Protecting Solar Collector Fields from Sudden Wind Ramps Using Scanning LiDAR

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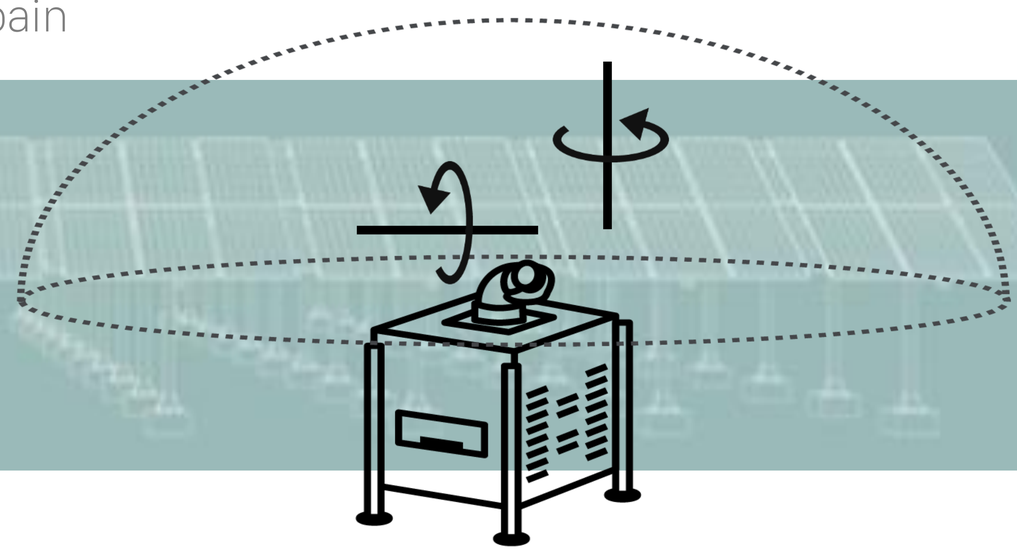
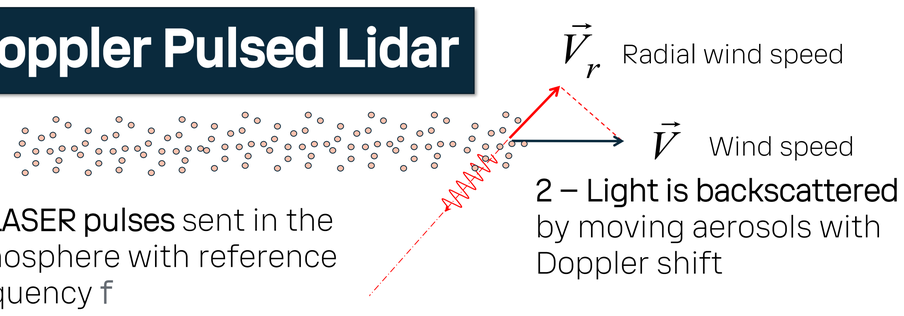
How to prevent damages on solar pannels with a scanning wind lidar ?



