

Introduction

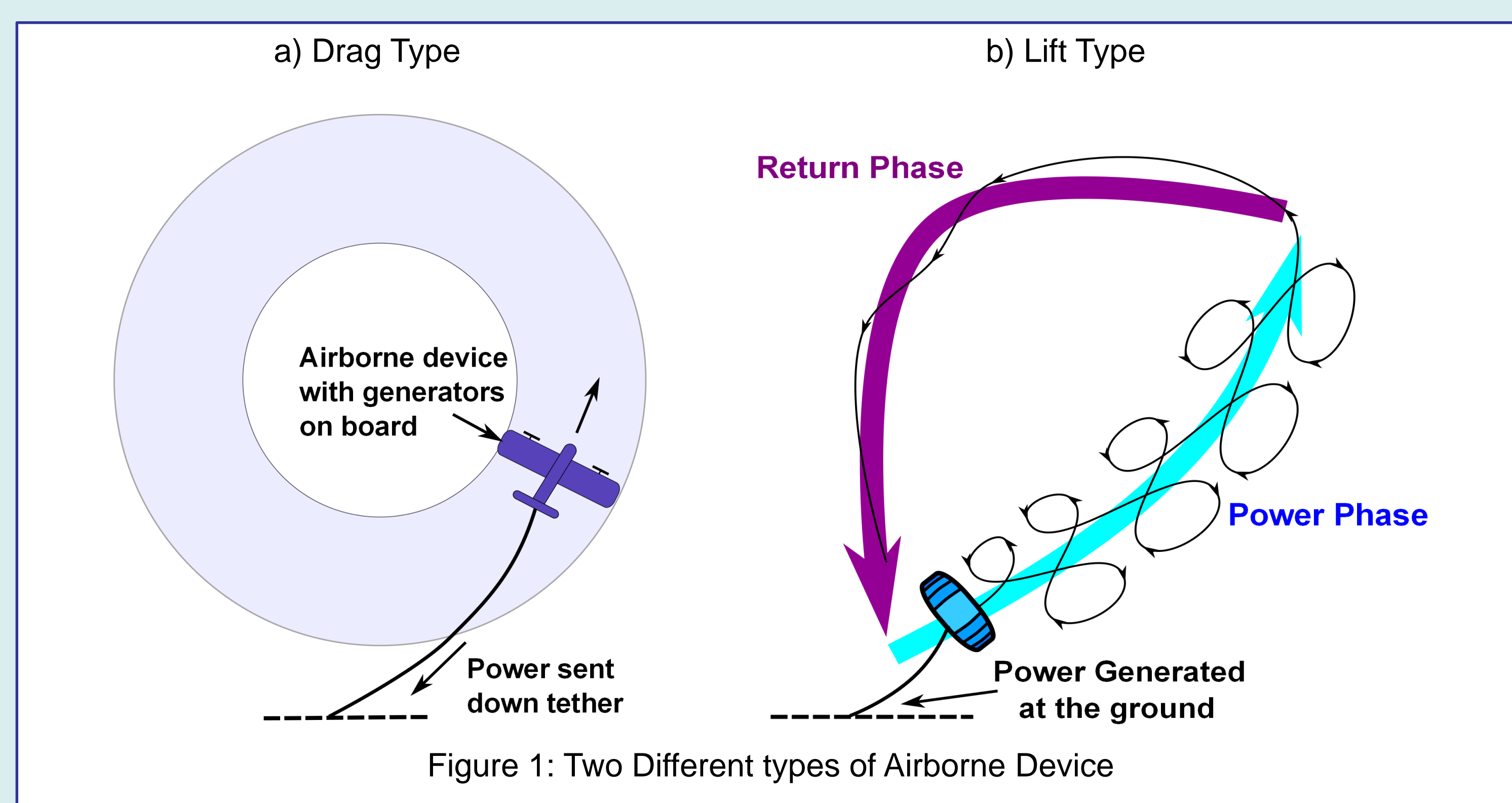
Airborne Wind Energy (AWE) is a novel way of harnessing the wind. The potential benefits include higher yield due to the increased wind and its more persistent nature at higher altitudes (100m-1000m). Also, the overall cost of the system is reduced since large, steel devices are not required. This results in a potential step down in the cost of energy for offshore wind systems.

