Forecasting Wind Ramps with Scanning Lidar to Minimize Wind farm safety and energy Imbalance Costs

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AGENDA

- Wind Ramps Impact
- Solution and technology overview
- Wind ramp examples
- Gust detection algorithm
- Comparison methods and results
- Evaluating benefits for a new project
- Conclusion



What is a wind ramp ?

Detecting wind variations ahead of — and around — a wind farm protects revenue, assets, and people.



Why minute-scale wind ramps matter

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.



Energy Trading

Spot & reserve markets

cause production – forecast mismatches, leading to grid imablance penalties, higher costs and revenue losses



Grid Stability (TSOs)

Reliable grid operations

Accurate short-term ramp forecasts cut grid balancing effort, support frequency stability, and unlock higher wind penetration on the network



Asset & Operations

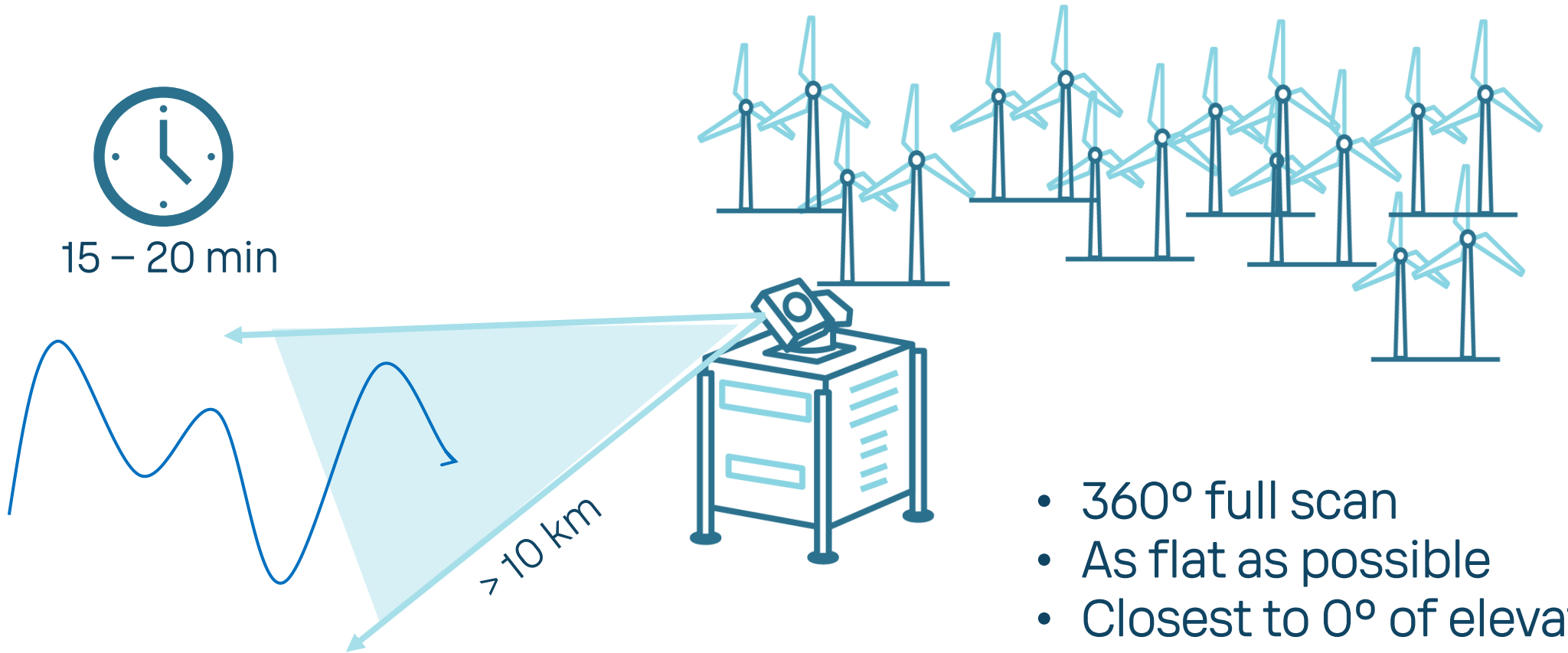
Loads, fatigue & lifespan

Increase turbine loads, raising the risk of damage and sortening equipment life
Accurate short-term wind monitoring secures safer lifting and craning operations and helps optimize work windows

Internal

Lidar-based short-term forecasting solutions

Detecting wind variations ahead of — and around — a wind farm protects revenue, assets, and people.



