Topic for Master Project

Contents

Meteorological Considerations on Atmospheric Irrigation with Wind Turbines

Introduction

At the Wind Energy Technology Institute (WETI) of Flensburg University of Applied Sciences, a system has been invented (patent pending) that allows using wind turbines (WTs) to impact on the natural water circuit of the atmosphere. The motivation for this invention is to mitigate the problem of aridity and water scarcity. General meteorological considerations on the application of this irrigation system shall be the scope of a master thesis. This document briefly introduces the considered system and outlines the tasks to be accomplished within a master thesis.

A Brief Introduction to Atmospheric Irrigation with Wind Turbines

The Atmospheric Irrigation with Wind Turbines (in the following called “irrigation system”) utilizes some advantageous characteristics of modern WTs to emit water into the atmosphere. A detailed description of how the irrigation system works shall be omitted here. It shall be sufficient to mention that water is emitted with the rotor blades of the WT. This allows enriching the air, which passes the rotor, with water, i.e. it allows increasing the humidity in a tubular layer of air. This air volume has approximately the diameter of the WT rotor and its center is initially in a height above ground, which equals the hub height of the WT.

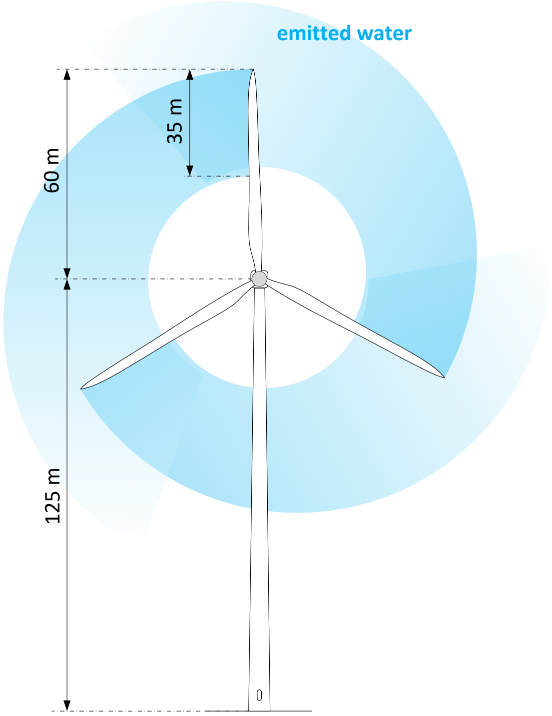

Figure 1 WT emitting water into the atmosphere.

Figure 1 illustrates the concept qualitatively. For illustration, Figure 1 shows, in an exaggerated manner, that the wake of a WT increases in diameter, because the WT extracts kinetic energy from the air. Also shown in Figure 1 are dimensions of a state-of-the-art WT and realistic dimensions of the area of the WT rotor blades where water emitting nozzles could be located.

The nozzles in the rotor blades can emit water in two different ways: They can either use the effect of vaporization to emit water vapor, or they can emit droplets. After the water is emitted into the air, the wind transports the water (in the form of vapor or droplets) through the atmosphere. These two operating modes are the premise for the different fields of application, which are outlined in the following subsections.

Transporting Water over Longer Distances

The water has to be vaporized in order to be transported over longer distances. Figure 2 illustrates a conceivable scenario, where the shown WT stands representative for an arbitrary number of WTs. It is obvious that the amount of water, which can be emitted, increases with the number of WTs. Further it is obvious that several WTs next to each other (looking in wind direction) increase the width of the layer of air which is enriched with water. Several WTs behind each other (in wind direction) can lift the humidity of the air to a higher level, and hence, bring the air closer to the dew point.

The scenario in Figure 2 is characterized by the location of the WT at the estuary of a river, and by the wind direction. Fresh water is extracted from the river before it enters into the sea, where it becomes unusable saltwater. The onshore wind transports the water, which the WT emits into the atmosphere, back inland.

