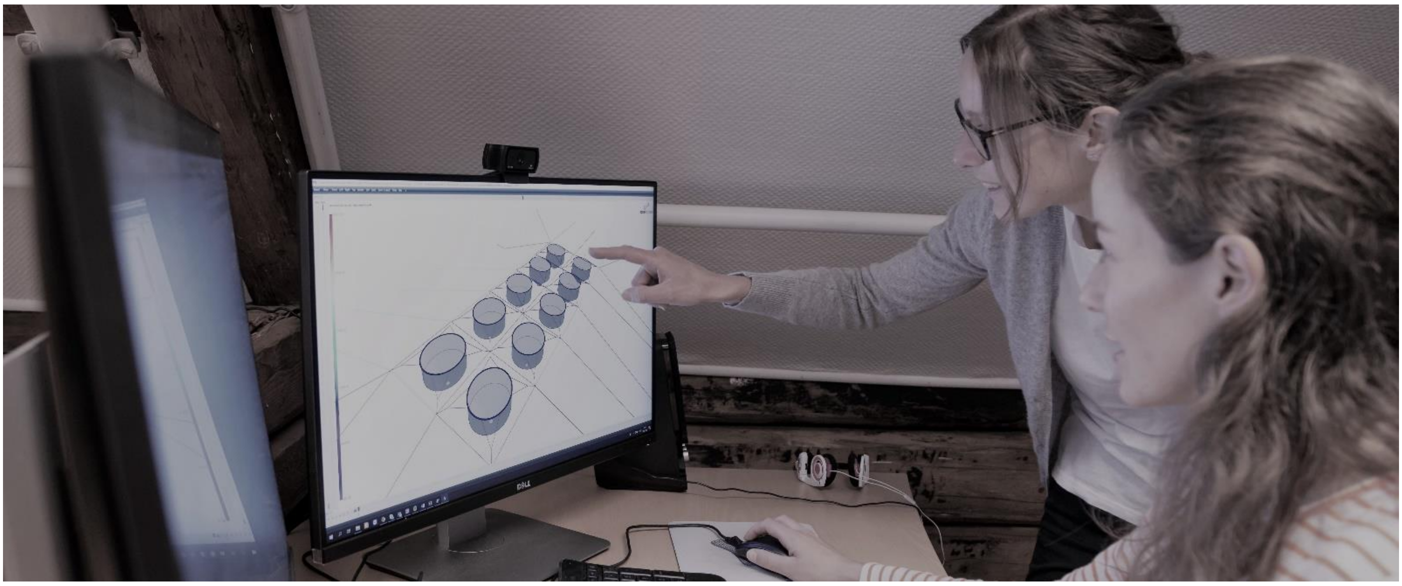
AquaSim training courses

- **Wind loads**

  Mean wind

  Wind gust



Revision: 1.0

AquaSim version: 2.18

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Content

1 Prerequisites

The tutorial presents a simple case study with the purpose of demonstrating functionality in AquaSim.

It is assumed that the user is familiar with the basic principles of modelling and specifying material parameters in AquaEdit, as well as conducting analyses. If you are looking for an introduction to AquaSim we advise you to start with the Basic program tutorials.

2 Case study – Wind

2.1 Learning objectives

Upon completion of this case study, you will be able to:

- Understand the opportunities that are for wind loads in AquaSim
- Specify wind load parameters
- Run analysis that includes loads from wind

2.2 Introduction

There are several component types in AquaSim. For most it is possible to carry out analysis with wind on these components. Some component types have even several options on how to introduce wind. Wind loads may be applied to account for any part of a system being in the air, which can be utilized to find response in systems that are exposed to wind. This can for instance be a wind turbine, as shown in this figure. This is a model of an offshore wind turbine, moored in a classical frame system with floaters, and turbine blades.

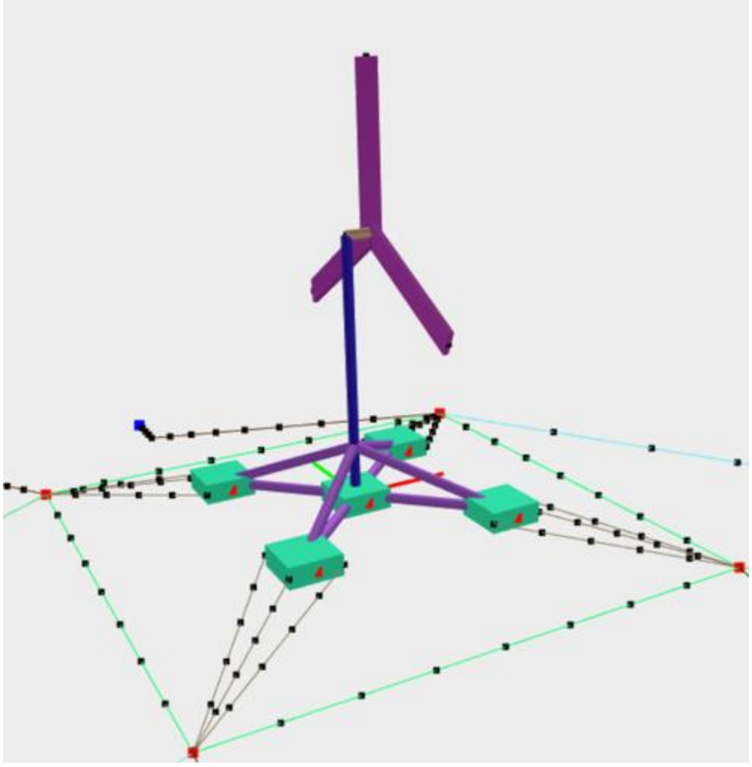

Figure 1

Theoretical formulations for wind loads are found here: https://aquasim.no/files/validation/TR-FOU-2328-4_Rev1.pdf

2.3 Beam – Type 1 (mean wind)

2.3.1 AquaEdit

In this first example we are going to look at wind type 1 for beam elements. The basic assumption for wind type 1 is that the elements in the component group represents a ship shaped structure horizontally in the water line. This type of wind is supposed to represent wind fetch on parts of the hull not being modelled, but where there is an actual wind exposure.

Open the AquaSim model *WindType1.amodel* that is associated with this tutorial.