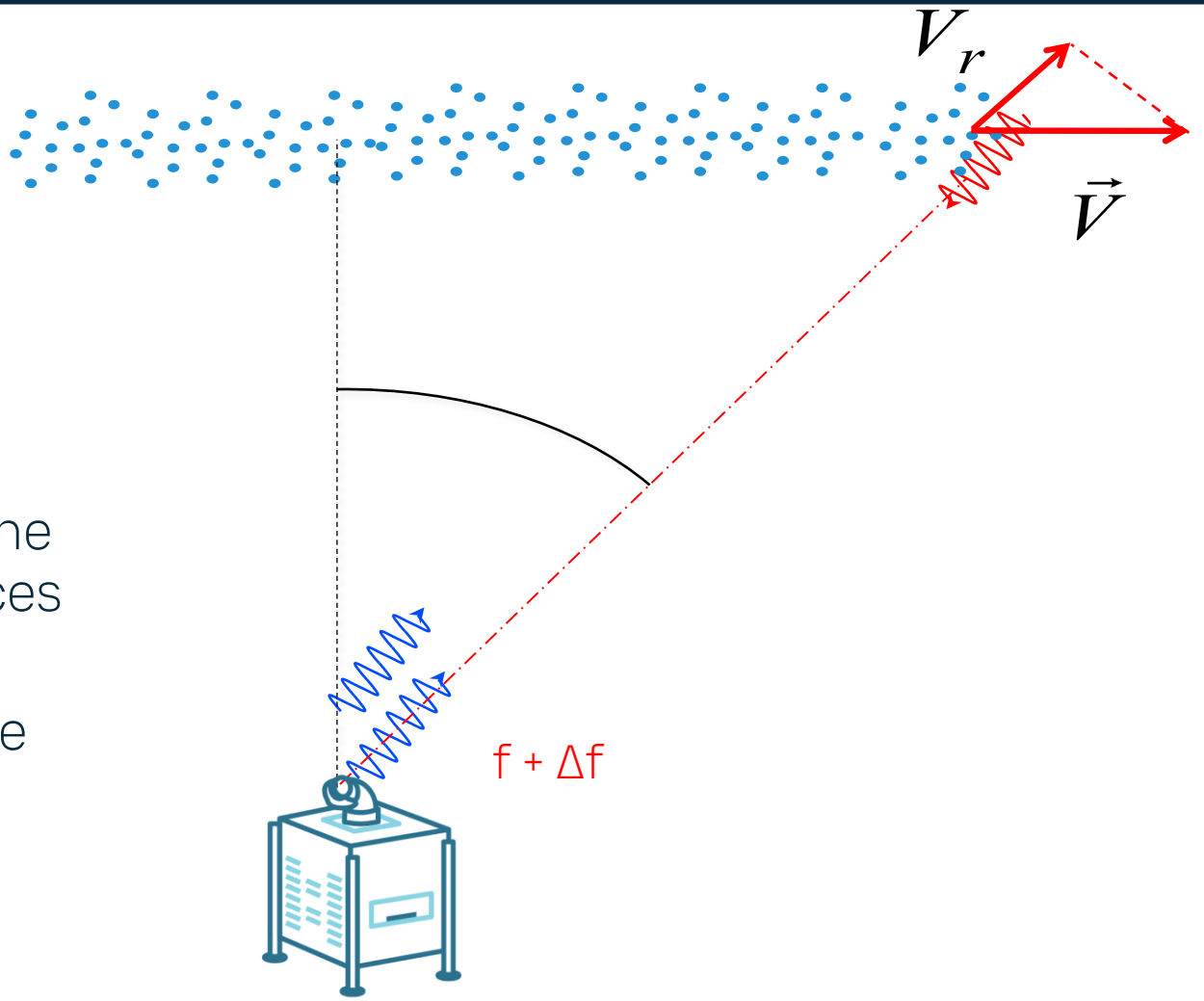
- 360° full scan
- As flat as possible
- Closest to 0° of elevation
- 1 minute per scan

Internal

Doppler pulsed Lidar

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

- The laser beam is emitted into the atmosphere
- Light is scattered by moving aerosols
- Backscattered signal is collected by the lidar and processed at several distances simultaneously.
- The doppler shift is proportional to the radial wind speed.



