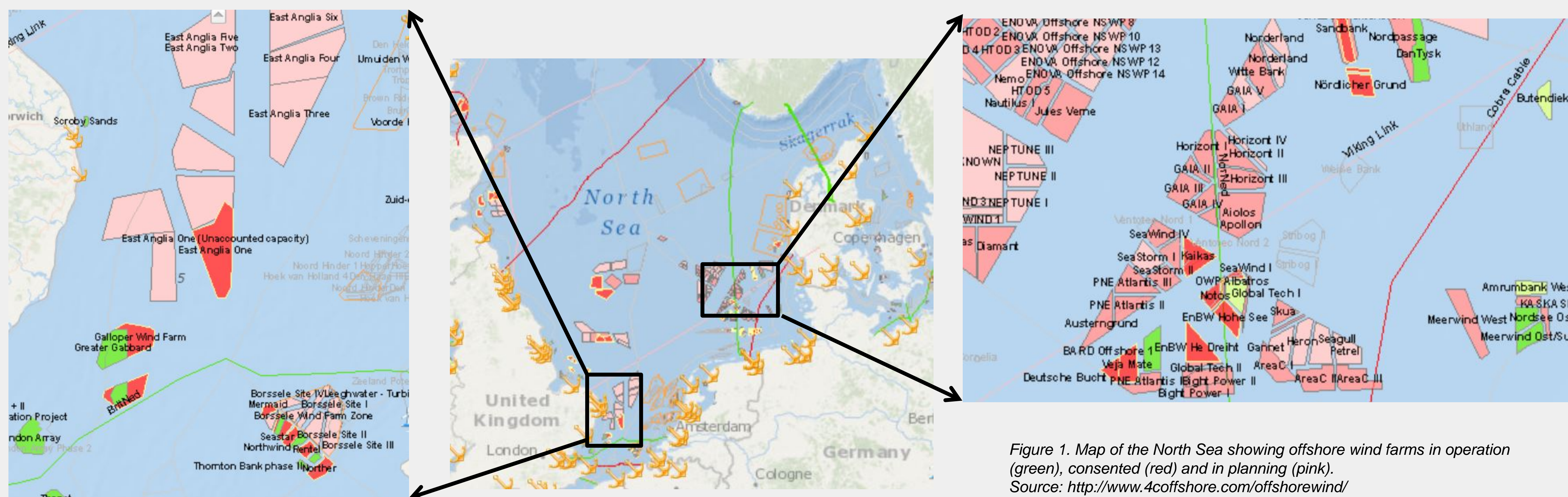


Figure 1. Map of the North Sea showing offshore wind farms in operation (green), consented (red) and in planning (pink).  
Source: <http://www.4coffshore.com/offshorewind/>