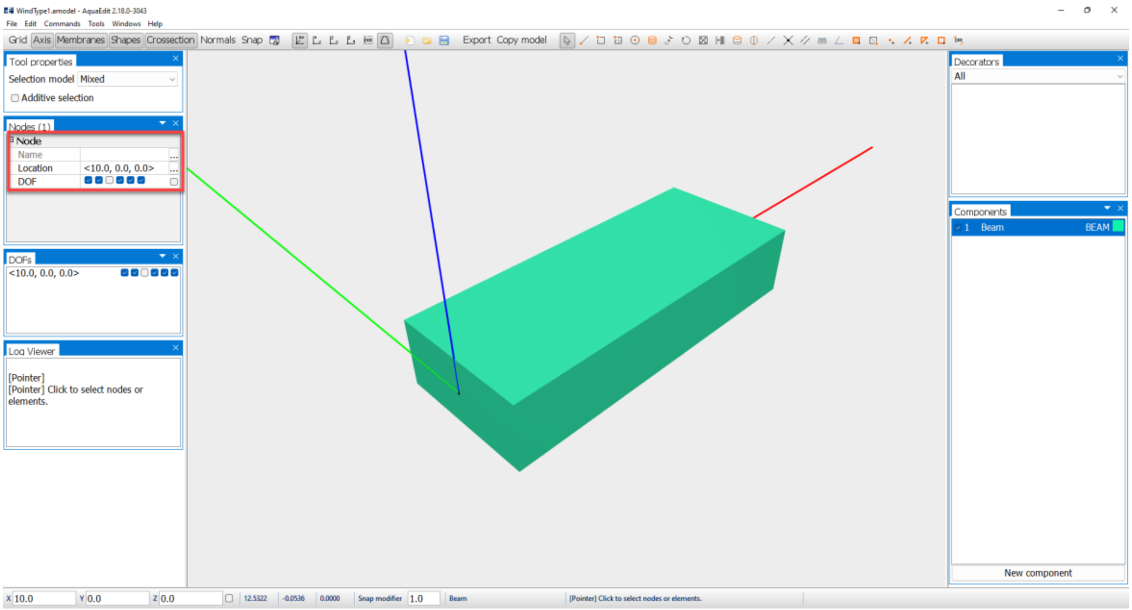

Figure 2

A simple one-element beam is modelled along the x-axis. One of the nodes are fixed, except for the z-direction. Options for including wind is found in the **Edit beam** window. **Doble click** on *Beam* in the components window and go to the **Elements**-tab.

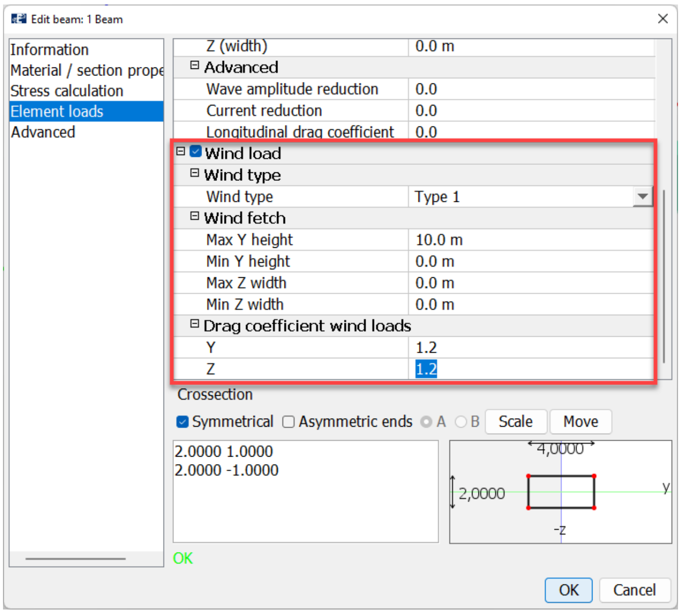

Figure 3

Wind loads are activated by toggle on the checkbox for **Wind Load**. Then a menu with sections for defining the **Wind type** and **Wind fetch** becomes available. From the drop-down menu in Wind type, select **Type 1**.

Wind fetch defines the area that is exposed to wind. This can extend further than the element size itself. The **Max Y height**, and **Min Y height** means to set wind fetch transverse to the element direction, in the horizontal plane. **Max Z width** and **Min Z width** is useful if the ship rolls. Then the deck also can be exposed to wind. Drag coefficients for the wind are set here fore y- and z-direction, see the section **Drag coefficient wind loads**. Apply the values as given in the figure above. Select **OK**.

The wind velocity itself is defined in the **Environment** window in the **Export** menu.

2.3.2 Analysis

Open the Export menu and select the Normal-tab.

Mean wind can be defined in both x- and y-direction. In the load condition line, these are identified as **wX[m/s]** and **wY[m/s]**. In this case study, a mean wind velocity of 30 m/s is applied in the y-direction. A logarithmic wind profile is assumed, and it is the 10-minute mean wind, 10 meters above the mean water line that is the input.

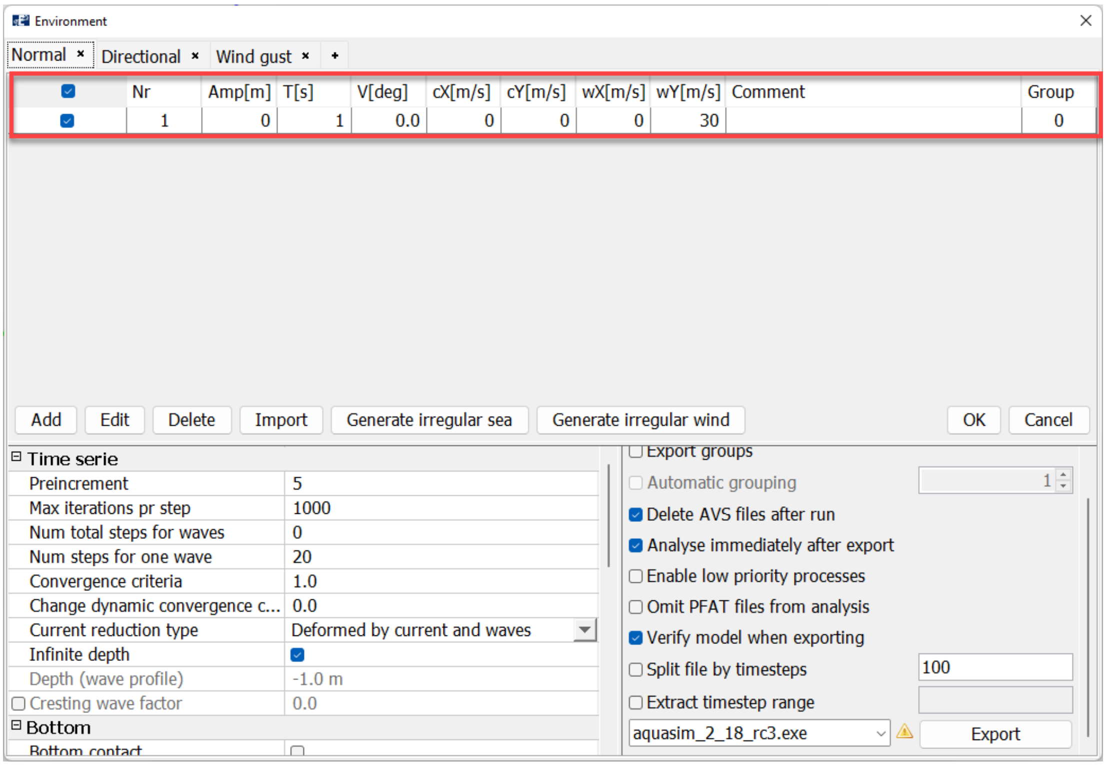

Figure 4

Go down to the **Time serie** section: mean wind is applied in the initial static steps in AquaSim. We leave **Preincrement** = 5 and set **Num total steps for waves** = 0. In this way, only the static steps will be considered.