Internal

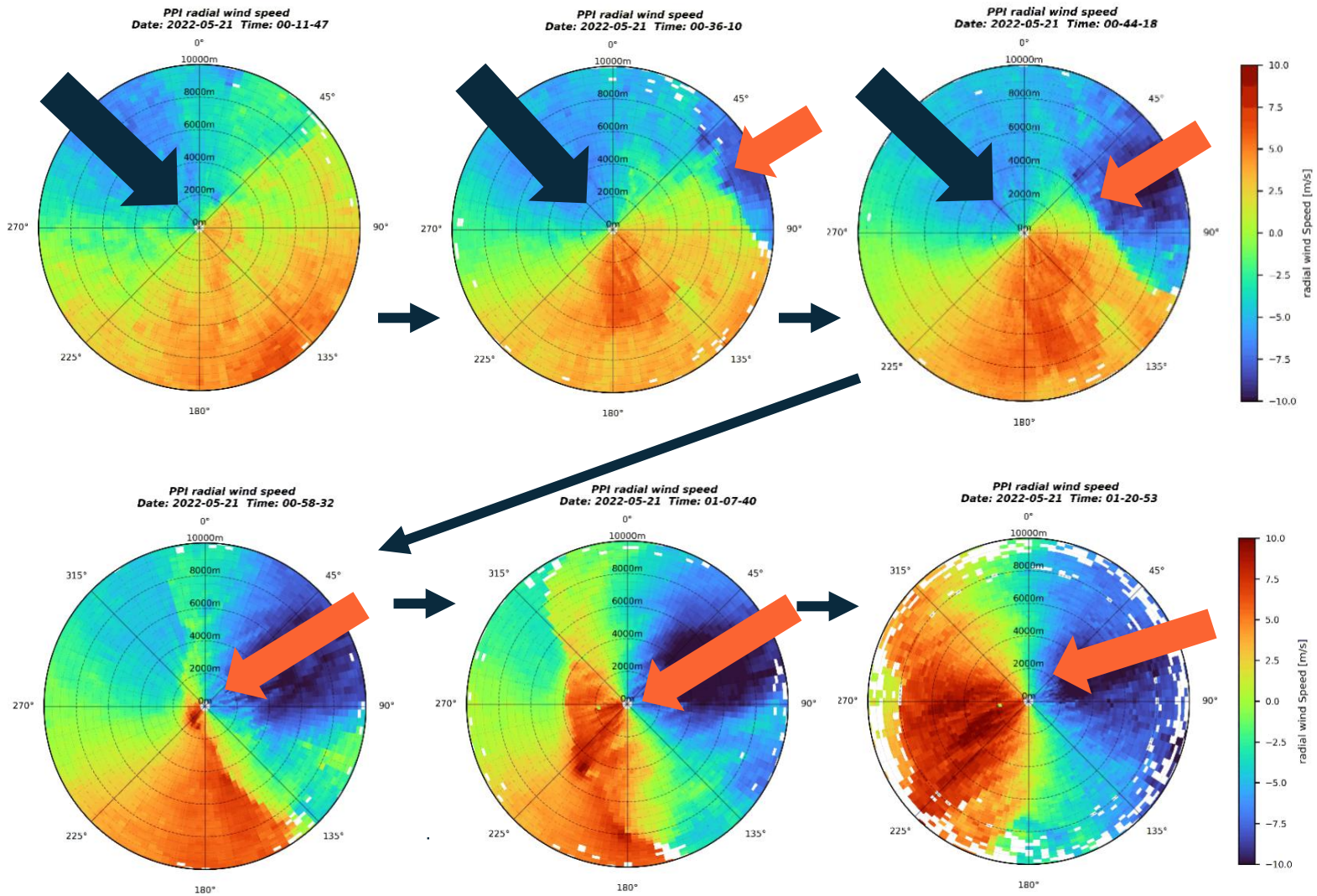
Space & time coherent variations captured by a WindCube Scan

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

Blue arrow: Wind direction before the weather front

Red arrow: Wind direction after the weather front

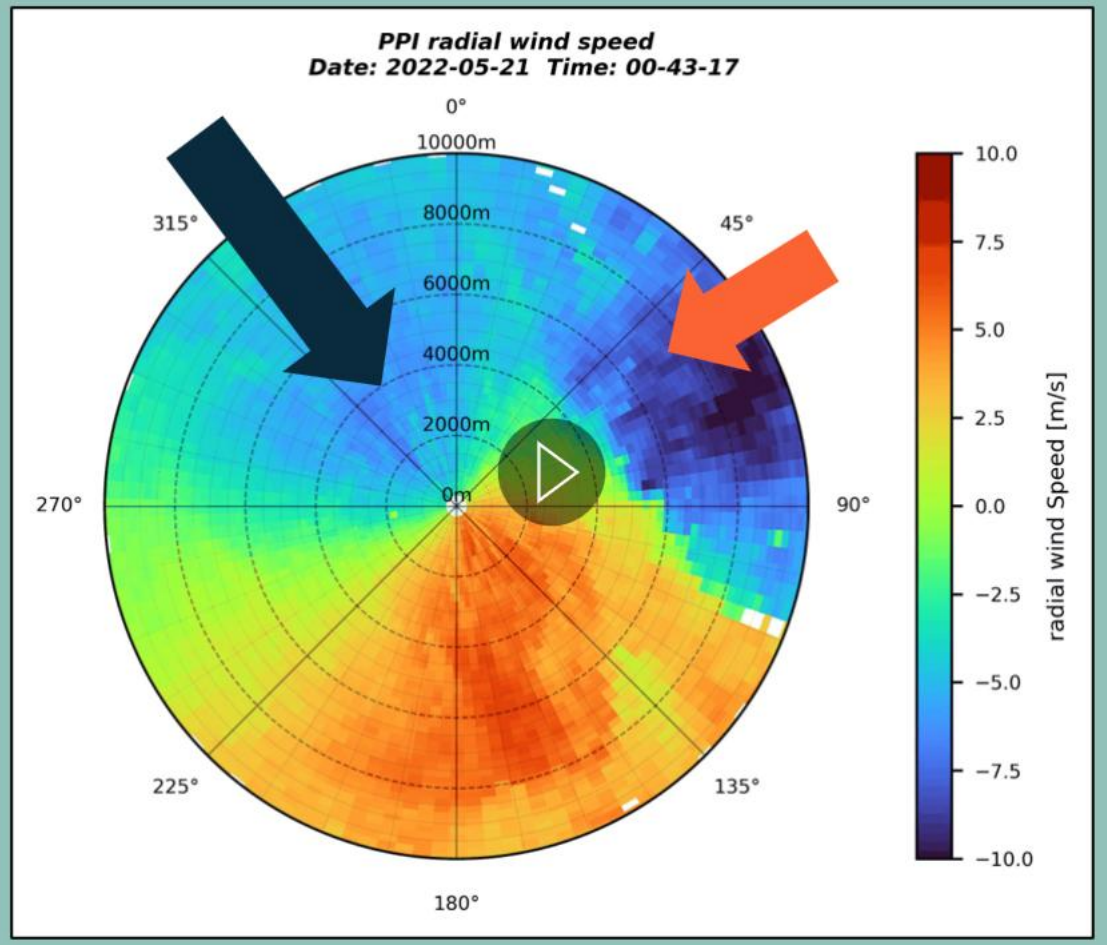
10km range wind measurement – 360°



Space & time coherent variations captured by a WindCube Scan

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

First appearance:
00:32 am
Impact at the center:
00:52 am
Alert leadtime:
20 min ahead