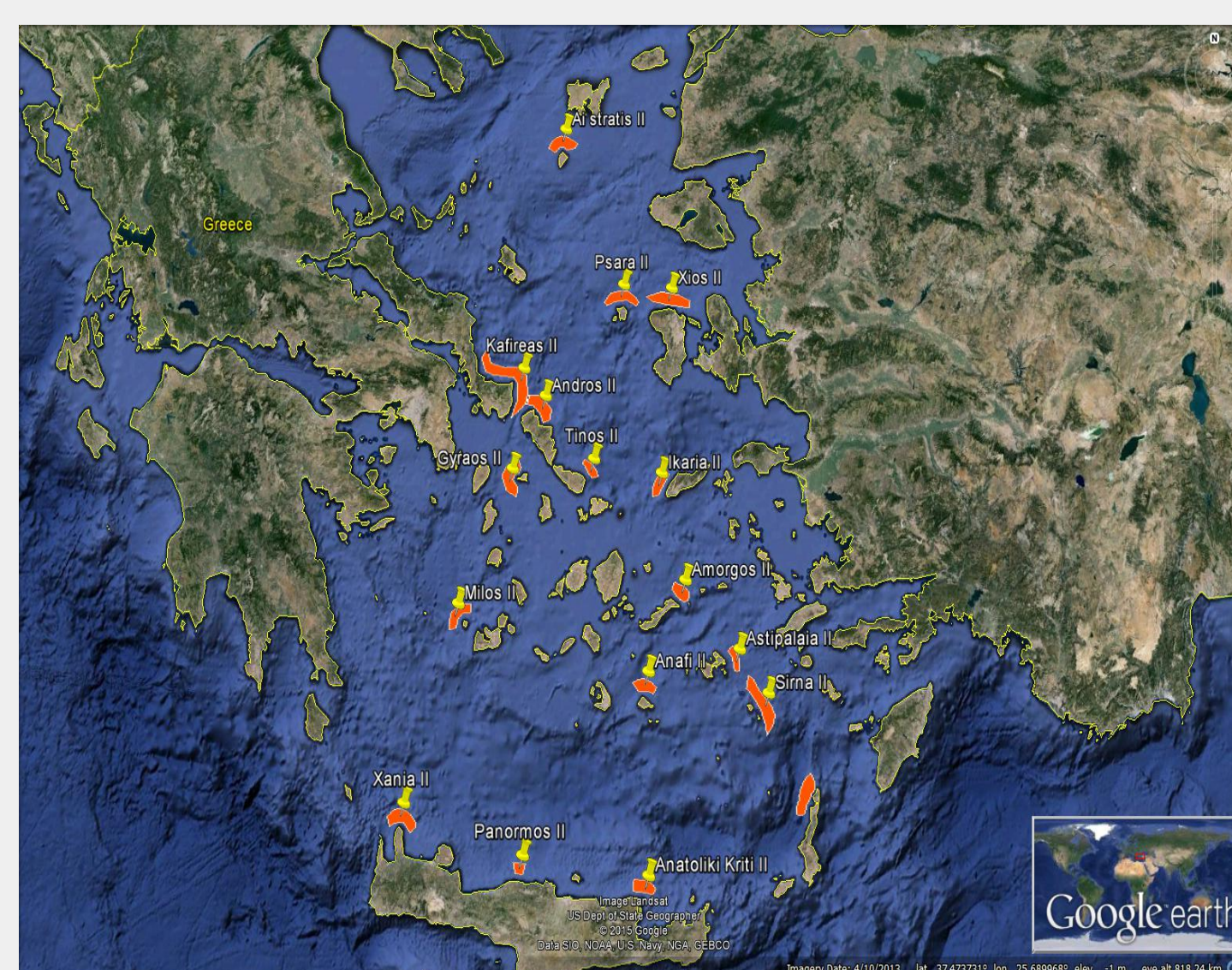