To start the analysis, select **Export** in the lower right corner of the **Environment** window. Save the analysis a suitable place and **Start** the analysis. We have named the analysis *type1_mean_*.

Note: if you run the analysis in batch-mode, the CMD window will appear and view the status of the calculated steps. This is the same text that will appear if you select **Show messages** in the **Analyse**-window.

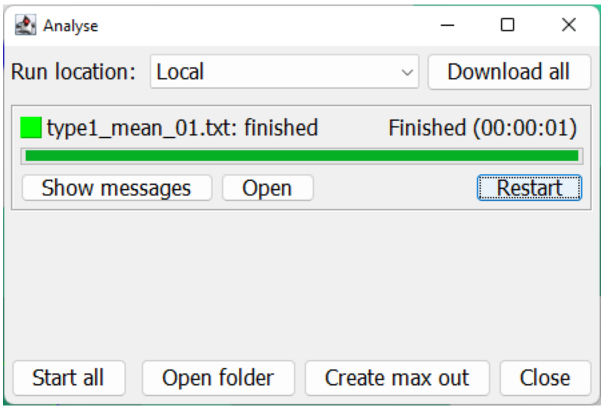

Figure 5

The analysis should be finished within seconds. Open the result file in AquaView through selecting **Open** from the **Analyse** window.

2.3.3 AquaView

In AquaView, we choose to view the shear force in y-direction. Select **Result** > **Local section forces** > **Shear force Y [N]**.

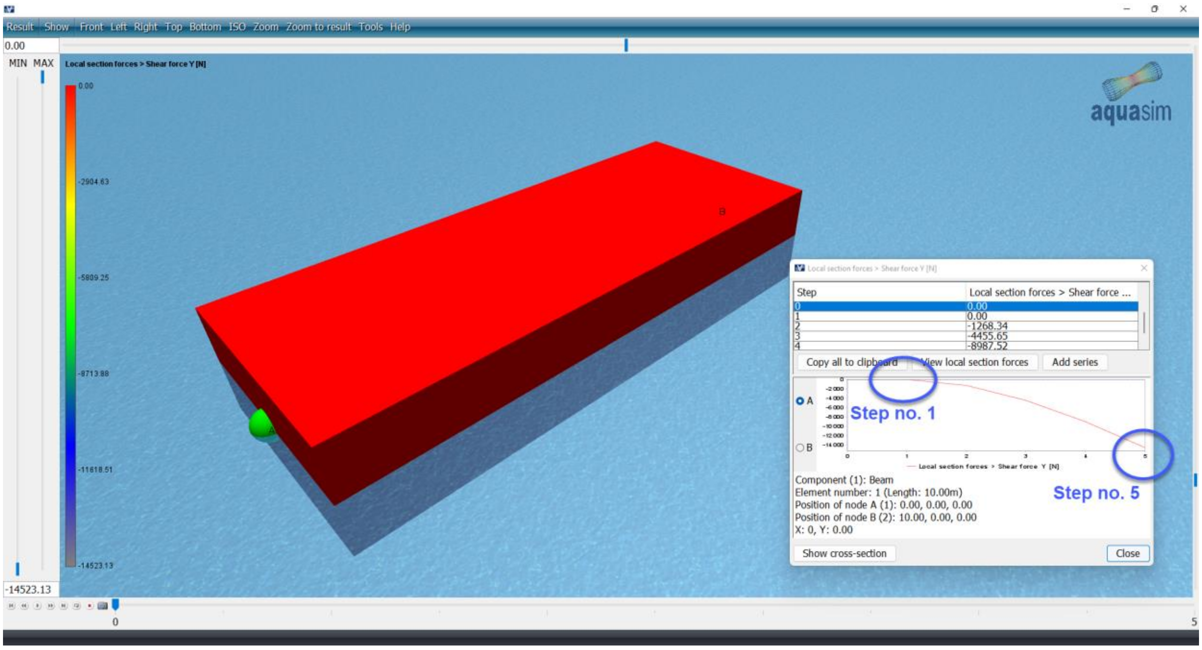

Figure 6

Wind is linearly increased from zero to its full value according to the number set in Preincrement in the Export menu. Therefore, the shear force **is zero in the first analysis** step. It is **fully developed** in step number 5. Ok, so this was mean wind for beams with wind type 1. In the next section, we investigate wind gust.

2.4 Beam – Type 1 (wind gust)

Go back to your AquaEdit model. Options for applying wind gust, or irregular wind spectrum, is also found in the **Environment** window in the Export menu, select **Export**. We have prepared a wind gust spectrum in the tab named *Wind gust*. When a wind gust spectrum is applied the sections **wX[m/s]** and **wY[m/s]** will come out grey in the load condition line.

In AquaSim, the mean wind is the basis, and wind gust are applied upon this. First, one need to establish a wind spectrum. This can be done through the **Edit** selection.

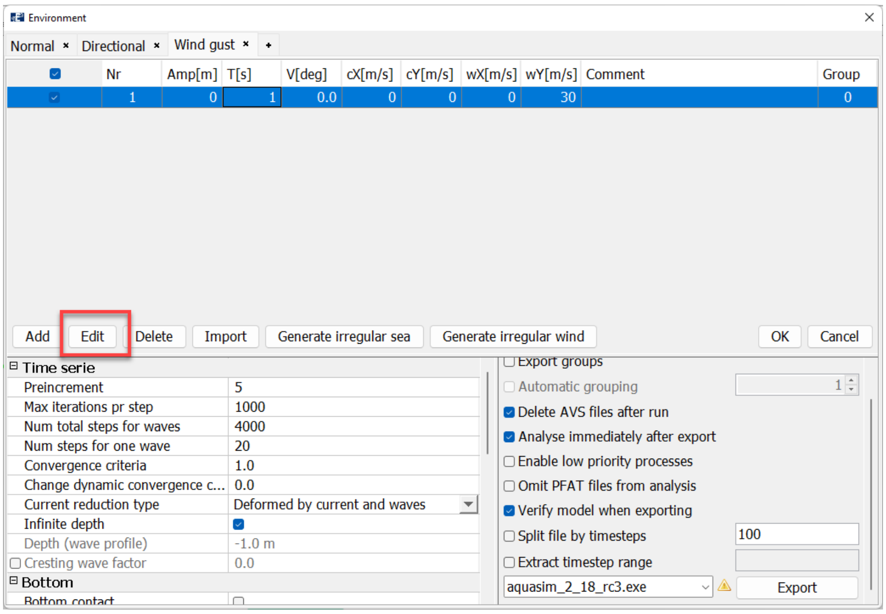

Figure 7

In the section **Wind type**, one can choose between **Regular wind**, this is the mean wind. **Irregular wind** and **NORSOK** spectrum. The selection Irregular wind provides the opportunity the input a custom spectrum. The NORSOK spectrum is based on the N003, Actions and action effects.