10km range wind measurement – 360°

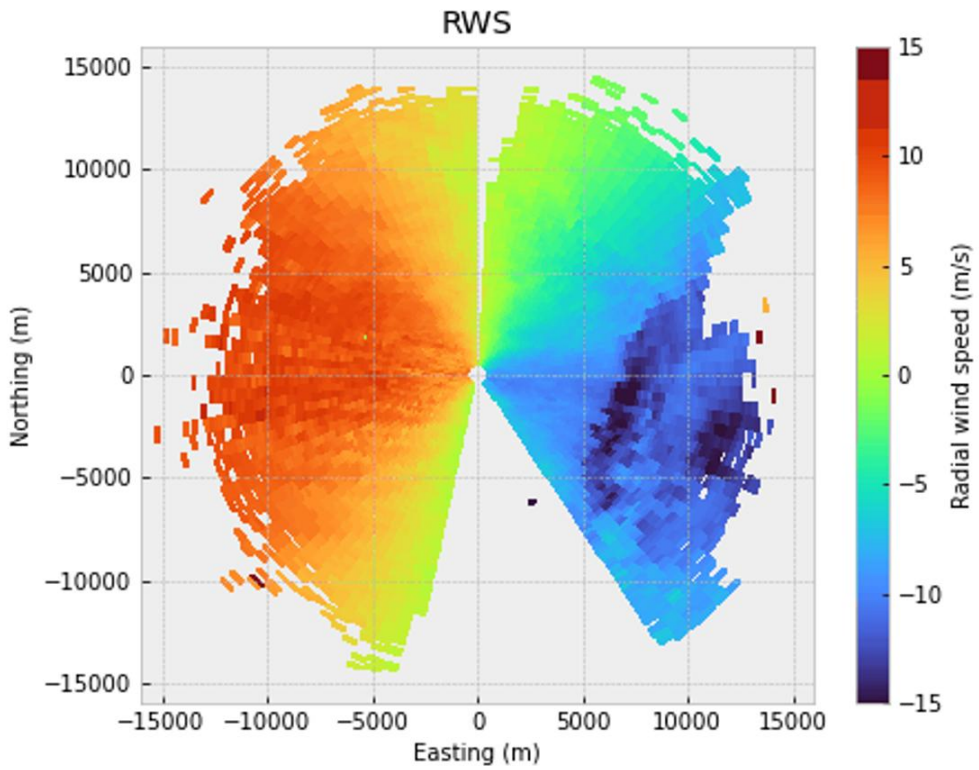
Blue arrow: Wind direction before the weather front

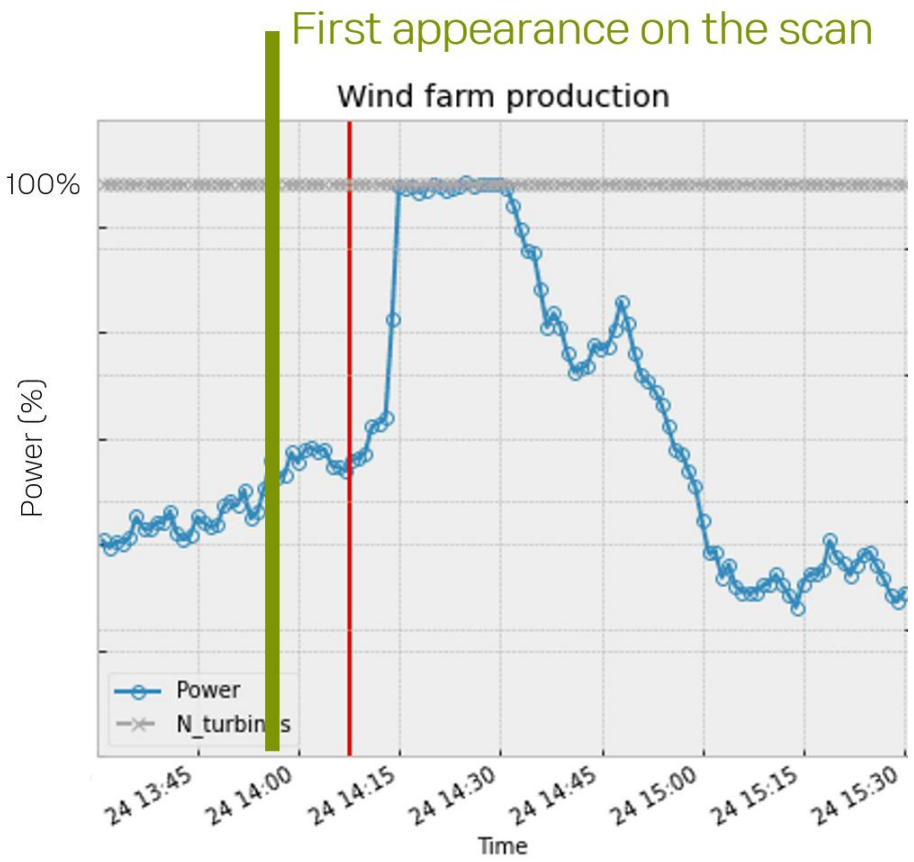
Red arrow: Wind direction after the weather front

Internal

Real-time Wind ramp detection and tracking from operational wind farm project

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.