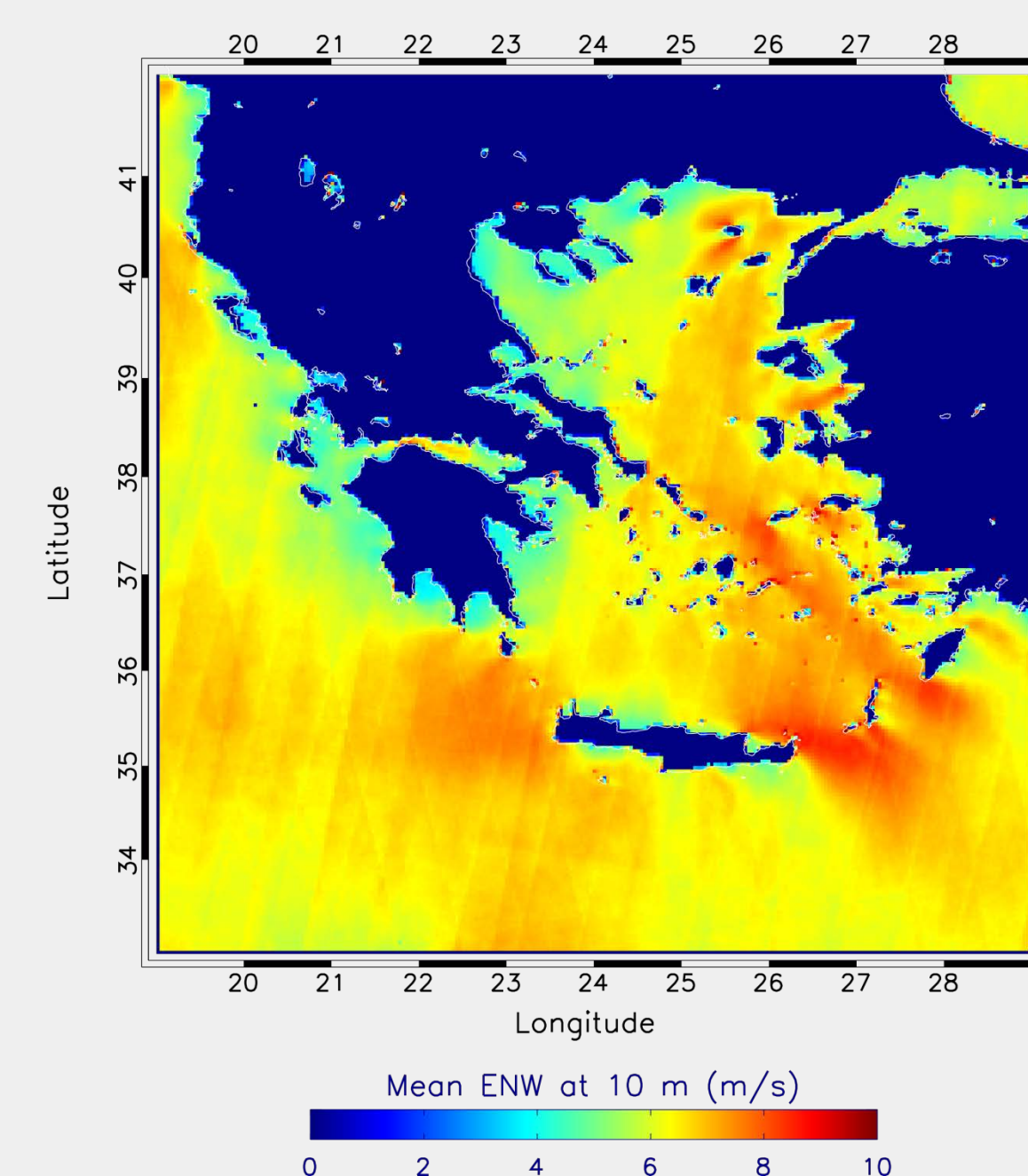
