LiDAR: the modern wind force measurement technology

An overview of measurement methods, technology, and the application of Doppler Wind LiDAR measurement devices.

Wind energy will be the most important component in our future renewable energy supply in the context of the EU's stated goal of achieving climate neutrality by 2050 and reducing CO_2 emissions over the coming years. The measurement tasks required in advance for planning and optimising wind turbines and wind farms are continuously being redefined in response to market demand and the trend is towards higher and faster systems and more complex applications.

Because of the increasing hub heights, higher wattage classes, and wider rotor diameters of modern wind turbines, the contemporary wind force measurement masts, and the installed and calibrated sensors they contain (wind vane, cup, and ultrasonic anemometers) are reaching their logistical and economic limits. The cost of these wind force measurement masts, and the sometimes long and complex installations and approval procedures are increasingly making this type of monitoring equipment seem unattractive. Cup and ultrasonic anemometers are particularly suitable for measuring wind speeds at a specific point at a given installed height and there are currently thousands of cup anemometers in use around the world.

Acquisition of data from ordinarily inaccessible parts

However, some novel and fascinating options have been available for several years that are based on modern and innovative LiDAR (Light Detection and Ranging) measurement technology. The LiDAR-based wind measurement principle is based on the emission of short, single light pulses, which pose no threat to eyesight, into the atmosphere at a fixed frequency, and the subsequent detection and analysis of the light that is backscattered by atmospheric aerosols. Commercially available LiDAR systems are increasingly being used to measure horizontal and vertical wind speeds and wind direction profiles. Mathematical functions are then used to calculate the wind speed's individual wind vector components *(u, v,* and *w)* after which the scalar, vectorial, or hybrid averages are determined.