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12/06/2026 Alert leadtime: >15 min ahead

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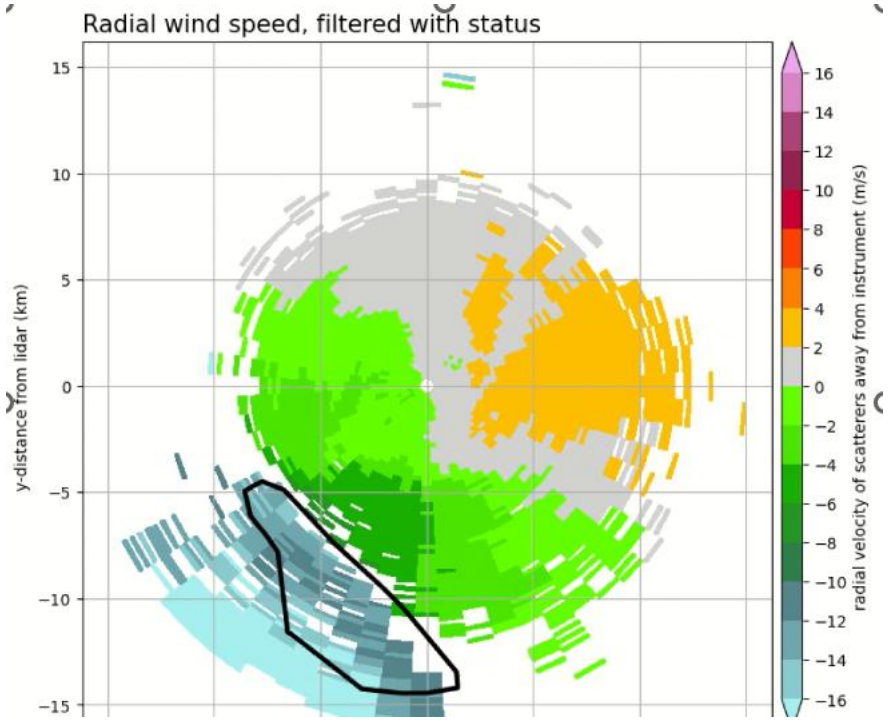
Gust detection algorithm

Detecting wind variations ahead of — and around — a wind farm protects revenue, assets, and people.

Wind ramps detection algorithm

Tracking Wind ramps

Forecasting



Internal

Gust detection algorithm

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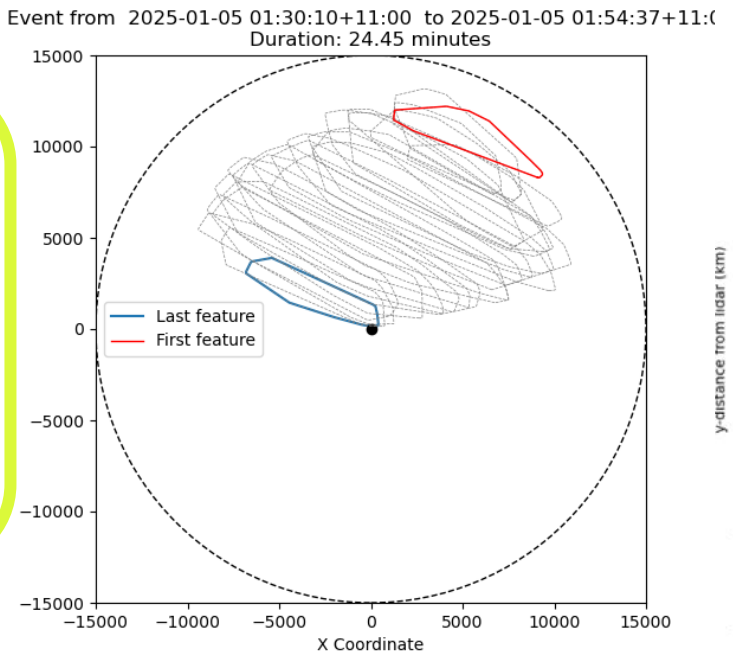
Wind ramps detection algorithm

