Shorter Wind Measurement Campaigns

Speeding up wind farm developments with LiDAR

Summary

The maturity of LiDAR technology means that it can now replace a traditional tall mast for on-site wind measurement campaigns. Since LiDAR does not require the same extensive permitting as a mast, the campaign can begin much faster. And it is even possible to characterise the annual wind climate without a full 12-months of measurements. This can help wind farm developers to speed up projects in their pipeline.

The wind climate varies a lot through the seasons and, despite advances in Measure-Correlate-Predict (MCP) techniques, this seasonality significantly affects estimates of the long-term wind climate. Measuring on-site for only a single season (3 months) can lead to a difference of ±10% in the calculated long-term mean wind speed. To remove this seasonal bias, it is common practice to measure on-site for a period of 12-months. However, this campaign design does not take full advantage of the ease of re-deployment of a LiDAR.

Ecofys has designed a wind measurement campaign that samples the wind climate in all four seasons. 6 months of on-site measurements are divided into four periods, with the resultant estimate of long-term wind climate differing by only ±1% relative to a 12-month campaign. This makes excellent use of LiDAR investment, reducing campaign costs by about 35%. And it is also more time efficient, as the LiDAR is available for 6 months, allowing either a concurrent campaign at a second site or a number of other uses.

This example illustrates how beneficial it can be to re-think wind measurement strategies in light of the latest technological and industry developments.

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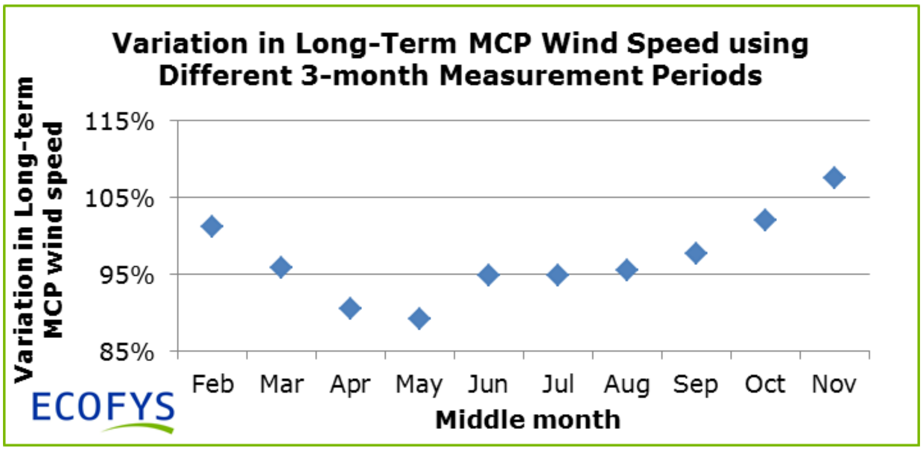
The same site during summer and winter [Project reference: MM04, Test Site Lelystad]

Long-term Wind Climate Estimates can be Highly Affected by Seasonality

It is common practice to extend on-site wind measurements to represent the long-term wind climate, using nearby reference data and a Measure-Correlate-Predict (MCP) method. Several studies of the accuracy of long-term correlation methods have shown that the minimum period for on-site measurements should be 10-12 months ([1], [2], [3]). This is necessary to reduce the uncertainty related to seasonality, as the measurement and reference sites can be differently affected by season.

Seasonal effects include different terrain (consider crops or forests, in the summer versus winter), weather patterns (such as the frequency of northerly storms in the winter and calmer southern winds in the summer) and atmospheric stability (the wind profile changes through the year due to thermal stratification).

A recent Ecofys study of the long-term wind climate at a Dutch inland site, calculated using MCP with a single season (3 months) of on-site measurements, shows ±10% variability in the mean wind speed dependent on the measurement period. There is clear seasonality to these results, with lower calculated long-term wind speeds using summer months, and higher wind speeds using winter months. As noted in other investigations [6], the MCP transfer functions do not account for differences in seasonal stability. For the winter periods, temperature stratification is more stable and wind gradients are high, which leads to an overestimation of long-term wind speeds.



Re-thinking Campaigns with LiDAR

This highlights why a full-year of measurements is typically recommended, in order to reduce the uncertainty relating to seasonality. However, this recommendation considers a traditional campaign design and does not account for the flexibility of LiDAR deployments.

LiDAR is now a mature technology that has been proven to be as accurate as high-quality anemometers. Industry acceptance of LiDAR measurements, as well as our experience with LiDAR deployments, leads Ecofys to recommend a stand-alone LiDAR campaign as a replacement for a traditional met mast in simple terrain [4].