Doppler Pulsed Lidar

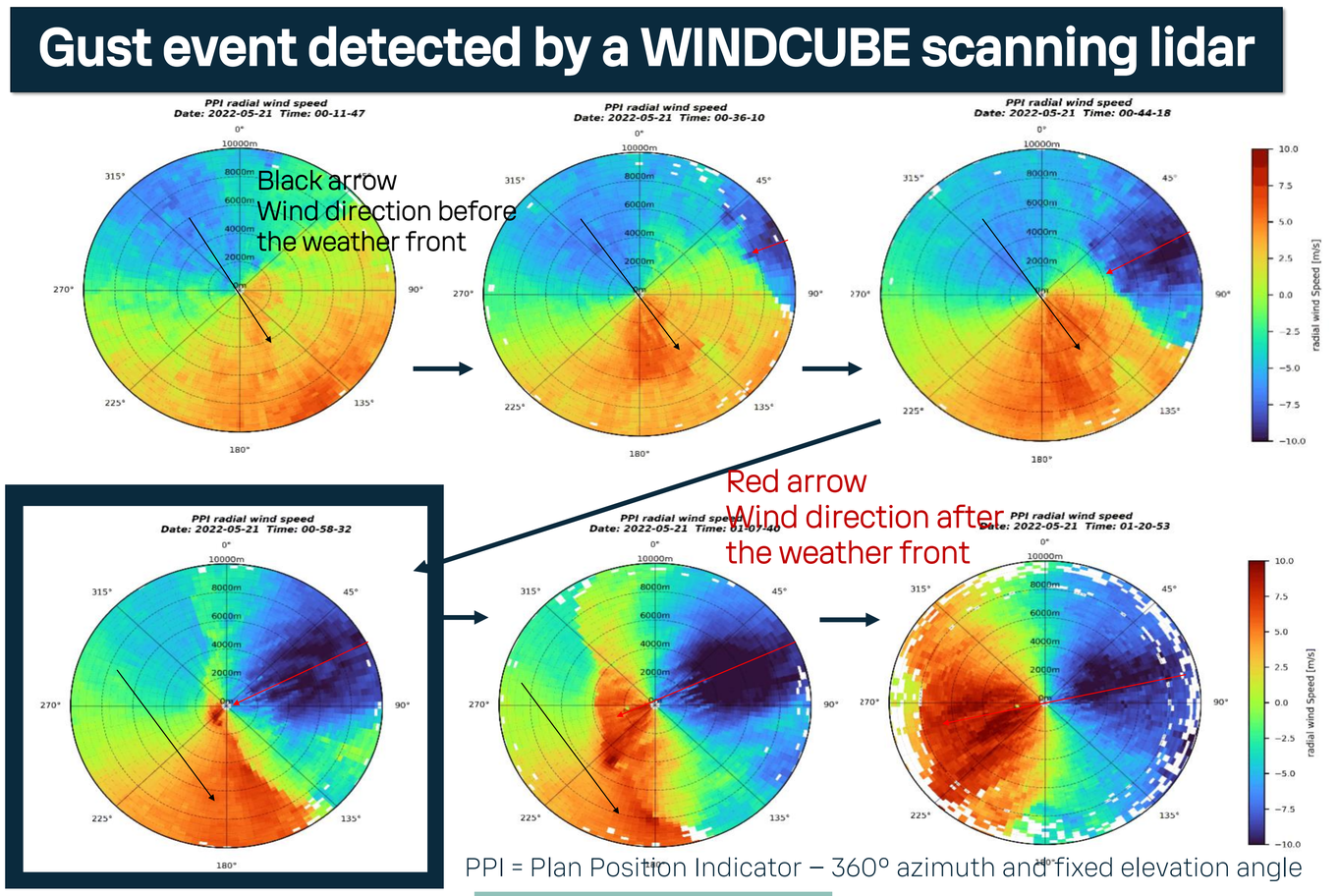


3 - Backscattered signal is processed for all distances (range gates) at the same time

- ➡ Measure wind speeds >10 km
- ➡ Capture spatial and temporal wind coherence
- ➡ Track evolving wind structures in real time

The Doppler shift is proportional to the radial wind speed

Gust event detected by a WINDCUBE scanning lidar



PPI = Plan Position Indicator – 360° azimuth and fixed elevation angle

Method

The stow strategy dilemma

- ➡ **Early stowing** protects equipment by reducing structural loads
- ➡ But **stowing too often** lowers energy production and profitability
- ➡ Operators must balance protection with performance

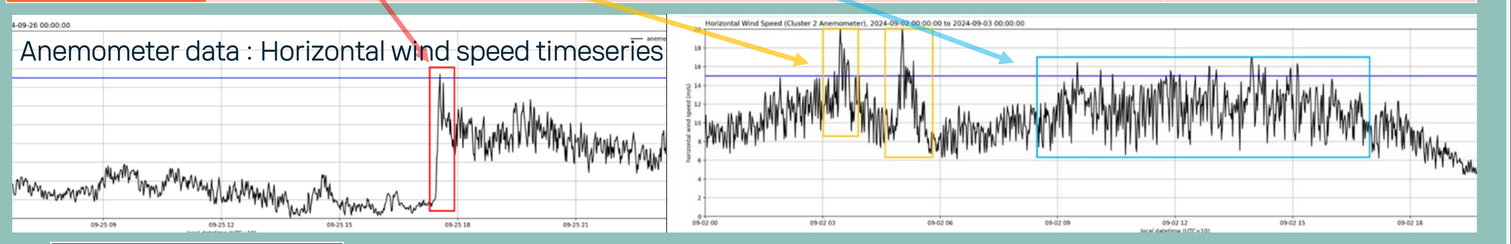
Scanning Wind LiDAR Solution

- ➡ Provides **precise, long-distance wind measurements**
- ➡ Detects wind ramps **before they reach the site**
- ➡ Enables smarter, timely stow decisions
- ➡ Helps solar operators manage risk without compromising efficiency