Figure 2 WT emits fresh water from a river. Onshore wind carries the vaporized water inland. Mountains deflect the humidified air vertically, which causes the air to cool down and the water to condense.

The scenario shown in Figure 2 assumes that the dew point is reached when the air is deflected vertically by a mountain ridge. For this purpose, it is irrelevant whether the irrigation system achieves humidifying the air sufficiently to reach the dew point, or whether the local weather would have led to precipitation anyway. Either way, the precipitation quantity, and the amount of usable fresh water, is increased in the affected area.

Local Cooling

Vaporization extracts energy from the air. Hence, when vaporization causes water molecules to leave a water surface and enter into the air, the temperature of the air drops. Consequently, the air in the wake of a WT with irrigation system is cooler than the air in front of the WT. This cooling effect can be used locally in the near wake of the WT.

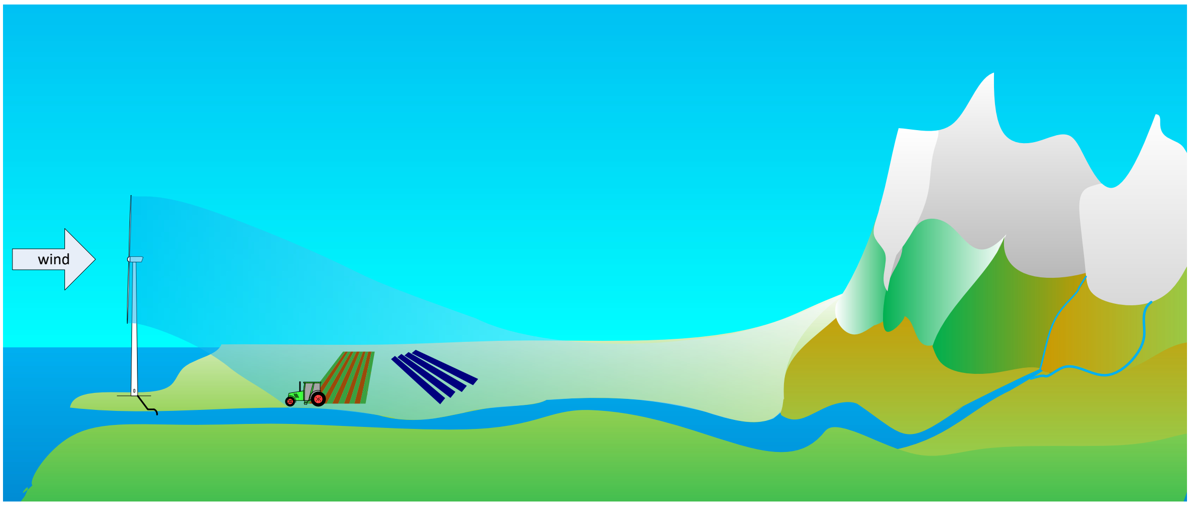

Figure 3 WT vaporizes fresh water from a river to cool down the air in its wake.

Figure 3 illustrates a scenario where a WT vaporizes water not for the sake of irrigation, but for the sake of local cooling. The cooler air in the wake of the WT can reduce drying out of, e.g., agricultural plants and soil. Another field of application is the cooling of photovoltaic power plants, whose energy yield rises substantially with decreasing temperature.

The water vapor produced by the irrigation system might, also in this scenario, lead to precipitation over land somewhere farther away from the WT. However, this is not in the focus of this field of application.

Direct Irrigation

The irrigation system can also be used for irrigating areas, which are in the wake and in proximity of the WT, with water droplets, see Figure 4. Conceivable applications are irrigation of agricultural land, as well as prevention or fighting of forest fires, bush fires and peat fires. In this case, vaporization is dispensable and the irrigation system has to emit water on a high rate. Most of the emitted water should be carried as droplets through the air until they reach the ground. However, although undesirable, some water will vaporize nonetheless.