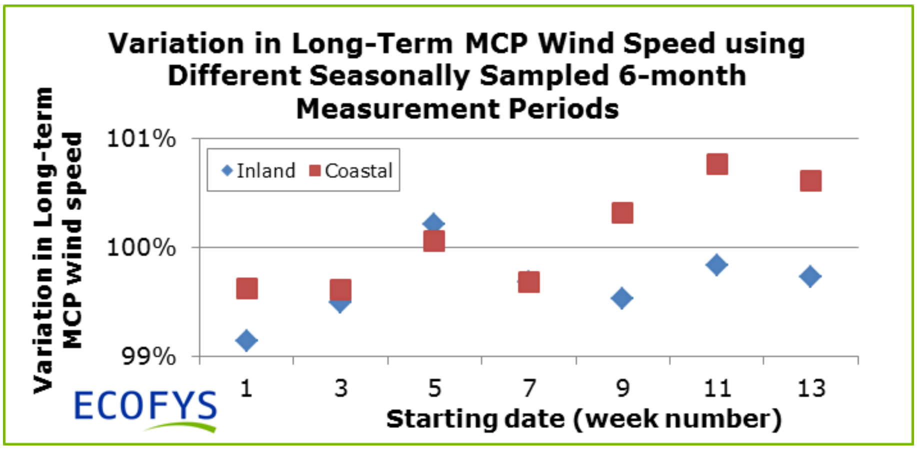
The costs of a LiDAR measurement campaign are structured differently than that of a met mast, which can lead to different targeted campaigns. Installation is one of the largest costs for a mast, so it usually makes sense to leave it at a single location for a long period. For a LiDAR, the largest cost component is equipment hire. Thus, it can be preferable to deploy a LiDAR in shorter campaigns to take advantage of its flexibility.

Overcoming the Limits of Seasonality with Shorter LiDAR Campaigns

With a LiDAR, it is possible to capture the seasonal effects without measuring at the site all year. Ecofys has designed a measurement campaign that samples the wind climate in all four seasons. A LiDAR is installed on-site for 6 weeks, then removed to another site for 6 weeks, then returned to the first site for 6 weeks, etc. In this way, a single LiDAR can measure the wind climate at two sites in one-year. At each site, there are now slightly less than 6 months of data, but with good seasonal representation.

A LiDAR can be moved between sites, while still sampling the wind climate in all four seasons. In this example, the LiDAR is deployed four times to the first site (shown in green) throughout the year. This frees up the LiDAR to measure at a second site (shown in orange) or for four 6-week campaigns. Some possibilities for a shorter campaign would be to characterise shear, complement noise measurements or assess performance of an operational wind farm.

The accuracy of the MCP calculation of long-term wind speed is significantly improved with this campaign design compared to measurements in a single season, as our analysis for two Dutch sites shows below. The inland site is based on the same dataset as the previous example for 3-month campaigns, showing that the variability can be reduced from ±10% to ±1%.



A wind measurement campaign of less than one-year will inherently have an uncertainty in long-term representation that is higher than a full-year campaign. However, our analysis shows that the added uncertainty can be minimal and there are significant cost savings. Carrying out measurements at two sites in one-year would typically cost about 35% less than two one-year campaigns.

Particular importance must be placed on ensuring high system availability during these campaigns, as downtime can have a larger impact on the accuracy of the MCP calculations than during a 12 month campaign.

Other Short LiDAR Campaigns

Measuring for only 6-months at one site frees up the LiDAR for other measurements. As an alternative to a wind resource assessment at a second site, there are numerous other possibilities for short LiDAR campaigns.

A LiDAR can complement a shorter met mast, either placed next to it or moved around the wind farm site to measure variations in the wind climate. This can be a cost-effective means to improve the accuracy of flow modelling and reduce the uncertainty in vertical and horizontal extrapolation. Sufficient data needs to be collected to calculate the relationship with mast measurements.

LiDAR deployed to complement met mast 4 km away [Project Reference: Delfzijl Noord]

Measurements up to 200 m are especially useful at sites where wind shear could be an issue, such as near forests. It is important to consider that shear is affected by stability and terrain roughness, so results will be heavily affected by seasonality. Still, a relatively short campaign can help to evaluate the sector-wise wind profile and aid in the selection of the optimal hub height for the wind farm.

A LiDAR can be easily deployed on-site during noise measurements. The wind measurements at hub height can help evaluate the impact of noise-mitigation strategies.

Wind measurements can play an important role after the construction of the wind farm, either in a post-construction energy assessment (e.g. for re-financing or sale) or in performance assessment. If a wind farm seems to be under-performing, it is often insufficient to use nacelle anemometers to analyse the wind speed. A short-term LiDAR campaign is a cost-effective means to verify wind turbine performance. Depending on the wind climate and undisturbed sectors, a 1-month campaign can be sufficient.

LiDAR deployed beside operational wind farm

Conclusions

LiDAR opens up new opportunities for wind measurement campaigns. By designing campaigns to make the most of LiDAR's flexibility and measurement heights, it is possible to overcome the challenge of seasonality. A LiDAR can be deployed for 6 months, divided into four periods throughout the year, with the resultant estimate of long-term wind climate differing by only ±1% relative to a 12-month campaign. Campaign costs are reduced by about 35% and the LiDAR is available for the remaining 6 months, allowing either a concurrent campaign at a second site or a number of other uses.

Key References

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