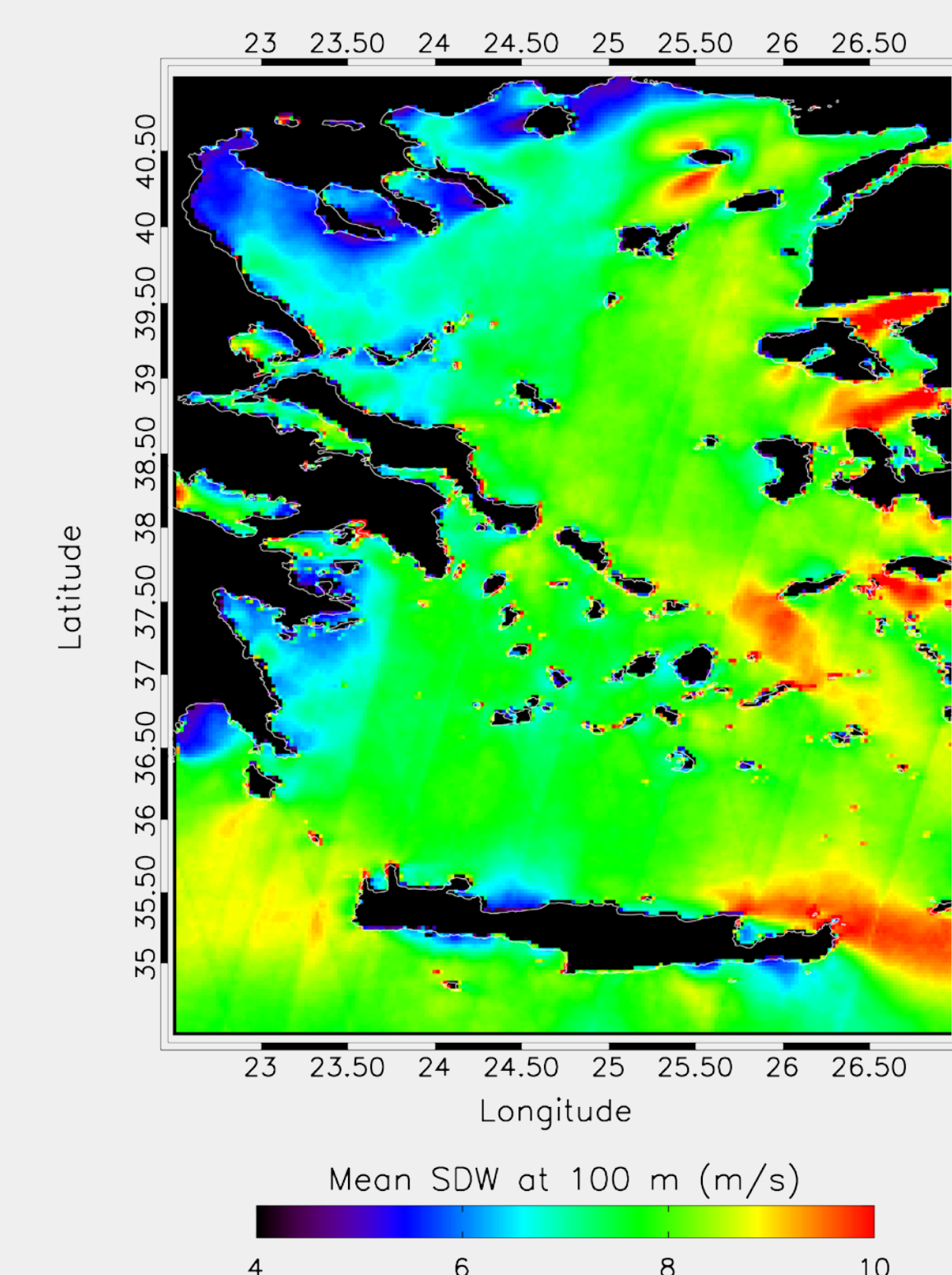