AWE converters work in one of two methods [1]. The drag devices have generators on board, and the tether transmits the power; lift devices reel the tether in and out of a ground based generator (Figure 1).

One problem the AWE sector faces is its understanding and evaluation of the available resource at such high altitudes. There is evidence of low level coastal jetting and reverse shear at heights as low as 100m. Since met masts normally operate at heights up to 80m, non-typical wind data sets are required for an accurate assessment of the wind speeds.

Standard shear profiles and models are only valid to a height of around 100m, but above this level the atmosphere is in a transitional zone between the upper and lower surface boundary layers [2]. The wind speed isn't only affected by frictional shear but also by the bulk properties of the atmosphere. This can result in errors in both the energy yield assessment and loading calculations for the offshore wind sector.

Current yield assessment methodologies are inadequate for large offshore and airborne wind. The industry accepted method of extrapolating wind speed data to hub height by using standard shear laws and roughness lengths will result in large inaccuracies in yield estimations [3]. For this reason, a novel method for yield analysis has been developed for unconventional wind. This project aims to evaluate the viability of this method of yield analysis.



Objectives

- Develop yield assessment methods for novel wind energy converters.

Method

Figure 2 shows a sample yield assessment of an airborne device. The assessment differs from traditional methods in two ways: (1) the average position of an airborne device varies with time, requiring a time step optimisation; and (2) the average wind speed across the entire flight path needs to be considered. In this case, the drag device was assumed to follow a circular flight path with the average “hub” height evaluated at the centre of the flight path.

The power available to an airborne device P is given by:

$$P = \cos^3(\alpha) P_w A C_L F$$

where P_w is wind power ($\frac{1}{2}\rho v^3$); A is the wing area of the device; C_L is the lift coefficient and F a dimensionless factor determined by the lift-to-drag ratio and the relative speed of the wind and device. The factor $\cos^3(\alpha)$ where α is the angle of the tether to the ground is due to the relative wind speed the device experiences at this angle. A longer tether can increase power output for a given device at a given height but increases the drag. Increased length may compromise the strength of the tether.

Results and Discussion

The airborne devices have been shown to have capacity factors of around 69%, which is almost double the capacity factor of a conventional turbine held at a constant hub height (shown by the dotted red line in Figure 2 (top)). The controllability of the turbine plays an important part in the performance of the turbine. Much of the high performance is due to the assumption the AWE converters will operate at the optimal altitude.

Figure 2 (top) shows the optimal height of the airborne device over time, and the wind speed at all heights and times. Figure 2 (bottom) shows that the device is running at full capacity for the majority of the time. Airborne devices perform at rated capacity at lower wind speeds than conventional wind, due to the crosswind nature of the flight path. However, at low wind speeds, some drag devices require power to be sent up the tether in order to power the device.