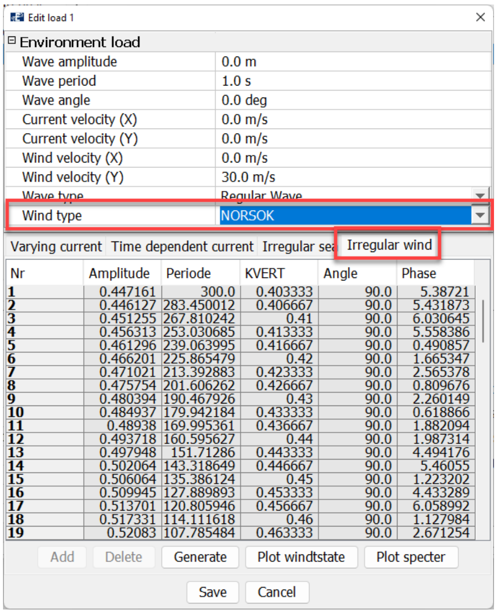

Figure 8

When selecting the tab **Irregular wind**, one can see the pre-generated wind gust spectrum. It can be generated through the **Generate** option in the lower part of the Edit window.

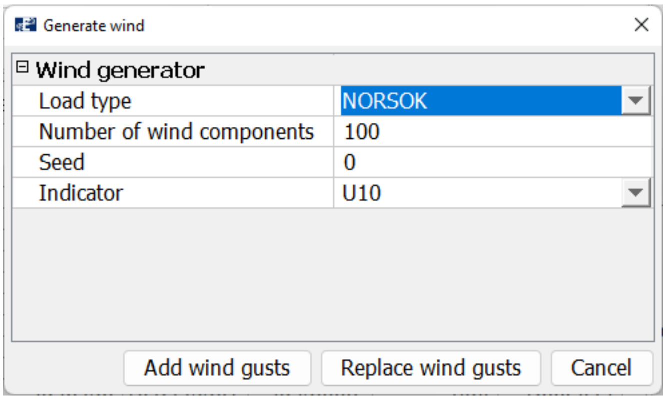

Figure 9

In the **Load type** section, the spectrum type can be selected. As for now only NORSOK is available. The **Number of wind components** defines how many sinusoidal components the wind gust should be discretized into. AquaSim generates the sinusoidal components from a random number, this is the **Seed**. In the last option, **Indicator**, you decide if the mean wind shall be interpreted as 10-minute mean wind or 1-hour mean wind. Wind gust can either be applied upon previously generated amplitudes (**Add wind gust**) or replace them (**Replace wind gusts**). We accept the predefined spectrum, and hence **cancel** this window.

Having generated a spectrum, one can **Plot the windstate**. **Plot the spectre**. Or view the **Standard deviation**.

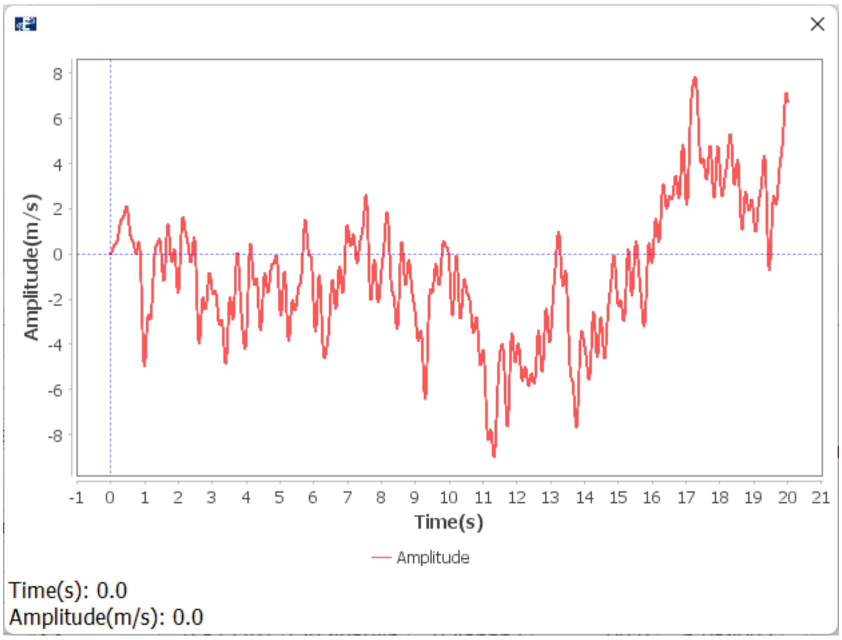

Figure 10

We **exit** the **Edit load 1** window and go back to the **Environment** window.

In the **Time serie** section, we choose to analyse with 20 wind components. Type **Num total steps per waves** = 4000 and **Num steps per wave** = 20. Leave **Preincrement** = 5.

2.4.1 Analysis

Let us run an analysis with these settings; select **Export** and save the analysis a suitable place. We have named the analysis *type1_gust_*.

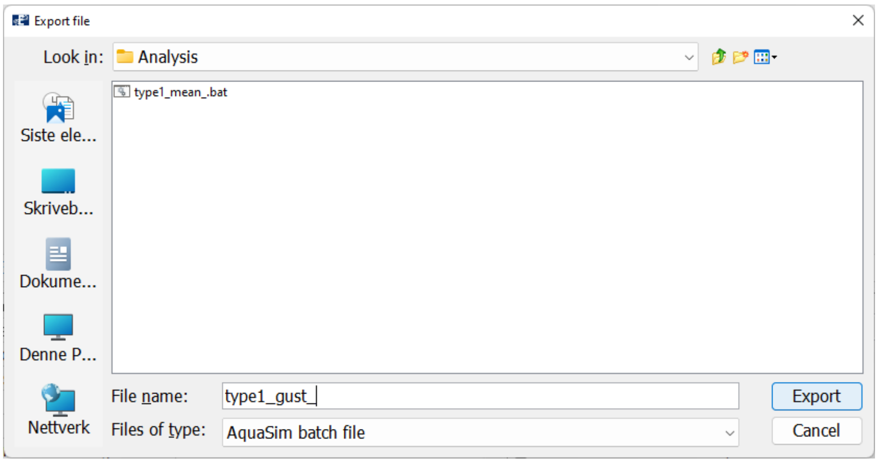

Figure 11

Select **Export** and **Start** the analysis from the **Analyse** window. When the analysis is finished, **Open** it in AquaView.

2.4.2 AquaView

In AquaView, we will look at the shear force in y-direction. **Result** > **Local section forces** > **Shear force Y [N]**. When viewing the shear force as a function of time-steps, one can **zoom into the graph** by left click and drag to the right.