Fig. 2. Map showing the Phase II wind farm locations in the Aegean Sea. Image courtesy Google Earth.

*The work is carried in the ESA ResGrow project.*



*Fig. 3. Map showing the mean wind speed (Equivalent Neutral Winds, ENW) at 10 m height from Envisat ASAR for the longitude range 19-29°E and the latitude range 33-42°N.*



*Fig. 4. Map showing the mean wind speed extrapolated to the 100-m level taking atmospheric stability effects into account. This gives the Stability Dependent Wind speed (SDW). The applied long-term atmospheric stability correction is calculated from WRF output data.*

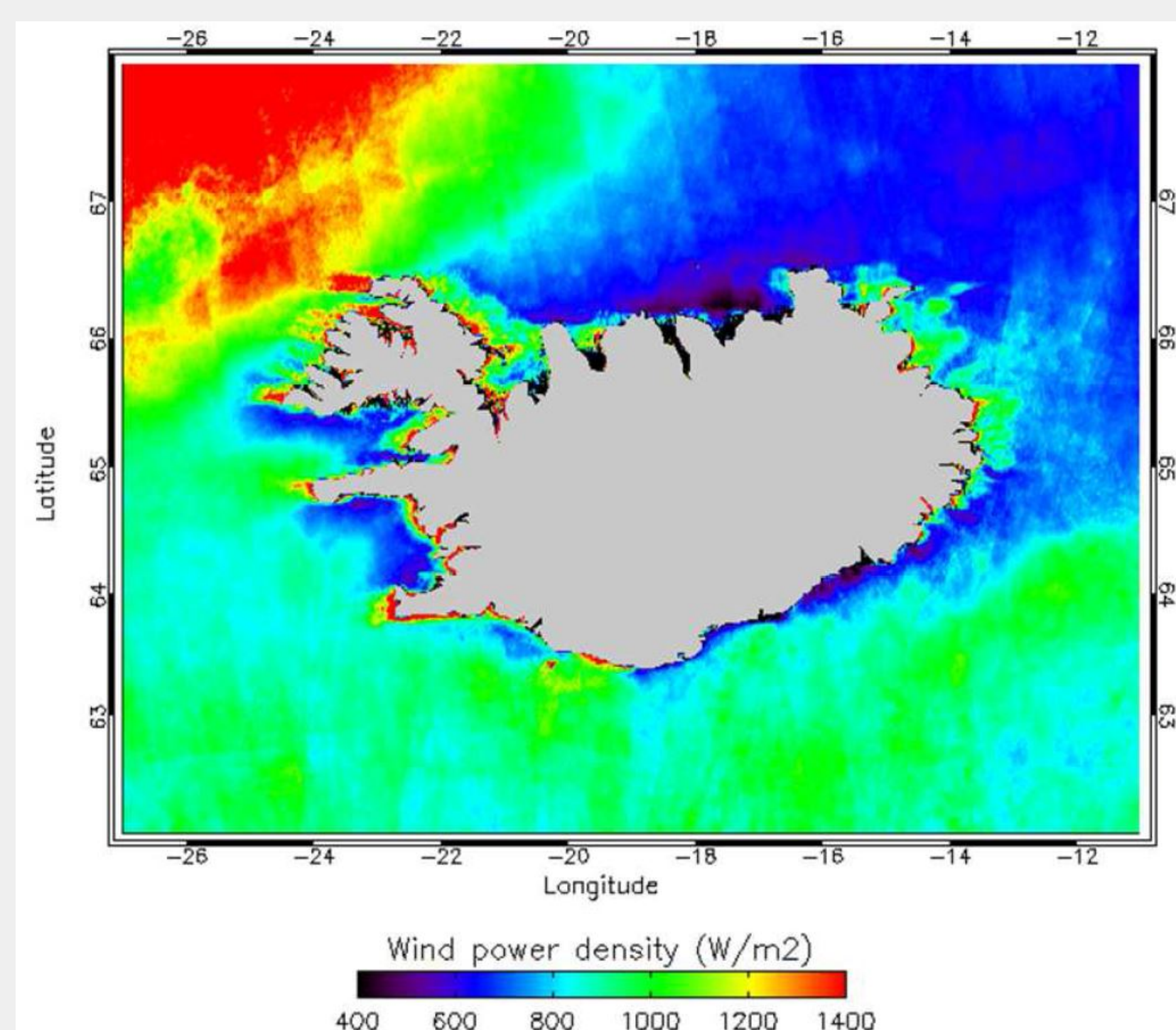


Figure 5. Offshore wind energy density at 10 m level in Iceland based on Envisat ASAR.

The work is from the ICEWIND project.

Published in Hasager *et al.* 2015a.