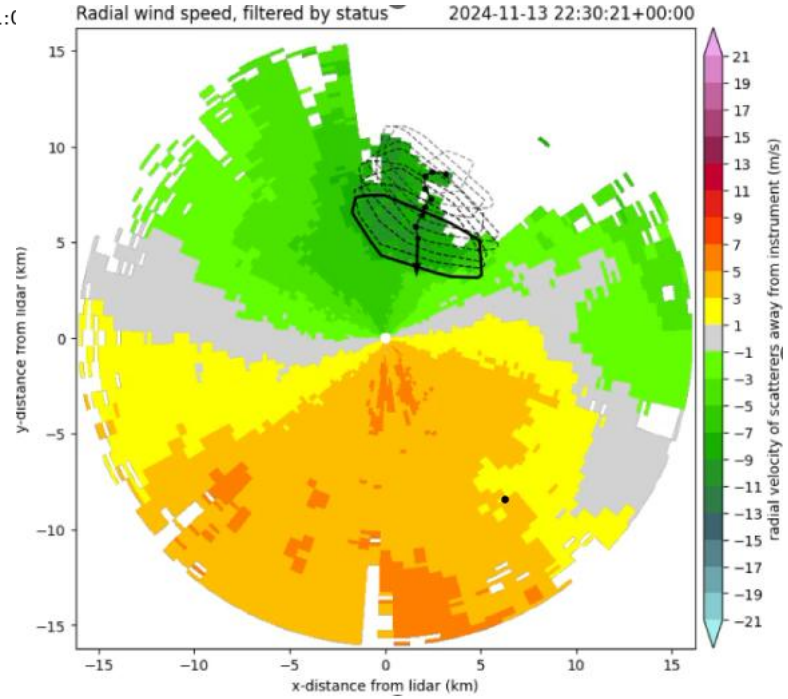
Tracking Wind ramps

Forecasting

Identify gusts that belong to the same event:

- Start and end
- Duration
- Metadata associated





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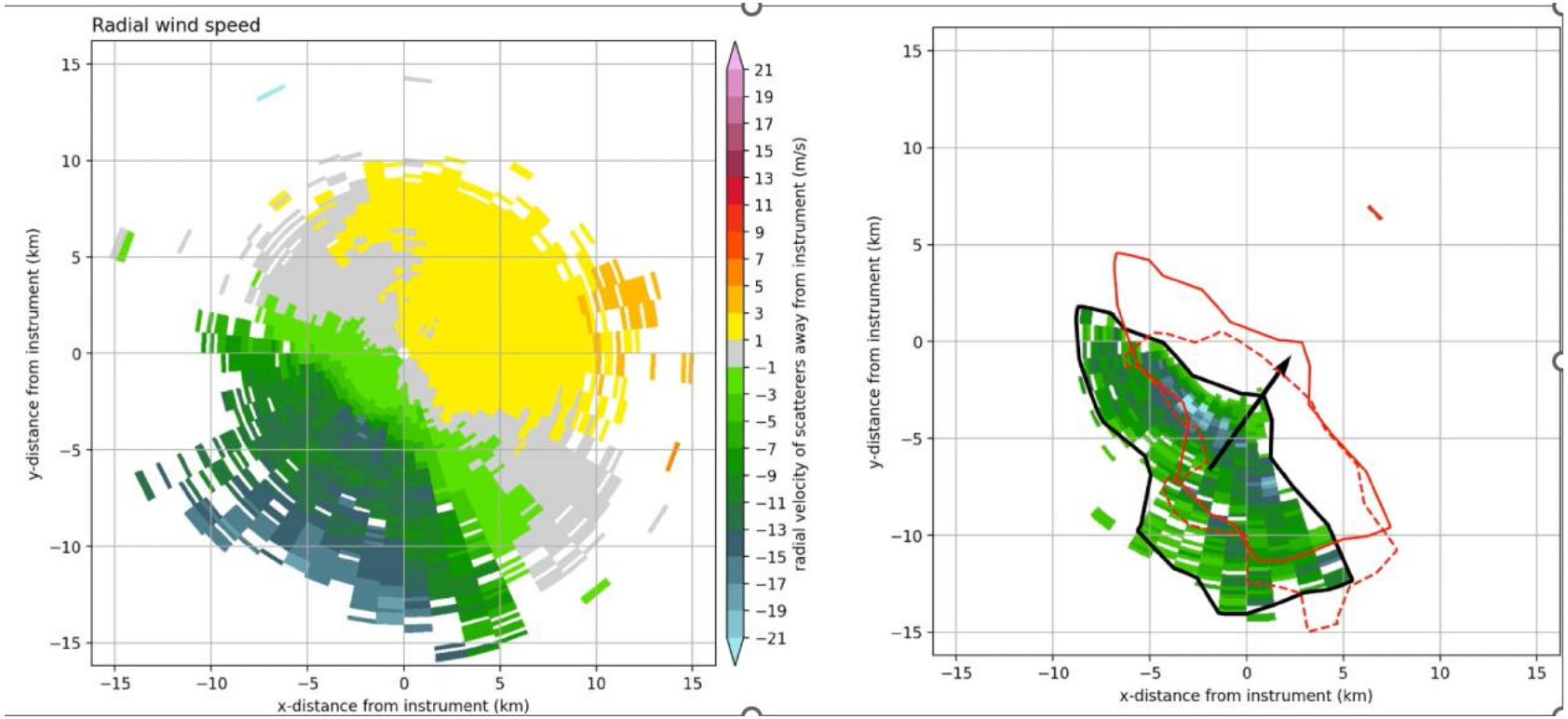
Gust detection algorithm

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Wind Ramps detection algorithm

