To simulate the use of LIDAR assisted wind turbine control it is necessary to use the appropriate wind settings to ensure that gust propagation is modelled correctly.

For many load cases the use of a 3D *.wnd file will be sufficient (either using the evolving or frozen turbulence options) to allow the LIDAR system to look ahead such that changes to the wind speed can be anticipated.

However, to model some load cases it is necessary to model transients. The standard transient feature in Bladed will modify the wind velocity simultaneously throughout the wind field. This is not appropriate for use in conjunction with LIDAR as the wind speed will increase at both the rotor plane and the upstream focal point simultaneously.

There is an option to switch on a propagating gust with the transient model (herein referred to as a propagating transient) using the following project info code:

```
MSTART EXTRA
GUSTPROPAGATION 1
MEND
```

This model adjusts the lookup time of the transient wind speed model in order to model the advance of the gust. This is explained in more detail in Section 1 below.

However, the gust propagation model does not work well for load cases that included a change in wind direction. This is explained in more detail in Section 2.

To resolve the issue, it is suggested that a 3D *.wnd file is used instead. Guidance on setting up the wind file is provided in Section 3.

When modelling a wind turbine using the 3D wind file (that represents a propagating transient) there will be differences in loading relative to the transient without gust and these differences are explained in Section 4.

1 PROPAGATING TRANSIENT

During a transient wind turbine simulation, the calculation code will “lookup” the wind speed at various locations on the turbine (blades, tower etc). It will interrogate the wind module based on the simulation time T

With gust propagation switched on the wind module modifies the simulation time at which the wind speed is looked up by $\delta t = x/\bar{U}$. The variable x is the along wind position of the location measured from the global origin.

Example 1 In the case of the hub, with an overhang of 4m and UBAR = 8m/s the wind speed is interrogated at +0.5s in comparison to when gust propagation is switched off.

It must also be noted that as the wind direction changes, Bladed rotates the “wind field” round such that updated alongwind position $x' = x\cos(\bar{D}_w)$, where $\bar{D}_w$ is the mean wind direction.

Example 2 Suppose that an extreme change in wind direction of amplitude 15 m/s (half cycle) coincides with an increase in wind direction (half cycle) 90 deg. The transients occur at the same time T = 10 s and have the same duration.

The outputs of hub wind speed are shown in Figure 1 for the wind turbine simulation described in Example 2. The two outputs correspond to the situation where gust propagation is on and off. For the case where propagation in on the wind speed increases before the transient start time of T=10s because the speed is looked up at the hub which is upwind of the global origin.

In the case of example 2 above $x' \rightarrow 0$ as $\overline{D}_w \rightarrow 90$ deg such that the gust on/off option is equivalent by the time the transient is complete. This can also be seen in Figure 1. In summary, the change in the shape of the hub wind speed profile between the two cases is because the wind direction changes.

