GIS-modeling of radar detection coverage and ground clutter within the complex environment of Smøla wind-power plant

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The goals and purposes of this work

Our main goals has been to develop a GIS- model for line-of-sight studies and ground clutter modeling in order to optimize the localization of a bird radar inside the Smøla wind-power plant.

An optimal radar location is where the radar sees little land clutter, while maintaining a good, unobstructed view to the area of interest. These are often conflicting requirements and usually a compromise has to be found.

The purpose of our work is therefore for any given radar location:
* To identify areas where the surface will be visible to the radar
* To create line-of-sight studies at different altitudes
* To model the land surface reflectivity inside the ground clutter areas

In this way a theoretical evaluation of new sites can be performed, and the best alternative chosen, without having to move the radar equipment around and perform several live tests to find the most optimal radar location.

The challenges

Using a radar inside such a complex environment as a wind-power plant represents several challenges. In addition to static ground clutter the wind turbines themselves are sources of radar interference of quite a particular kind. Each turbine gives a large echo which is strong enough to leak through the sidelobes of the antenna causing a ring-like clutter trace to appear.

But the most severe clutter from the wind turbines is the stripe of ground clutter behind each turbine. This clutter is caused by energy which is reflected off the nacelle and blades towards the ground behind the turbine, and takes the same way back to the radar. This clutter varies with the angle of the nacelle in relation to the fluctuating wind directions and is seen to flicker with the position of the turbine blades.
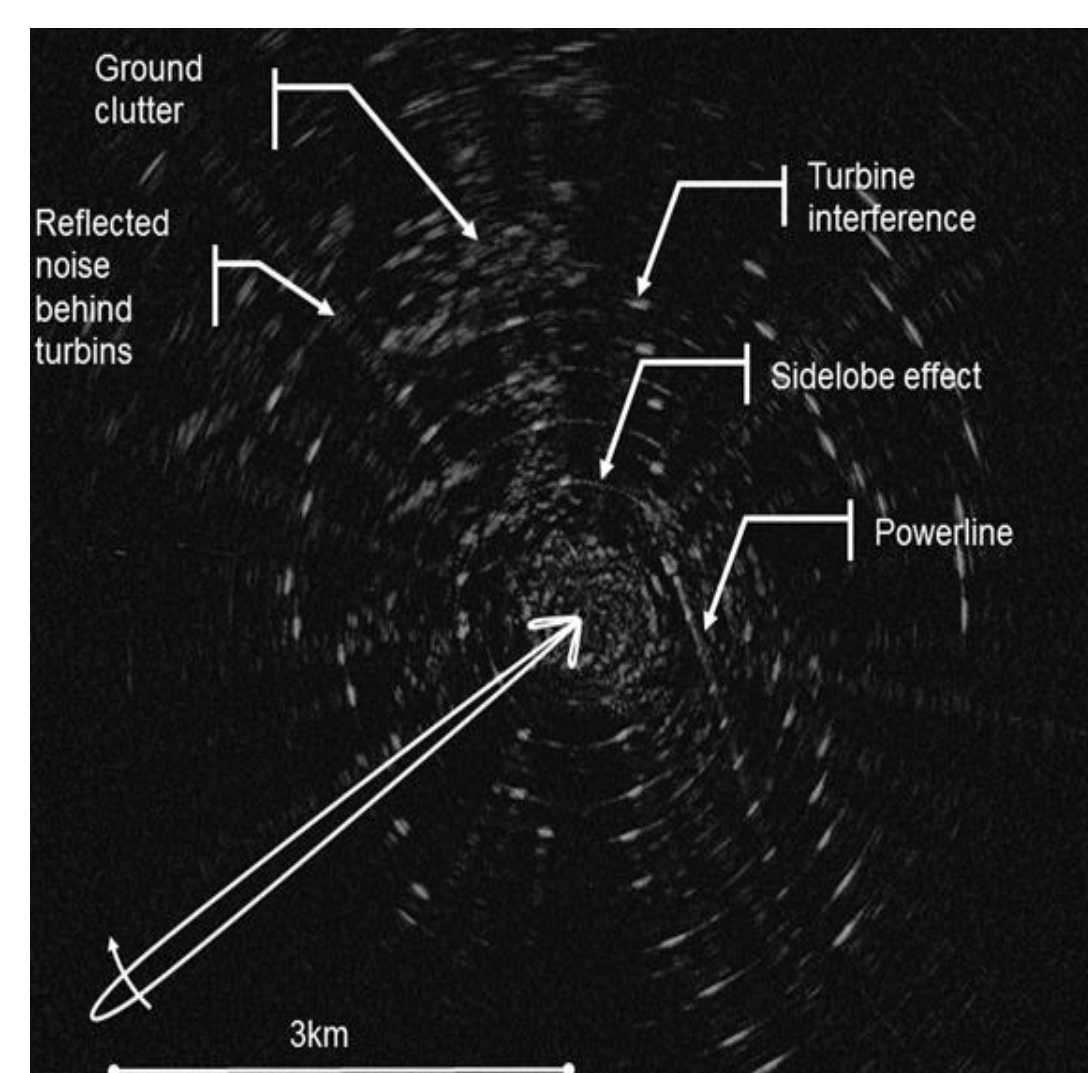