Tracking Wind ramps

Forecasting



Internal

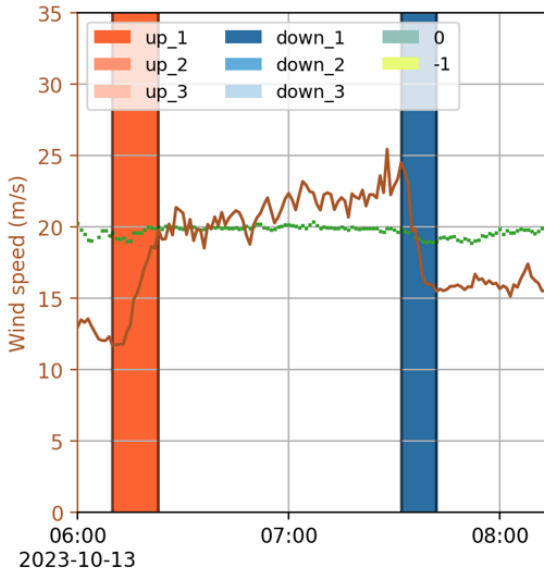
True event definition

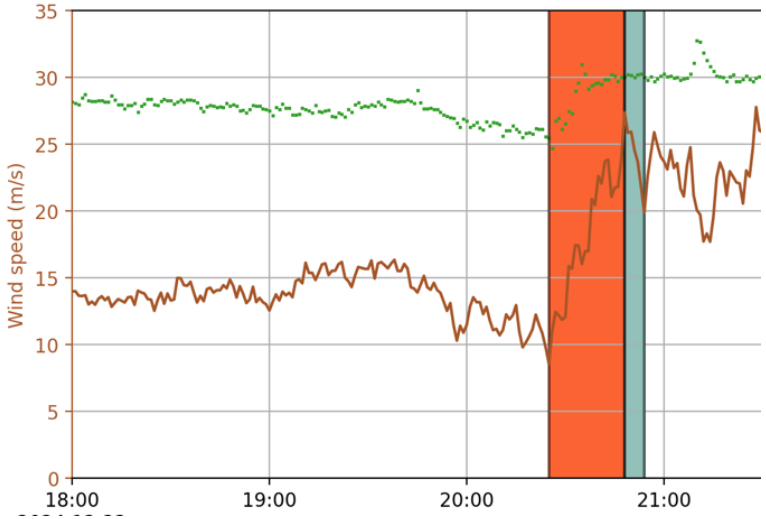
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Automatic detection of wind ramps on timeseries data (anemometer or SCADA data)

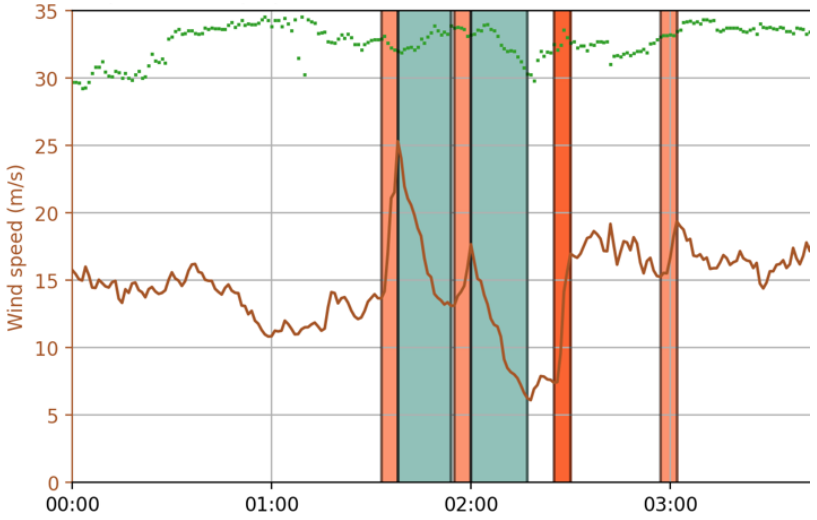
- Specific threshold adjusted according to customer needs

Type 1





Type 2



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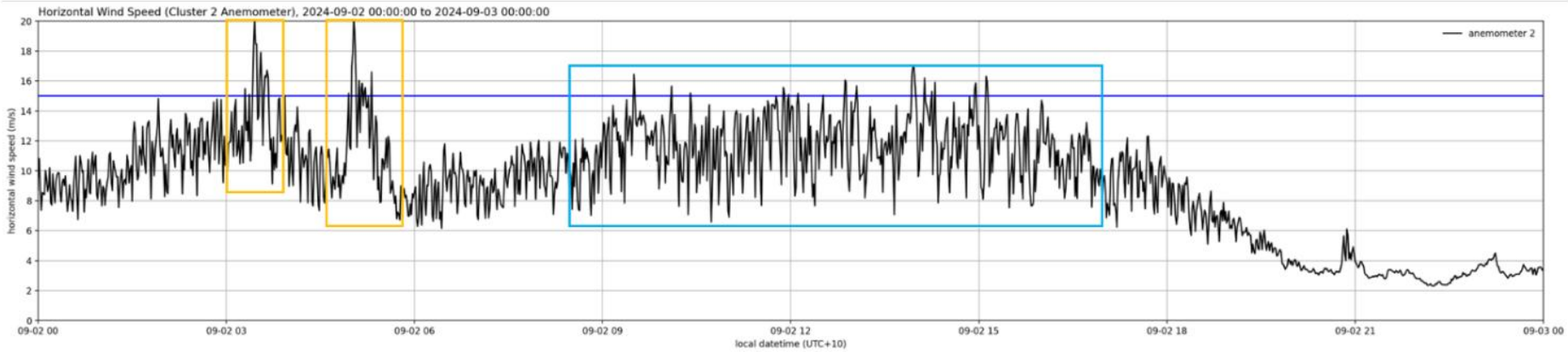
Wind Ramp types definition