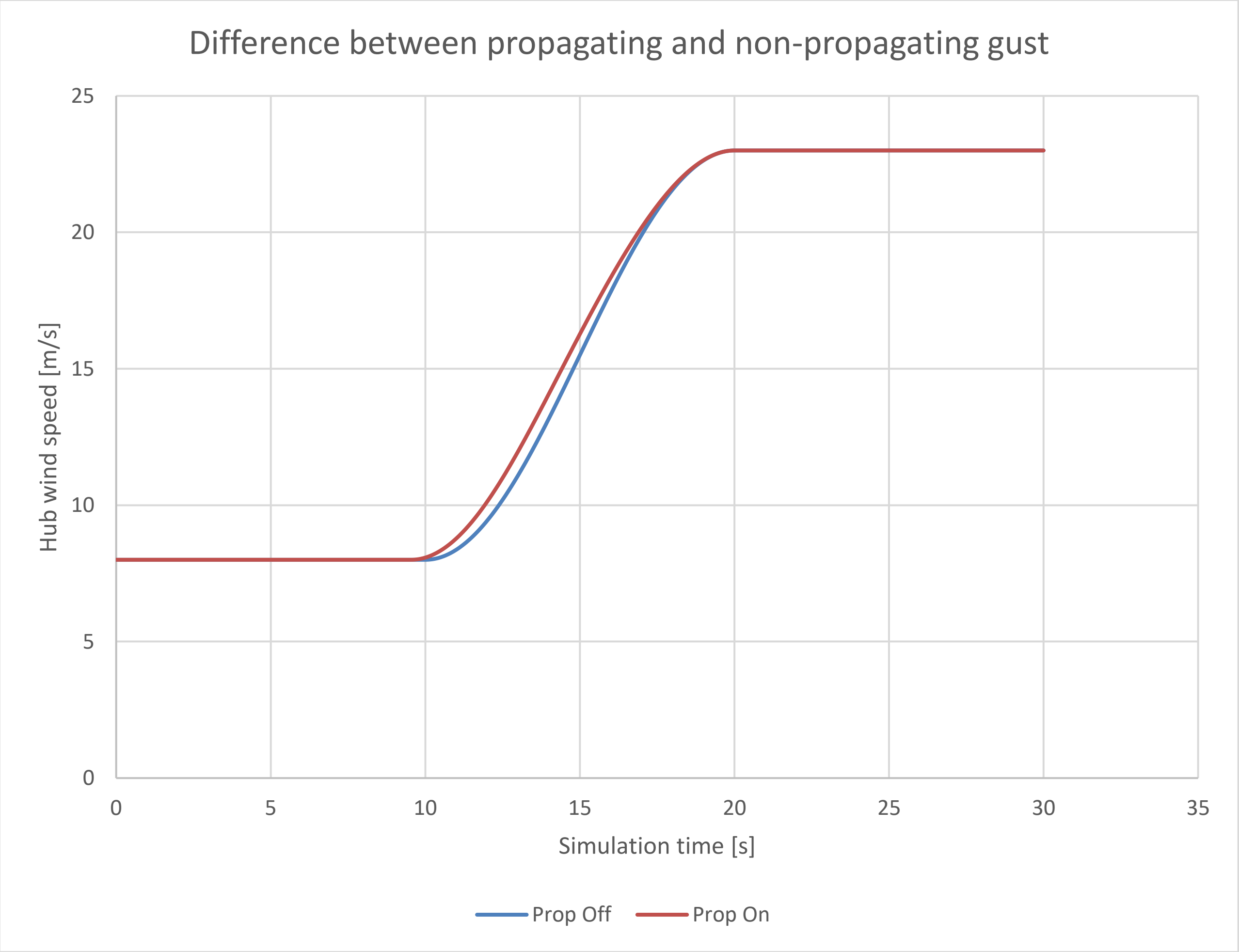

Figure 1 – Demo simulations with extreme direction change of 90 deg and wind speed increase from 8m/s to 23 m/s. The two curves relate to switching the gust propagation on/off.

2 PROPAGATING TRANSIENT LIMITATION

The option to model a transient as a propagating gust is not accurate when a large direction is also included. The results presented in Figure 1 only focused on the hub wind speed which varies little between the non-propagating and propagating cases. However, the wind speed at the blade tips can be much larger as discussed below.

This section focuses on example 2 that was described in Section 1. Figure 2 shows how the wind direction changes due to the propagating gust as it approaches the turbine rotor plane. Four stages are highlighted where stage 1 is the initial conditions where the direction of wind travel is straight towards the rotor plane and then two intermediary stages 2 and 3 where the wind direction turns. Stage 4 shows wind direction once the half cycle in wind direction has been completed.