Figure 1: Radar-induced clutter

The GIS- model

The GIS- model was developed in Modelbuilder using ESRI ArcGIS 10 (ArcInfo and Spatial Analyst). Model inputs has been a high resolution DTM based on LIDAR, a land cover map and the radar position (XYZ). The model first performs a series of viewshed analyses to identify theoretical ground clutter areas and line-of-sight visibility from the radar. The modeled clutter areas is imported into the radar detection database as a clutter mask. The clutter mask is used to help interpret the radar data automatically detected and recorded in the Horizontal S-band radar SQL-database. The land surface reflectivity of each radar resolution cell, which multiplied with the cell area, gives the resolution cell Radar Cross Section (RCS), and hence the ground clutter echo level. The land surface reflectivity was estimated using the simple «constant gamma» model

$\sigma^0 = \gamma \sin(\psi)$, where γ is the scattering effectiveness of the land cover and ψ is the grazing angles at the land surface in each radar resolution cell.
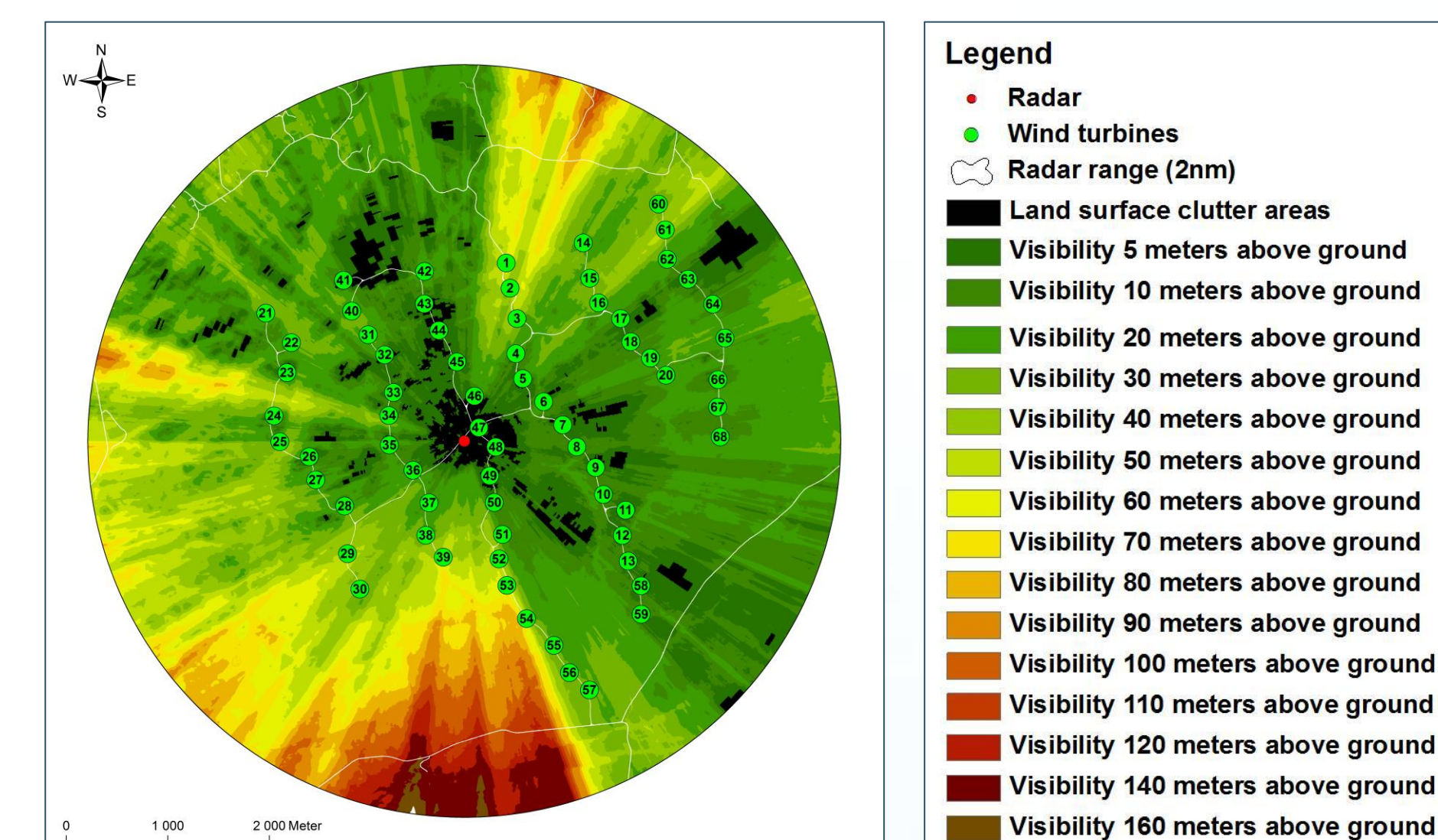

Figure 2: Line-of-sight study. The colors indicate the minimum elevation above ground for a target to be visible to the radar at the given position (red dot).

Validating the model against the radar clutter map

The line-of-sight study has been validated in several radar calibration campaigns at Smøla using ground- truthing and a remotely controlled model airplane equipped with GPS.

The modeled ground clutter (figure 3) seem to underestimate clutter compared to the radar-detected clutter map (figure 4). It is hard to validate the model statistically against the radar detected clutter map because of the great complexity of the sources of radar interference inside the Smøla wind-power plant. Also the model only includes a very simple method to account for refractivity and diffractivity effects. Last, but not least, could potential errors in the model inputs (the DTM and the land cover map) influence the model output.

The model does not include turbine interference, sidelobe effects or interference with elevated infrastructures such as buildings and power-lines etc. To compensate for the reflected noise behind turbines the model outputs shadowed areas behind the turbines as a general estimate of this type of clutter (see figure 3). This is a very simplified approach that has to be refined.