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

- Type 1: (Red) Sudden changes in wind speed associated with sustained change in wind regime



- Type 2: (Yellow) Transient wind ramps distinguishable from ambient turbulence
- Type 3: (Blue) Turbulent fluctuations around the mean horizontal wind speed

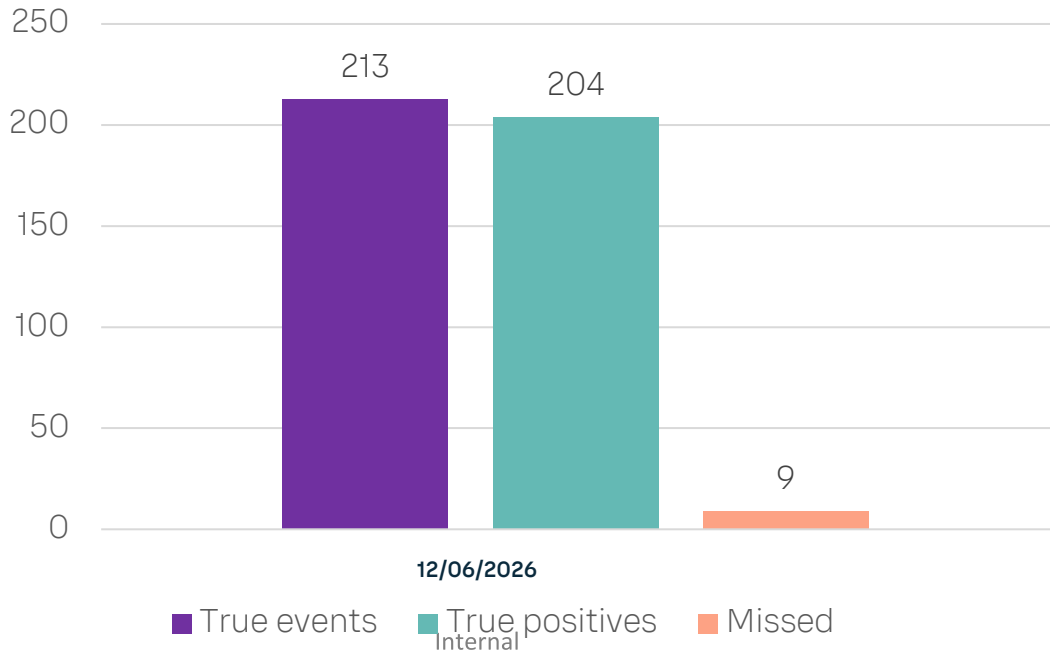


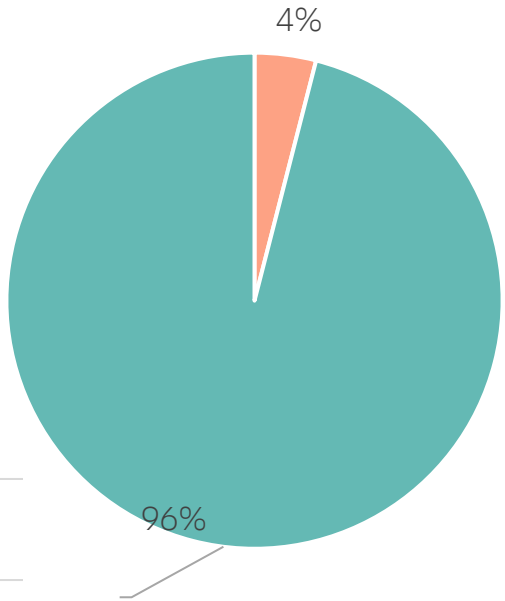
Results – Wind Energy Campaign

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

Campaign results

- Comparison data : SCADA on site (1min scale)
- 2 years of data
- Amplitude of Wind ramps : 5 m/s
- True events : ~10 per month





Missed events due to availability issues

Evaluating benefits of minute-scale forecasting for a new project

Detecting wind variations ahead of — and around — a wind farm protects revenue, assets, and people.

Point wind measurements on site

- Anemometers
- Scada data

Statistic Analyis site-specific

- Number of wind ramps
- Types of ramps
- And recommend a site-specific measurement/ forecast strategy

Gust of interests definition

- Gradient of ramps
- Amplitude of ramps
- Types of ramps

ROI Computation

- Different forecasting approaches

Conclusion and perspectives

Detecting wind variations ahead of – and around – a wind farm protects revenue, assets, and people.

- Proven minute-scale wind ramp detection and tracking with WindCube scan measurements
- Validated on multi-year data on a wind farm site with high detection performance
- Objectives : reduce imbalance penalties, better stability of the grid
- For new sites, we use the customer's own SCADA and met mast data to quantify the added value of Lidar-based ramp forecasting befor deployment

Thank you !



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