Key Challenge: How to stow early enough to prevent damage but not so early that you sacrifice output

Application: Already deployed in solar tower plants to analyze wind patterns

Type	Description	Impacts	Forecast techniques capability
1) Ramp-Up Gusts (red)	• **Sudden changes** in Wind Speed associated with **sustained change** in wind regime • spans **large spatial areas** • linked to **cold fronts** or downburst gust fronts	• **Severe** damages • **Large parts** of the plant	15 min ahead
2) Transient Spikes (yellow)	• Transient wind ramps **distinguishable from ambient turbulence** • Not tied to specific weather systems • Detected across multiple LiDAR scans	• **Costly** damages • **Limited segments** of the plant	5 min ahead
3) Turbulent Fluctuations (blue)	• Irregular variations around the mean wind speed • Can become dangerous during strong convective activity • Risk increases with rising mean wind speed	• Limited impact	



Results

Estimated performance statistics

How many Wind ramps in a year and how well can the LIDAR detect them

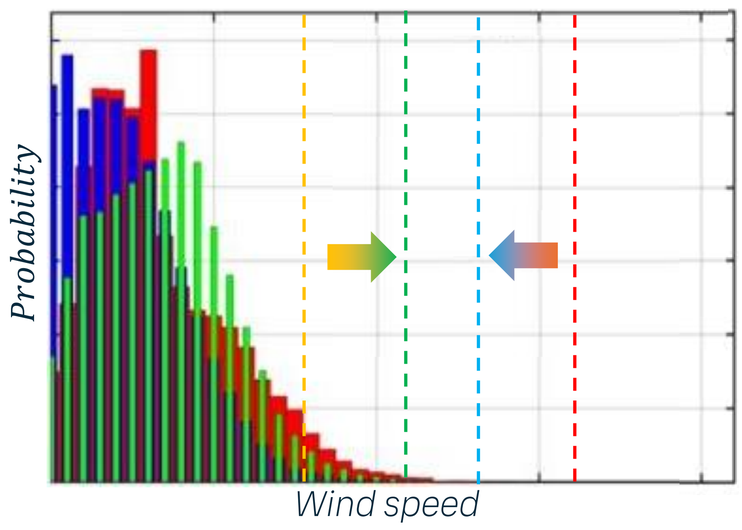
Forecast time		+ 0 min	+ 1 min	+ 5 min	+ 10 min	+ 15 min
Type 1	True positives ratio	100%	100%	100%	98%	88%
	False positives ratio	5%	10%	15%	18%	20%
Type 2	True positives ratio	100%	100%	95%	85%	80%
	False positives ratio	8%	15%	20%	25%	30%

True positve ratio = nb of LIDAR true positve events/ nb of true hazardous events
False positve ratio = nb of LIDAR False positve events/ nb of all LIDAR alert events

Disclaimer: The performance values provided in the table above are a generic estimate. They are based on data subsets. The final forecast performance values are subject to local atmospheric conditions (local topography, wind conditions, aerosol conditions) and Wind ramp frequency.

Benefits

Weibull distribution of 3 locations



Plant operation wind speed:
- w/o lidar
- w/ lidar

Heliostat design wind speed:
- w/ lidar
- w/o lidar

- ➡ With wind lidars, sudden wind ramps can be detected to prevent solar collectors from wind of speeds high above the operational wind speed of the plant. A resulting reduction of the collector design wind speed from e.g. 20 to 14 m/s corresponds to reducing the maximum assumed loads on the drive mechanism by half. This design optimization can **reduce collector field investment cost by 10-20%.**
- ➡ With wind nowcasting by lidars, the maximum wind speed at which the plant stays operating can be increased without increased risk of damage. This **increases the plant's energy gain by several percent**.
- ➡ Additionally, the **insurance cost can be reduced** because of the overall reduced risk of wind damage.