Conclusions

Even though there are some underestimations compared to the radar detected clutter complexity, the model correlates spatially relatively well with the radar detected ground clutter. The model is easy to perform and very useful in terms of finding suitable radar locations with a minimum of ground clutter while maintaining the required coverage.
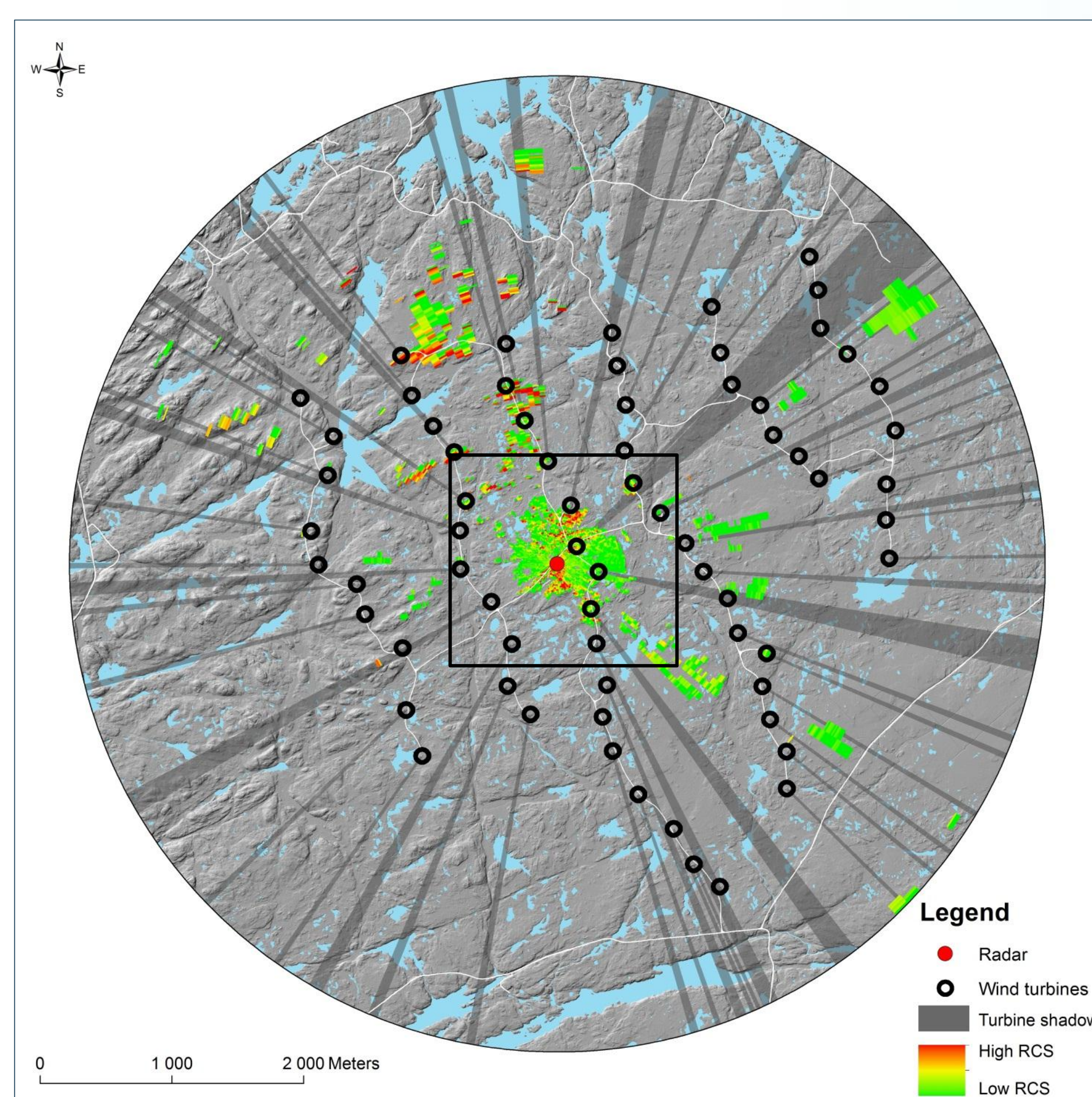
Acknowledgements