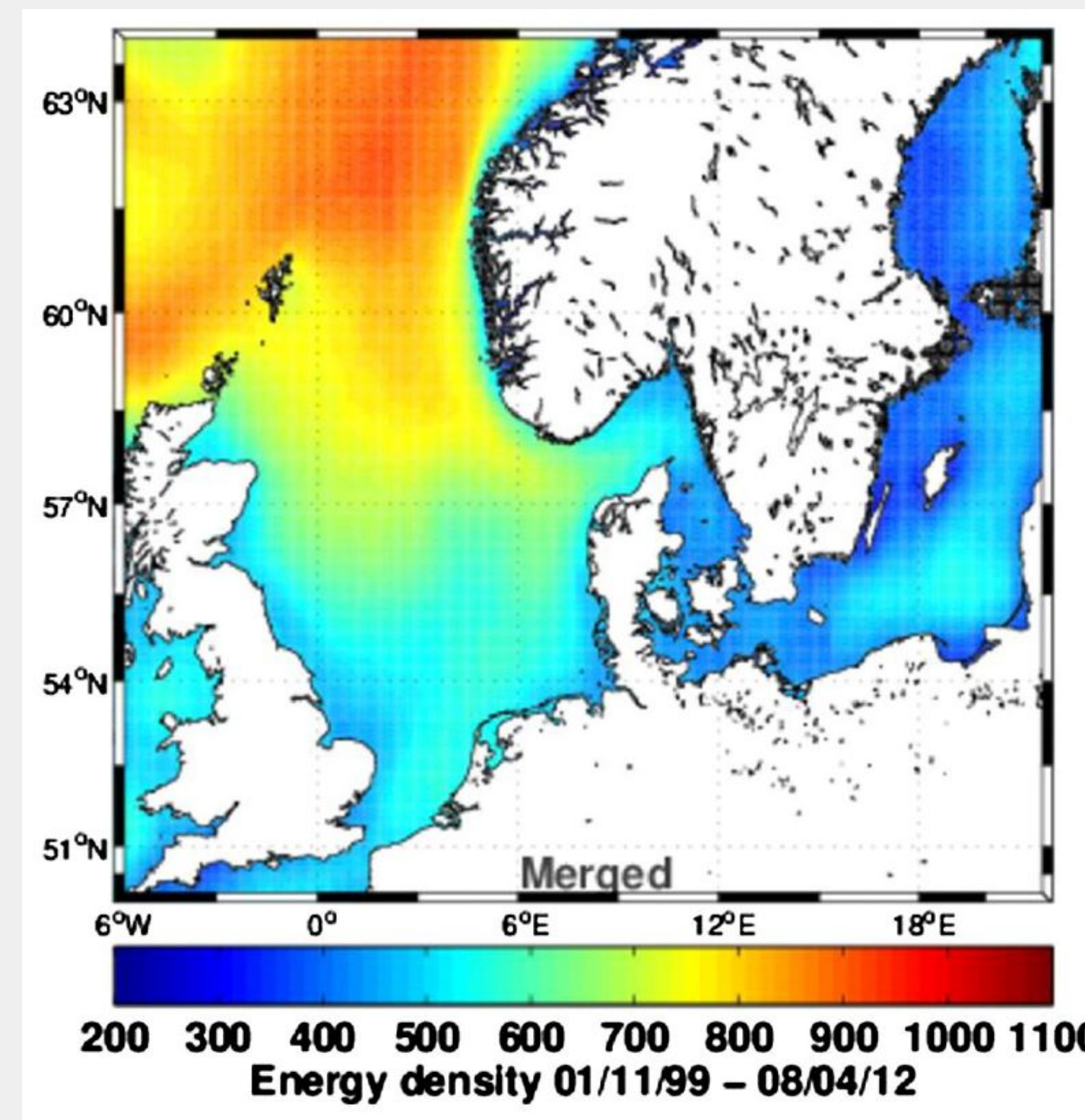


Figure 6. Synergetic use of Envisat ASAR (2002 to 2012), ASCAT (2007 to 2008) and QuikSCAT (1999 to 2009) for the Northern European Seas: wind energy density  $Wm^{-2}$ .

The work is from the EU NORSEWInD project.

Published in Hasager *et al.* 2015b.