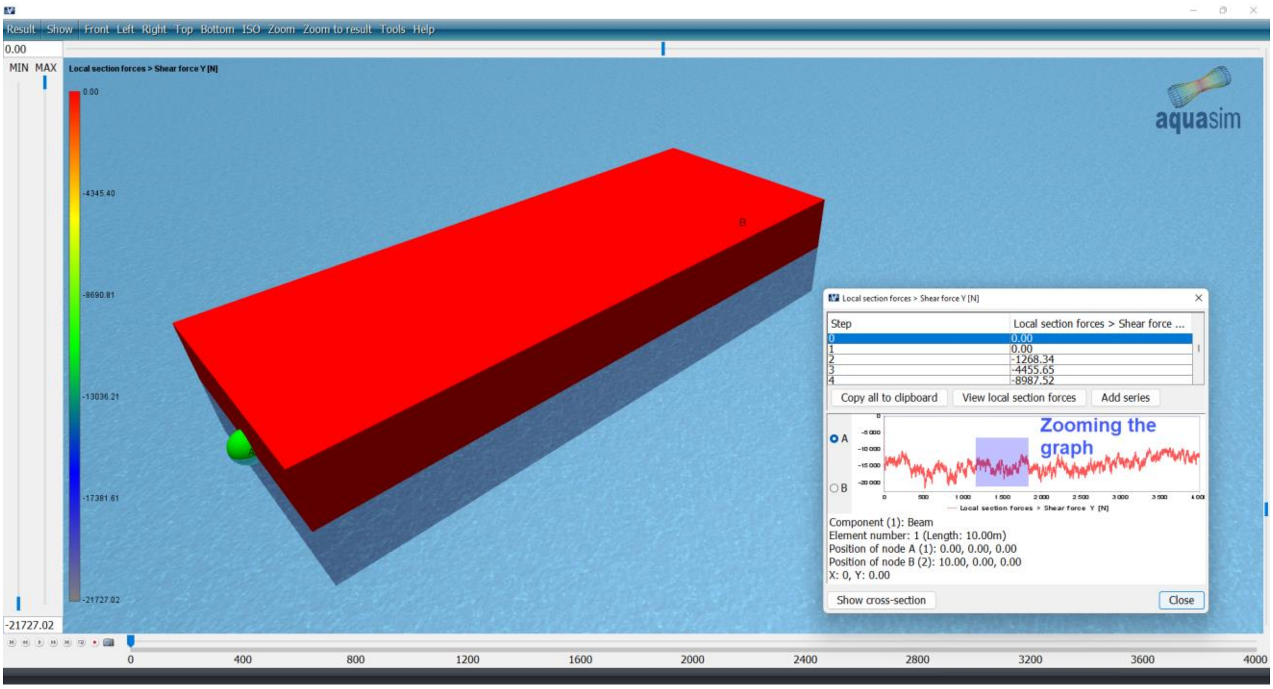

Figure 12

As seen in the zoomed graph below, there are sharp edges and fluctuations in the results. This indicates that the wind has components with high frequencies. In order to investigate this further, we run a second analysis with only a tenth part of the time series.

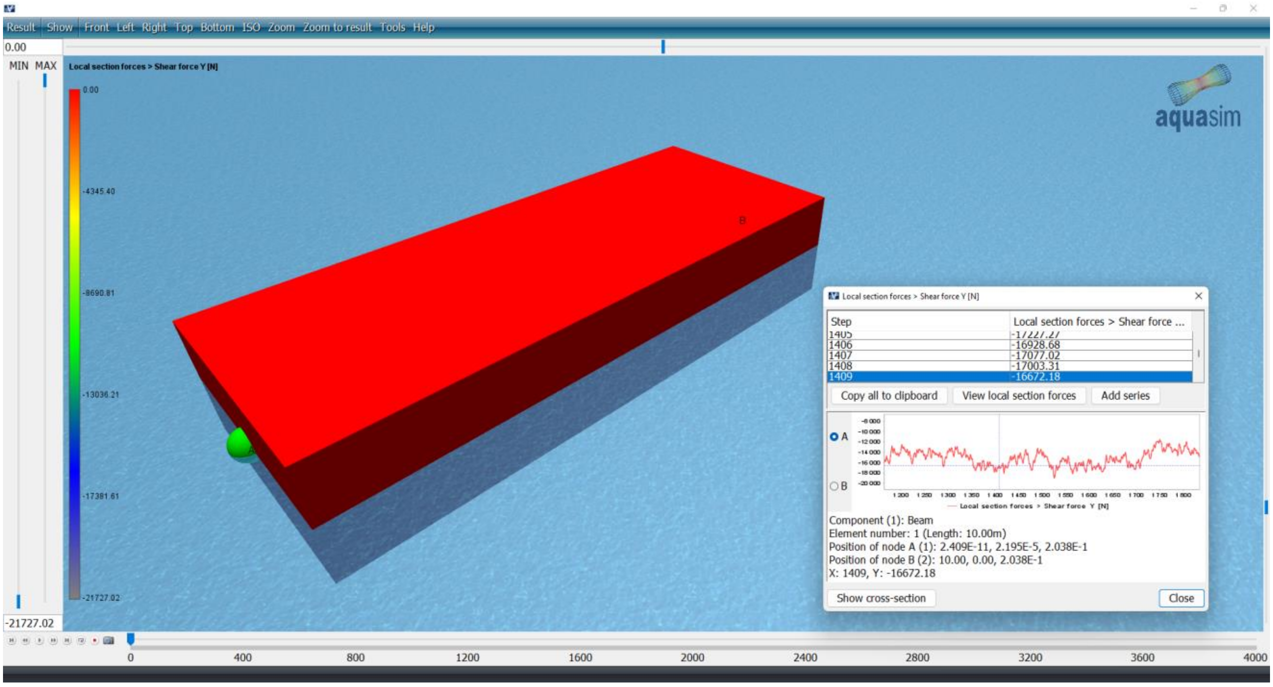

Figure 13

2.4.3 AquaEdit

Go back to your AquaEdit model and enter again the **Export** menu and the **Wind gust**-tab. Replace **Num steps per wave** from 20 to 200 steps.