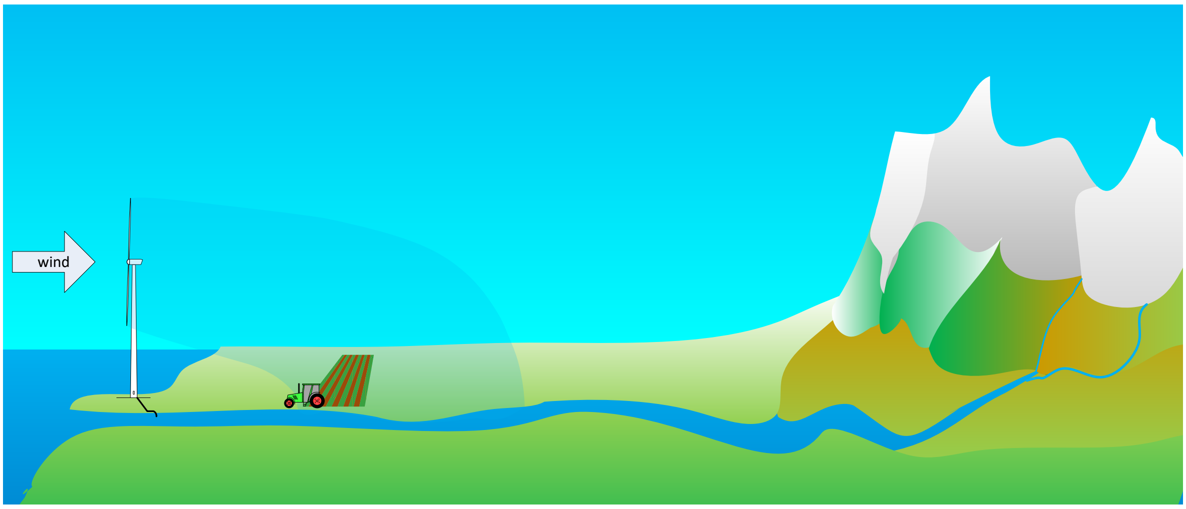

Figure 4 Irrigation system in a WT emits water droplets for directly irrigating agricultural land in its wake.

Tasks for a Master Thesis Project

A master thesis project shall analyze some meteorological aspects that are related to the irrigation system. To limit the scope of this project, for a start, only the effects in closer proximity of the WT shall be considered. Hence, the tasks to be accomplished will revolve around the two operating modes Local Cooling and Direct Irrigation only.

Some WT parameters are necessary to be able to work on the tasks. The geometrical dimensions of the WT to be considered are as shown in Figure 1. The rotor speed vs. wind speed characteristic of the WT will be provided in due time.

Local Cooling

Determine the impact of ambient temperature, humidity, wind speed, turbulence intensity and water temperature on the vaporization of the water emitted by the irrigation system. For the different conceivable combinations of these parameters, solve the following problems:

- Determine the maximum volumetric flow of water that can be vaporized, i.e. without residual droplets.
- Determine the temperature decrease in the wake of the WT from the latent heat of the vaporization.
- Determine the effect of the vaporization on the density of the air in the wake of the WT.
- Determine the propagation of the cooler air in the wake of the WT. Consider different ambient turbulence intensities.

Direct Irrigation

Determine the impact of ambient temperature, humidity, wind speed, turbulence intensity and water temperature on the propagation of water droplets emitted by the irrigation system. For the different conceivable combinations of these parameters, solve the following problems:

- Determine the minimum volumetric flow of water and the minimum size of the droplets that are necessary to avoid complete vaporization of the droplets.
- Determine the effect of the undesired but inevitable vaporization on temperature and density of the air in the wake of the WT.
- Determine the propagation of droplets. I.e. determine how far the wind carries the droplets and what percentage of water will not reach the ground due to vaporization.

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