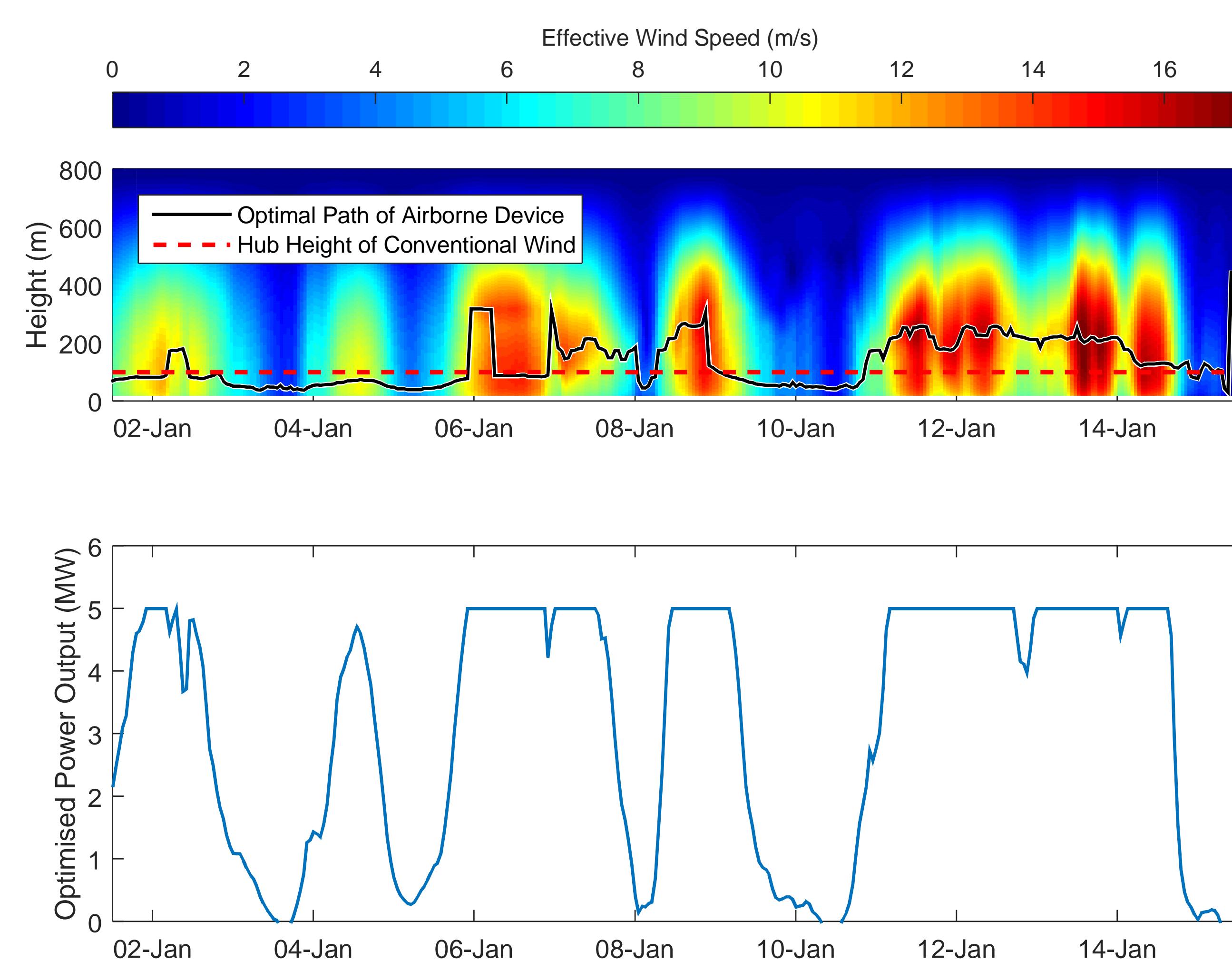


Figure 2: Optimal flight path (top) and power output (bottom) for a drag type device

Conclusions and Further Work

AWE could provide a low cost solution to harnessing wind energy offshore. Further study into the nature of the wind throughout the boundary layer is required. This involves both increased access to high altitude data (e.g. lidar), and high accuracy models. An increased knowledge of how the stability of the coastal atmosphere affects phenomena like Low Level Jetting would be a valuable tool in analyzing and predicting the potential power output of devices.

Further collaboration with developers is required to ensure the power curves are informative and useful for the yield analysis. Non-conventional parameters, such as a reference height for the wind speeds and tether lengths are required in order to carry out a valid yield analysis. Higher quality data for these parameters will give a higher quality yield estimate.

Whilst the future of airborne wind energy is still uncertain, there are several companies nearing the stage of large scale deployment. Developers will need to justify the commercial viability of airborne wind, especially at wind-farm scale in comparison to conventional offshore wind farms. With this improved yield estimate, a robust cost-benefit analysis could be performed in order to assess the needs of the industry as a whole.

References

1. ML Loyd (1980) "Crosswind Kite Power", *AIAA*, Vol 4(3): pp 106-111
2. R Stull (1988) "Introduction to Boundary Layer Meteorology", Kluwer Academic Publishers
3. S.-E Gryning et al. "On the extension of the wind profile over homogeneous terrain beyond the surface boundary layer" *Boundary-Layer Meteorology*, **2007**, 124, 251-268

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