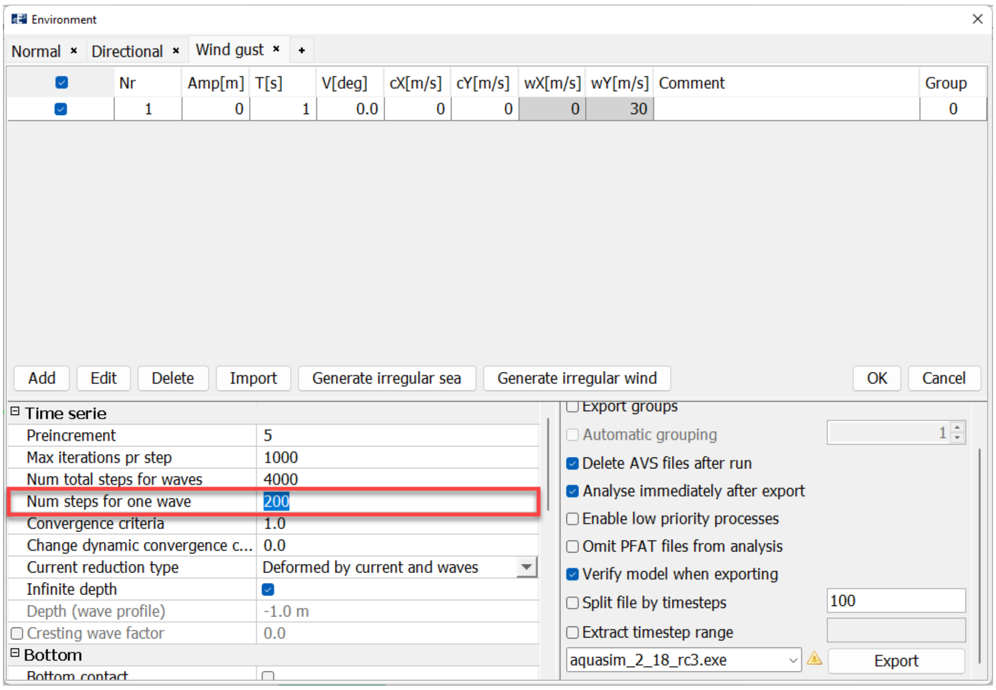

Figure 14

2.4.4 Analysis

Export the new analysis, we have named it *type1_gust200_*.

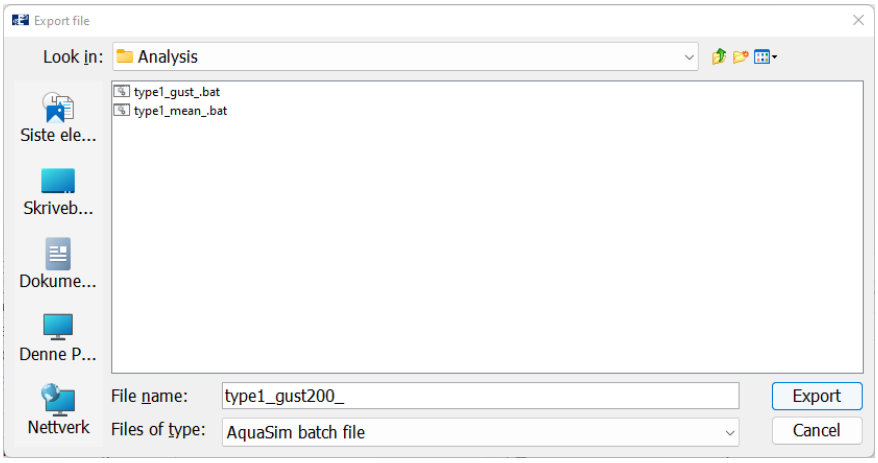

Figure 15

Once the analysis is finished, **Open** it in AquaView.

2.4.5 AquaView

Plot the shear force in y-direction again.

When we zoom into the time series, we see that the high frequencies are reflected in the shear forces. For large systems, the high frequency parts may be filtered out. But this depends on the mass and damping. The user is encouraged to investigate the effect of time series discretization for each considered case that should be analysed.

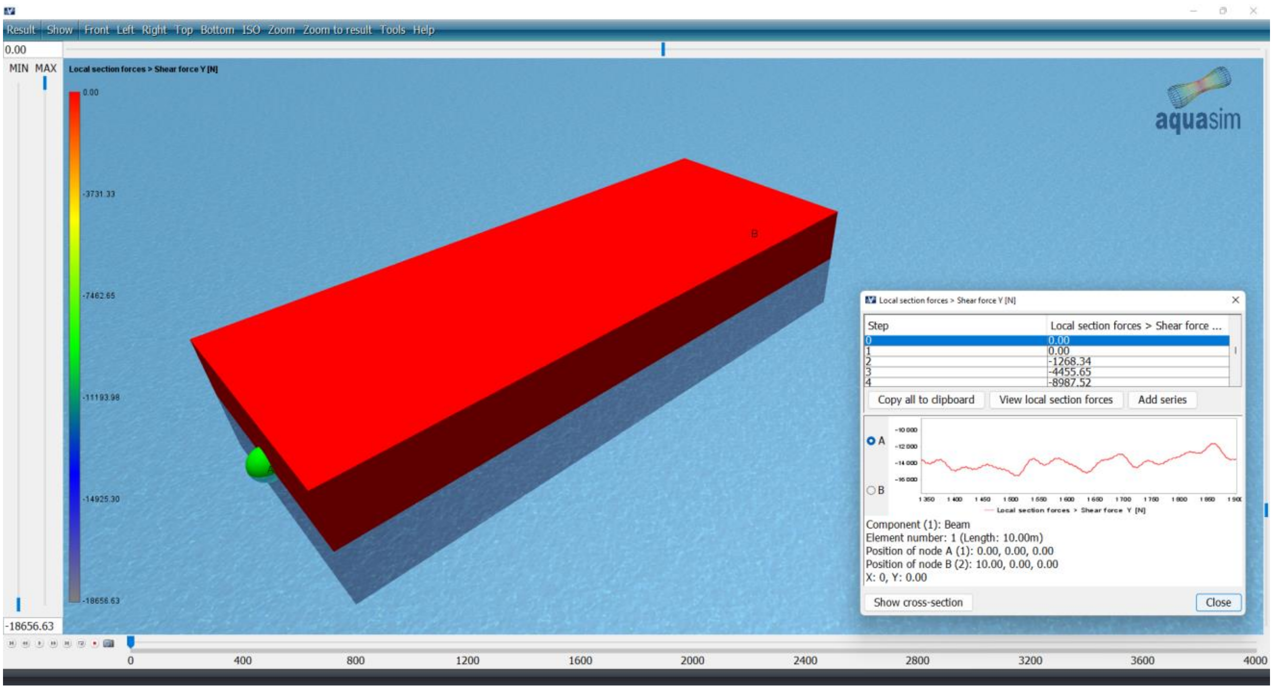

Figure 16

2.5 Beam – Type 2 (wind gust)

Another wind load type that can be applied is wind **Type 2**. The basis for the type 2 wind is that the parameters for drag loads are the same as for submerged elements.

Open the AquaSim model *WindType2.amodel* that is associated with this tutorial.