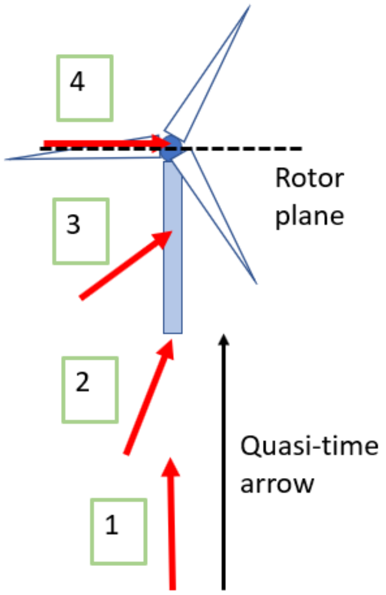

Figure 2 – Representation of how the wind direction changes as it approaches the rotor plane during a propagating transient simulation. The position of the red arrows relative to the black (quasi-) time arrow show how the wind direction changes in time as the simulation advances. The black arrow is not an absolute because the wind field rotates as the wind direction changes but gives a sense of how the wind direction changes as the gust propagates. The black dashed line represents the rotor plane.

Figure 3 shows how the coupled wind direction and wind speed half cycles change the wind speed throughout the computational domain. In stage 1 the wind direction is straight onto the rotor plane. The increase in wind speed is applied within the blue box depicted in Figure 3. Stages 2 and 3 show how the wind field rotates such that the wind speed increases on one side of the turbine and on the other side it remains at the initial value. In the final stage the wind speed has fully increased on one side of the rotor plane but is still at the initial value on the other. It is uncertain as to how physically representative this model is.

While the gust propagation is suitable for unidirectional/small direction changes in wind speed. It is not recommended for an extreme change in wind direction.

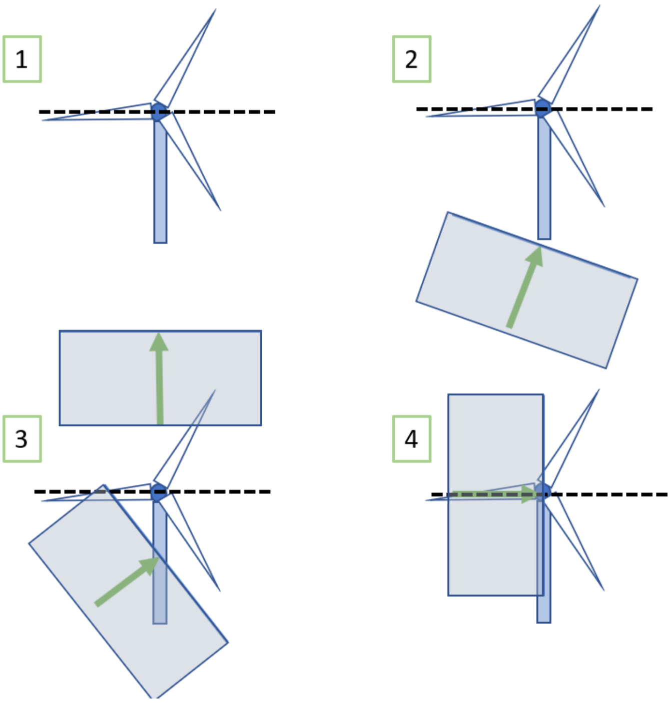

Figure 3 – Different stages of the propagating transient described in example 2. The blue box represents the area where the wind speed is increased during the simulation.

This issue can readily be observed the case of a wind turbine with two blades which are horizontal. Figure 4 shows the outputs of the local lateral wind speed at the blade tips. It is clear to see that in the case where gust propagation is on that the speed at blade tips 1 and 2 are significantly different in comparison to the scenario where gust propagation is off where the speed is identical at both blades.

This imbalance in the wind speed in the propagating gust case may lead to large changes in the stationary hub Myz load component relative to the scenario where gust propagation is off.

