The leading edge of wind turbine rotor blades is particularly susceptible to degradation caused by local impacts such as rain, hail, sand, or insects. Even small surface imperfections, including early-stage erosion or contamination by insect debris, can induce premature laminar–turbulent transition and flow separation. These effects can result in significant aerodynamic performance losses, reaching up to 25%. In addition, the progressive growth of surface defects increases the risk of fatigue damage. Consequently, the early and reliable detection of localized surface defects – including their position, shape, and size – is of great importance. This project aims to investigate the influence of localized surface disturbances on boundary layer flow and to exploit the resulting flow signatures as an indirect measurement principle for detecting rotor blade defects. The envisioned approach enables in-process assessment of blade condition on operating wind turbines without blade modification and from large stand-off distances. The core of the project is the development of an inverse model that connects defect properties of disturbance elements (such as shape, height, aspect ratio) to measurable features in the downstream flow field. The underlying cause-effect relationships and their sensitivity will be established using high-fidelity direct numerical simulations (DNS) supported by wind tunnel experiments. The requested computing time is essential to resolve the complex, transitional boundary layer dynamics and to systematically explore the parameter space of disturbance geometries and flow conditions. The results will quantify the fundamental potential of infrared thermography for indirect defect characterization on wind turbine blades and advance the physical understanding of disturbance-induced transition mechanisms in boundary layer flows.