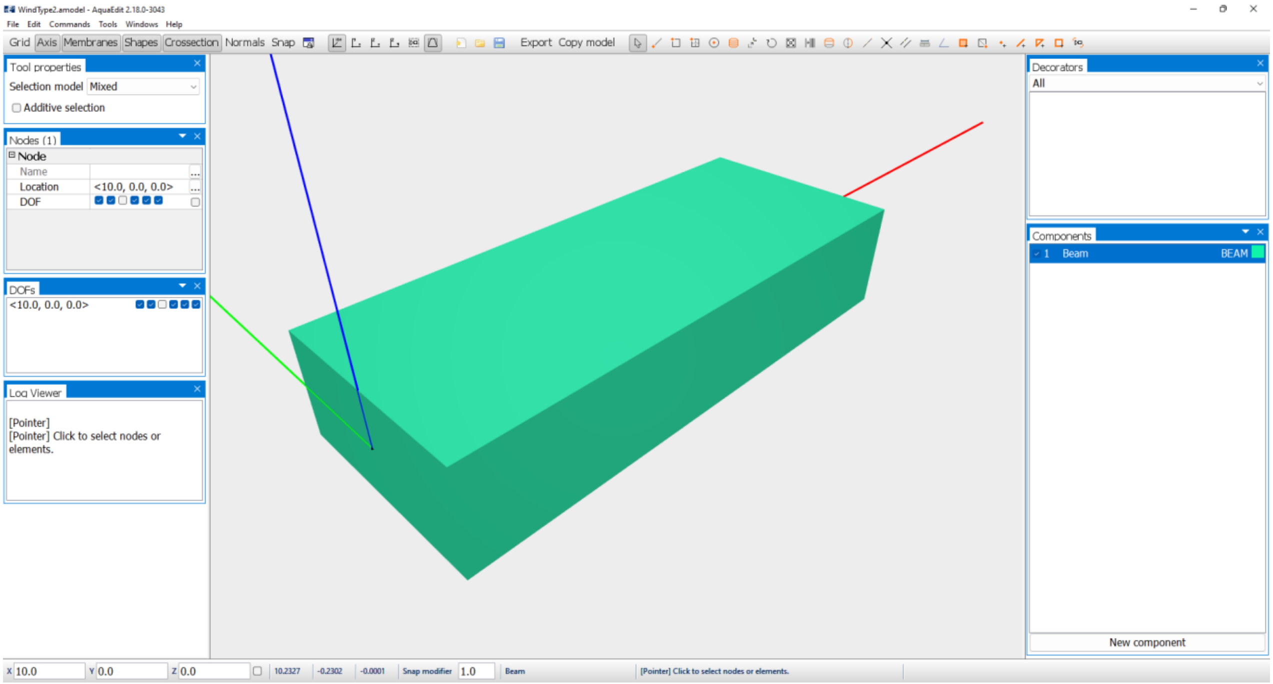

Figure 17

In AquaEdit we have a similar model as in the previous cases. Double click the component *Beam* in the components window and select **Element loads**.

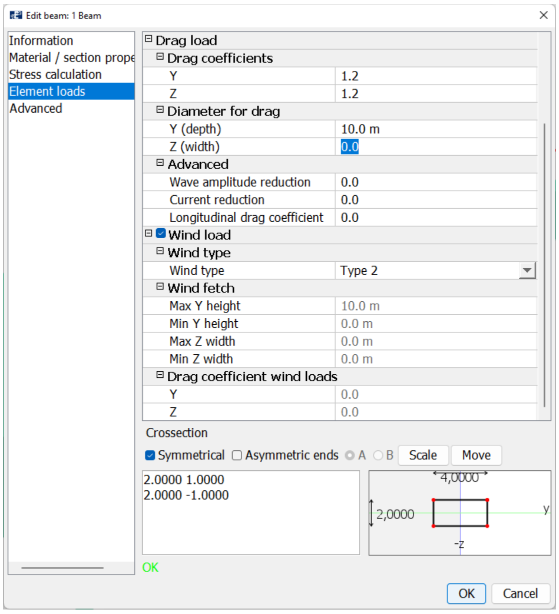

Figure 18

In the section **Wind type**, select the drop-down menu an choose **Type 2**. Then all the parameters for maximum and minimum Y and Z in inactivated. This also apply for the **Drag coefficients wind loads** section.

If we scroll up to the **Drag load** section, AquaSim now apply the values found under here. Then we need to define drag coefficients and diameter for drag in y- and z-direction. Let **Drag coefficients** Y and Z equal to 1.2 and **Diameter for drag** Y (depth) equal to 10. Select **Ok**.

Let us run an analysis with wind gust; go the **Export** menu and select the predefined tab **Wind gust**.

2.5.1 Analysis

Apply values according to the figure below.

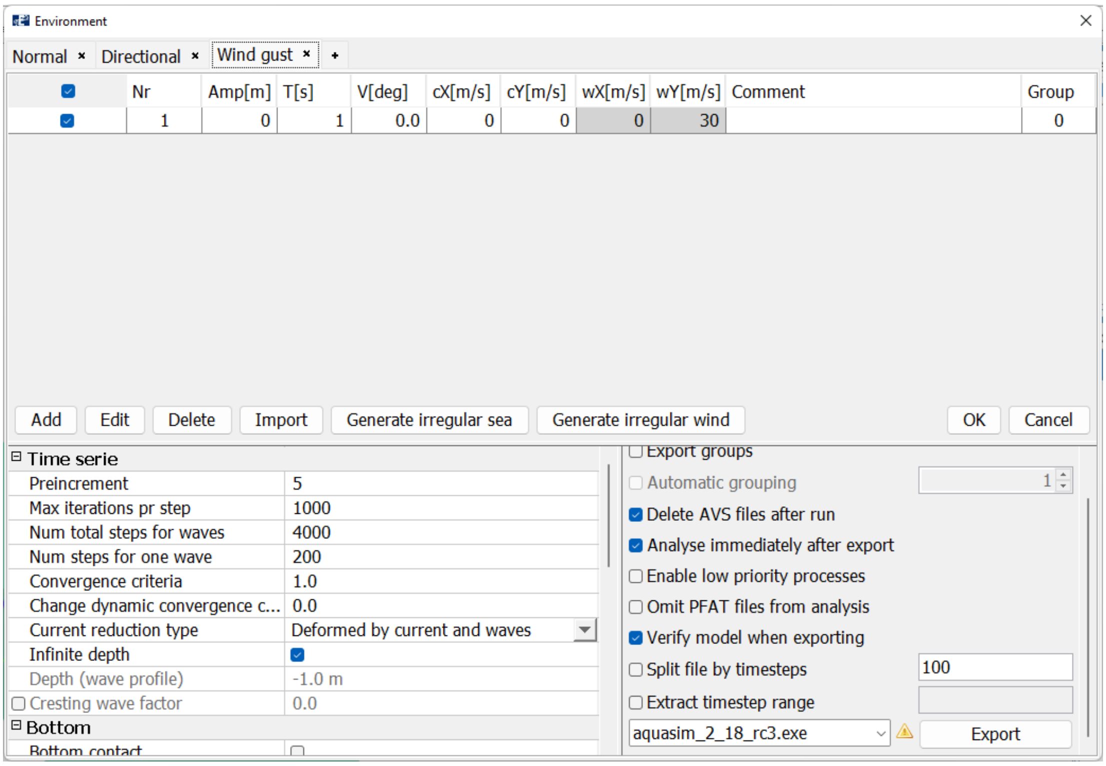

Figure 19

Then **Export** the analysis and **Start** it when it is saved a suitable place. We have named the analysis *type2_gust_*.