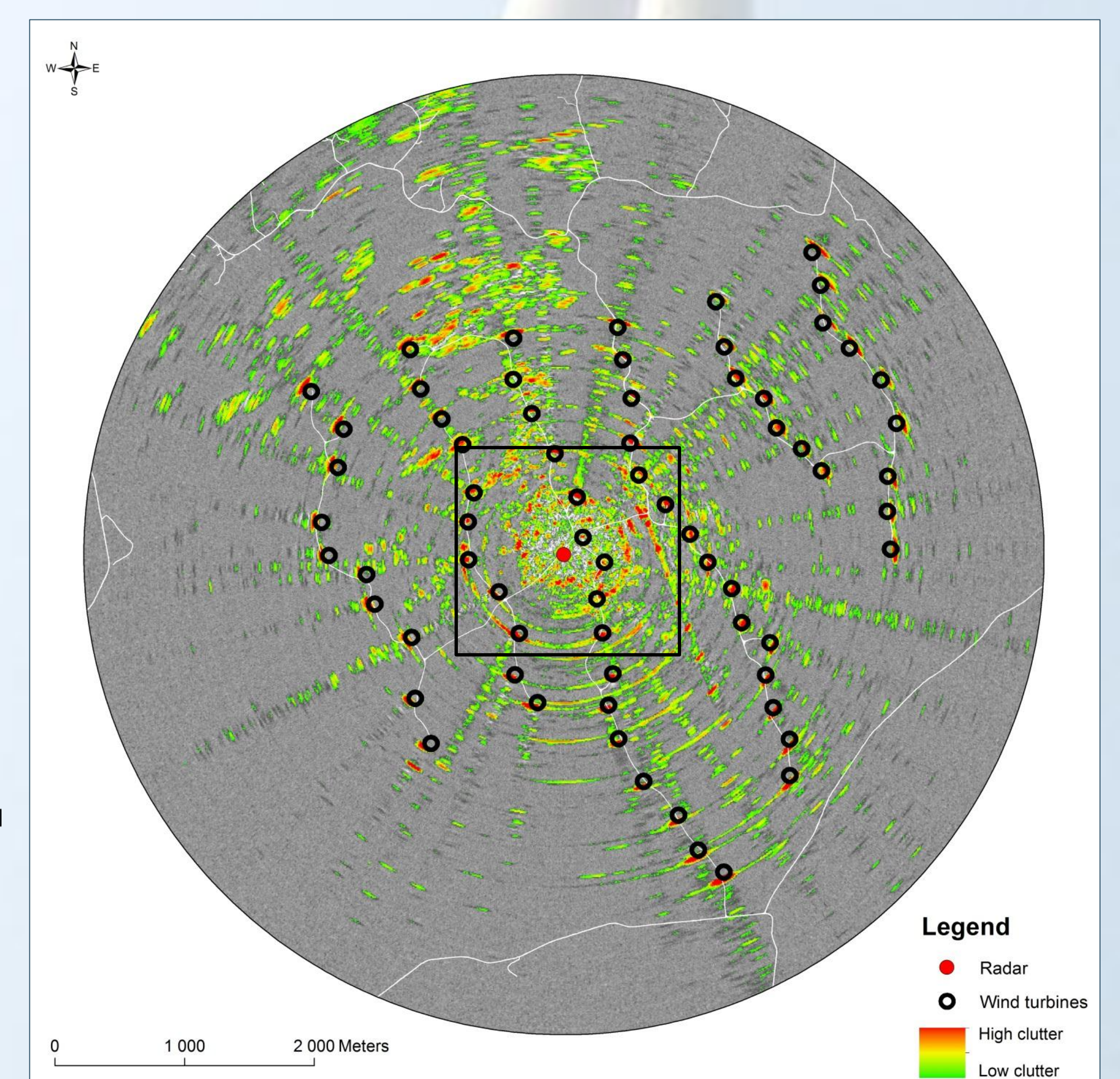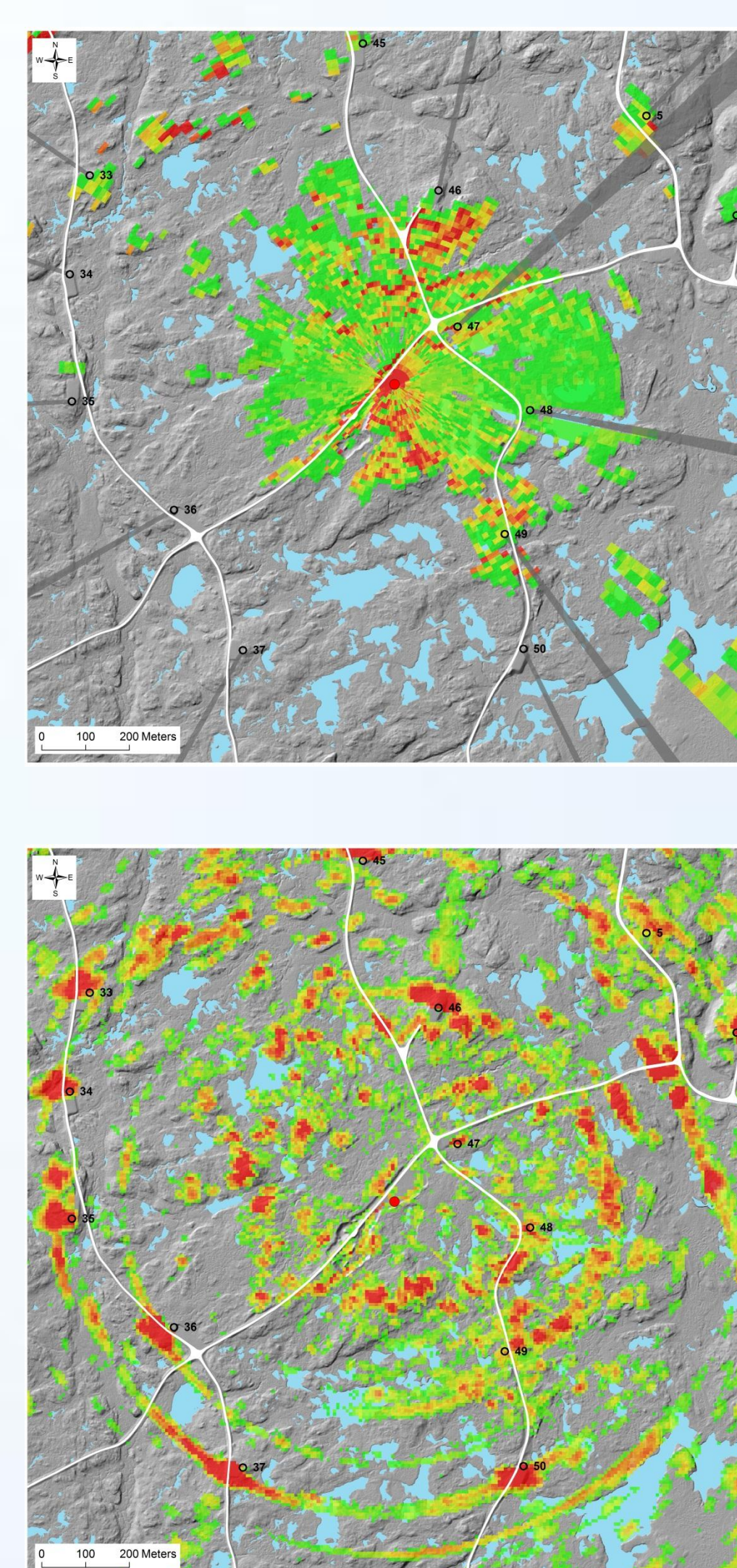*Figure 3: Modelled ground clutter echo level (RCS) and turbine shadows.*

Figure 4: Radar detected clutter map. Grey colors are excluded background clutter.

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