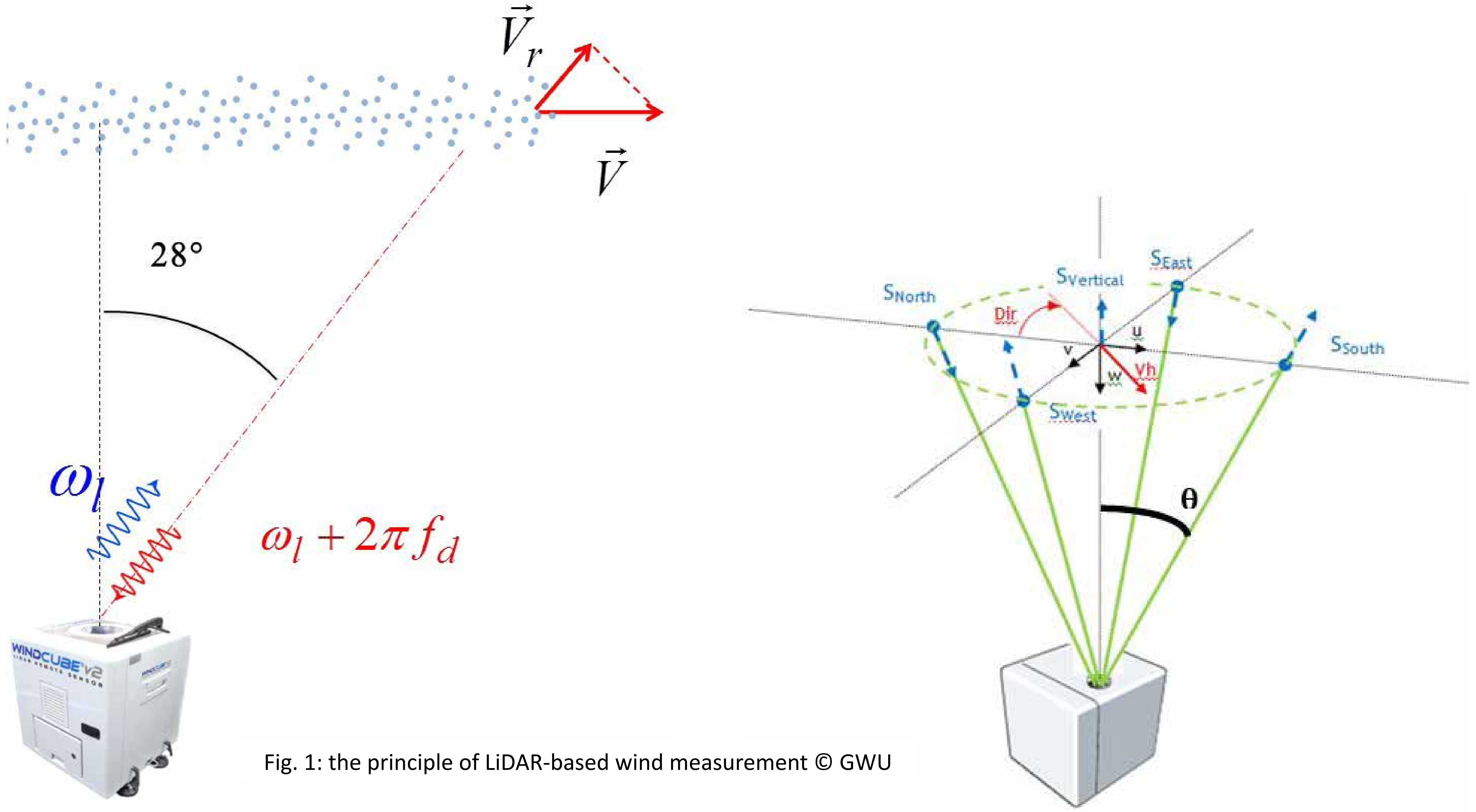

Fig. 1: the principle of LiDAR-based wind measurement © GWU

The major benefit of LiDAR-based wind measurement is the acquisition of data from ordinarily inaccessible parts of the extremely low-level atmosphere and the increased spatial representativeness of the measurement results. Contemporary wind LiDAR systems, WindCube type (Fig. 2 on the next page), are able to take continuous vertical wind profile measurements in the **40-300m height** range and at up to 20 freely definable measurement heights. For advanced applications in the on- and offshore sector as well as in meteorology, more powerful wind LiDAR systems such as 3-D scanning Doppler LiDAR systems are used, which can measure wind data at a maximum range of **12-14km** and using over 250 freely definable measurement windows.

Fig. 4: WindCube Nacelle © GWU

Usable as trailers or as installed systems

Ground-based Wind LiDAR systems are robust and compact and can usually be transported or installed and later dismantled by just one or two engineers. Using a GWU LiDAR trailer (Fig. 3) with an integrated independent power supply makes the Wind LiDAR an ideal system for field use and for short-term monitoring (so-called quick looks) e.g. for site surveys or wind turbine power curve measurements. These systems have also been used for quite a while for long-term monitoring operations (>12 months) in compliance with the relevant guidelines. Wind LiDAR systems are also used in the offshore sector where they are installed on offshore platforms and measuring buoys.

Fig. 2: Doppler Wind LiDAR © GWU


Fig. 3: GWU LiDAR Trailer with its own power supply © GWU

LiDAR systems are also installed directly on wind turbine nacelles, (Fig. 4) where wind forces are measured at distances of **50-700m in front of the wind turbine** using up to 20 freely definable measurement windows. The systems are installed on a wind turbine nacelle depending on the task in hand, which may include such things as yaw misalignment, power curve measurements, or the nacelle transfer function. The system enables wind turbine operators and manufacturers to evaluate the performance of the turbines in an efficient and accurate manner. Their simple installation, lightweight hardware components, full integration capacity, and easy configuration processes ensure rapid value creation in any wind farm.

The best technology for precise wind measurement

These wind measurement systems provide precise analytical data with a high temporal and spatial resolution and can easily be installed or dismantled in a rapid and cost-effective manner in complex and / or wooded terrain without taking up much space. They are currently being used in wind farm planning and optimisation scenarios, follow-up investigations, and for local wind forecasts. Doppler Wind LiDAR technology is the best and cheapest way to measure the local 3D wind field to comply with the accuracy and quality requirements demanded of measurement technology.

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