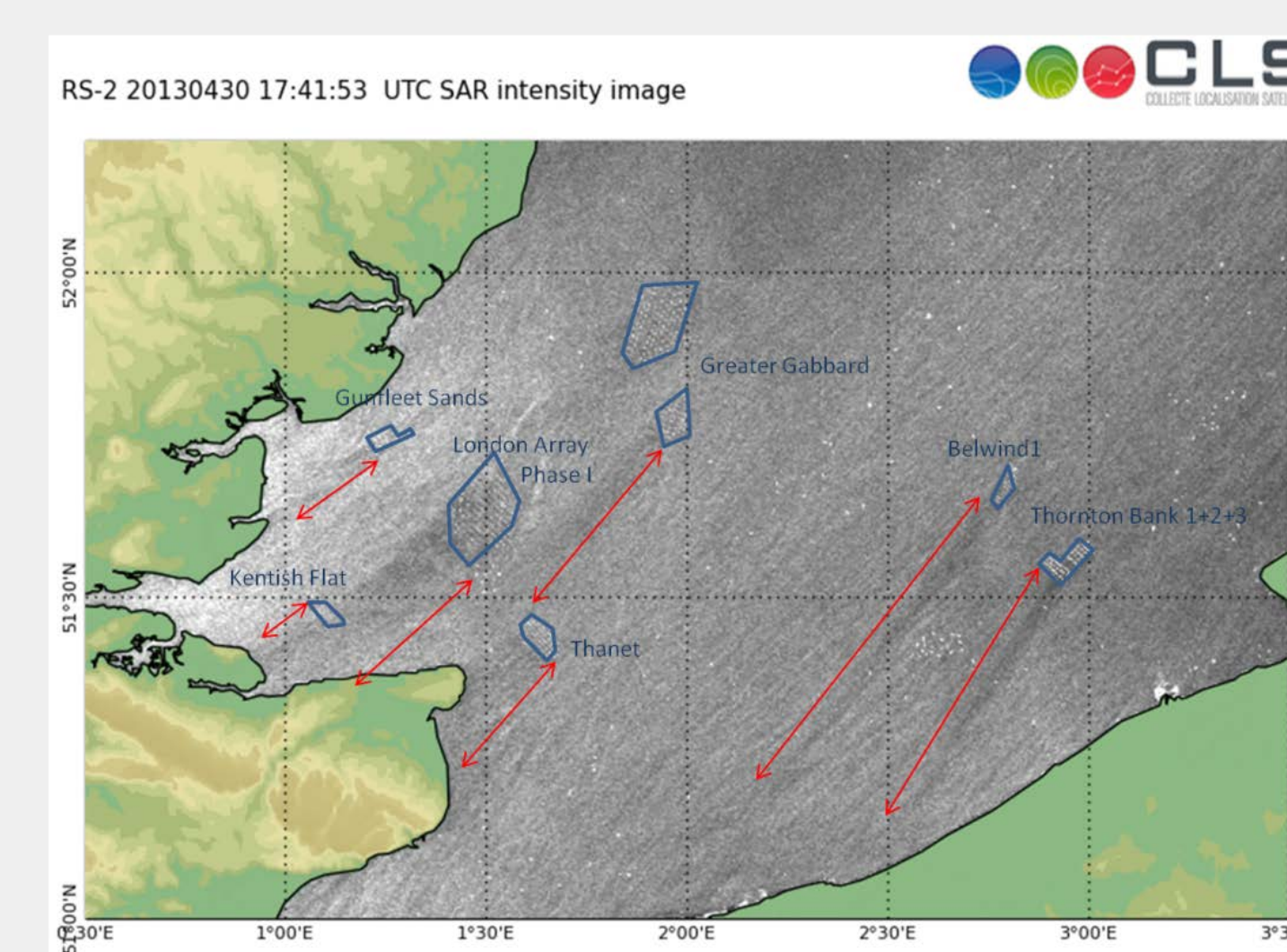


Figure 7. RADARSAT-2 intensity map of the southern North Sea observed 30 April 2013 at 17:41 UTC. The blue lines outline wind farms and the red arrows the wind farm wake.

The work is from the EU EERA DTOC project.  
The RADARSAT-2 image has been processed at CLS by Romain  
Husson, Pauline Vincent and Alexis Mouche.

Published in Hasager *et al.* 2015c.

**References:** Badger, M., Peña, A., Hahmann, A.N., Mouche, A., Hasager, C.B. (2015) Extrapolating satellite winds to turbine operating heights. *JGR Oceans* (in review)  
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