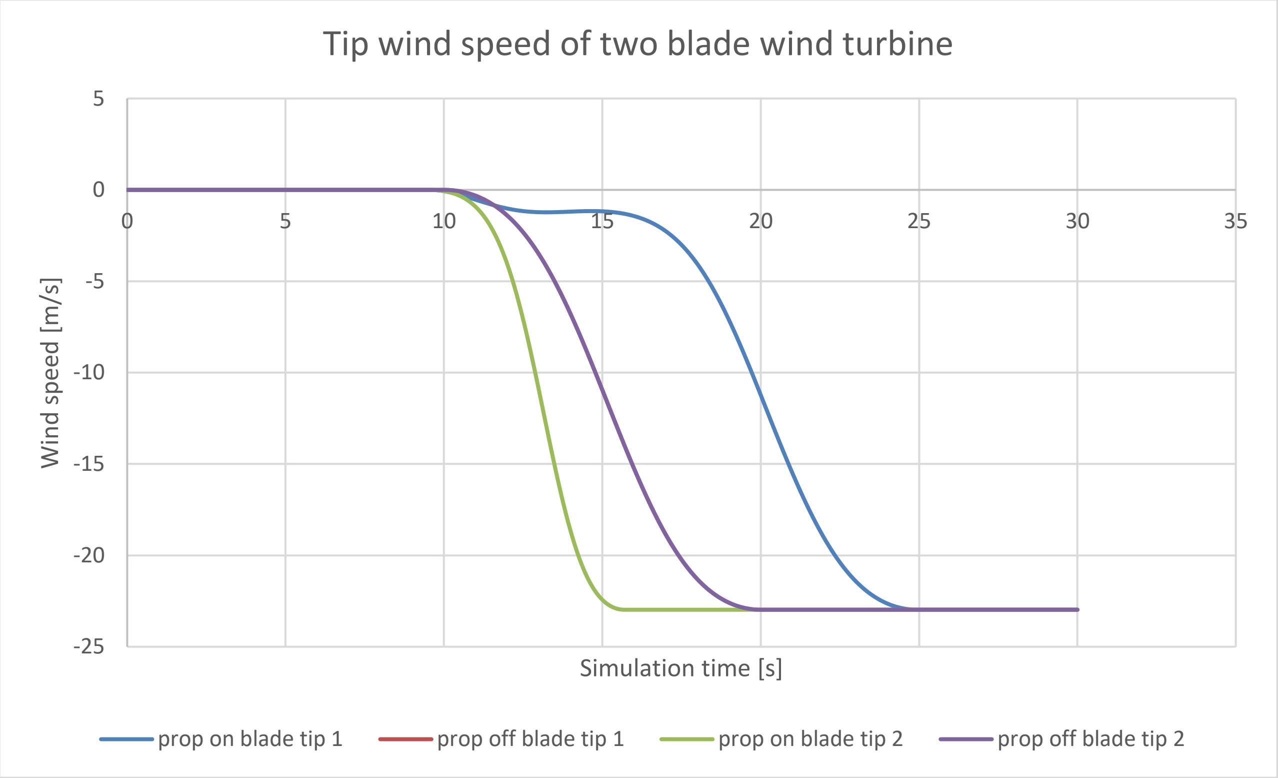

Figure 4 – The lateral wind speed outputs from a two bladed rotor from two simulations where the gust propagation option has been switched on and off.

3 WRITING A *.WND FILE TO MODEL A PROPAGATING TRANSIENT

The proposed solution of how to model the propagating wind field but to avoid the unphysical changes in wind speed across the rotor plane as outlined in Section 2 is to write a *.wnd file and use this to model the transient instead.

1. It is recommended that a time series is created that matches the hub height wind speed, direction and upflow of the desired transient.
2. Normalise this time series and write the data to a *.wnd file using the description of the *.wnd file format that is available on the Bladed portal.
3. Use the appropriate starting wind speed and set the turbulence intensity to create the correct amplitude of transient.

4 GENERAL NOTES ON RESULTS DIFFERENCES

There will remain some results differences between the scenario where a transient is modelled using a 3D *.wnd file and the standard transient model.

Any remaining discrepancies in the load outputs will most likely be attributed to the fact that speed changes will occur on blades at different times (when using the *.wnd file) which cause a load imbalance across the rotor.