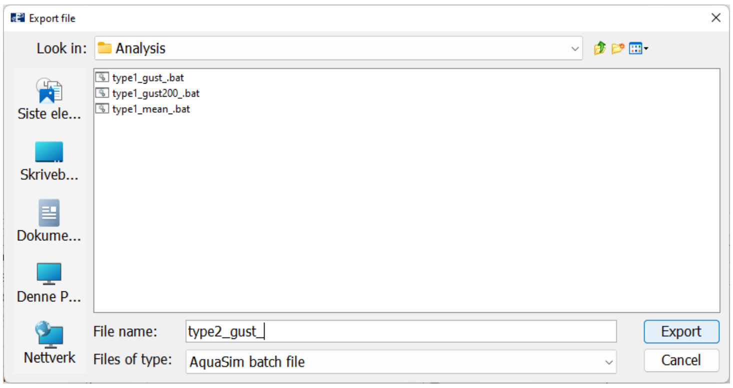

Figure 20

When the analysis is finished, **Open** it in AquaView.

2.5.2 AquaView

Plot the shear force in y-direction.

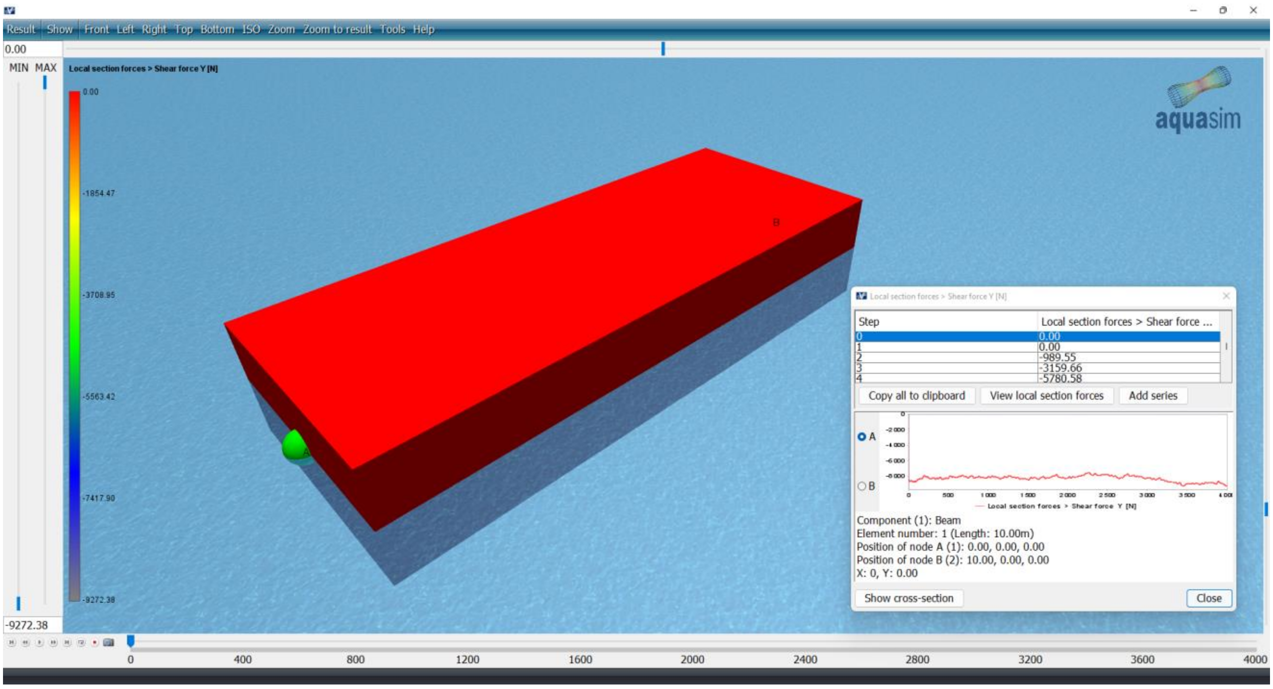

Figure 21

If we compare the shear force of wind type 1 and type 2, we can see that there are variations due to how the wind is calculated based on different assumptions.

2.6 Truss – Type 1 and 2 (mean wind and wind gust)

Wind can also be applied on Truss components. Applying wind on Trusses works in the same manner as for Beam components, where Type 1 and Type 2 are available.

Options for applying wind is found in the **Edit** Truss window, in the **Wind load** tab.

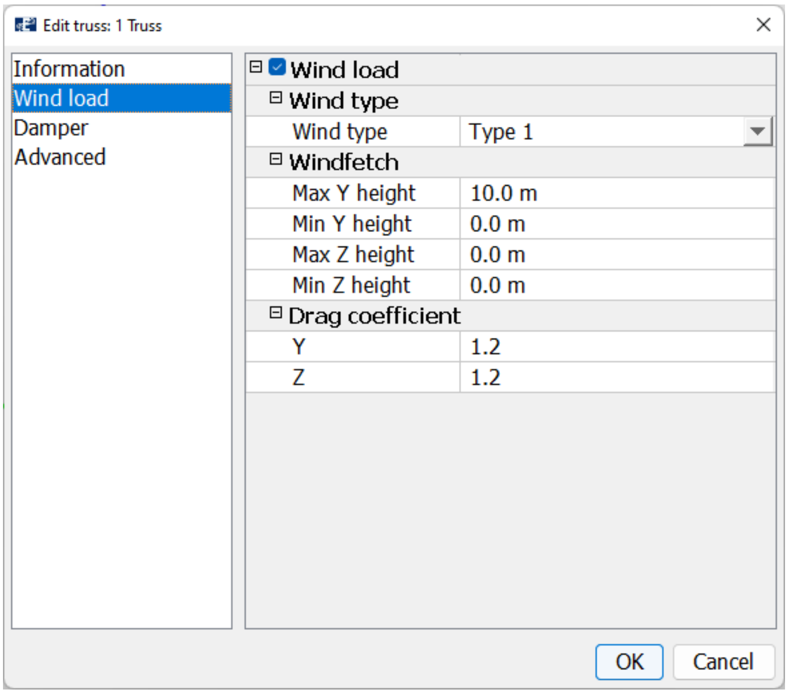

Figure 22

An example model is prepared in the AquaSim model *WindType1_truss.amodel*. To run analyses, you can follow the same steps as presented in the previous sections of this tutorial.

2.7 Membrane (mean wind)

Wind can also be applied to Membrane components. In this case study, a membrane of type Normal in combination with the Load formulation Normal is presented.

Open the AquaSim model *Wind_Membrane.amodel* in AquaEdit. This is a simple model with 3 one-element membrane panels at three different vertical locations.

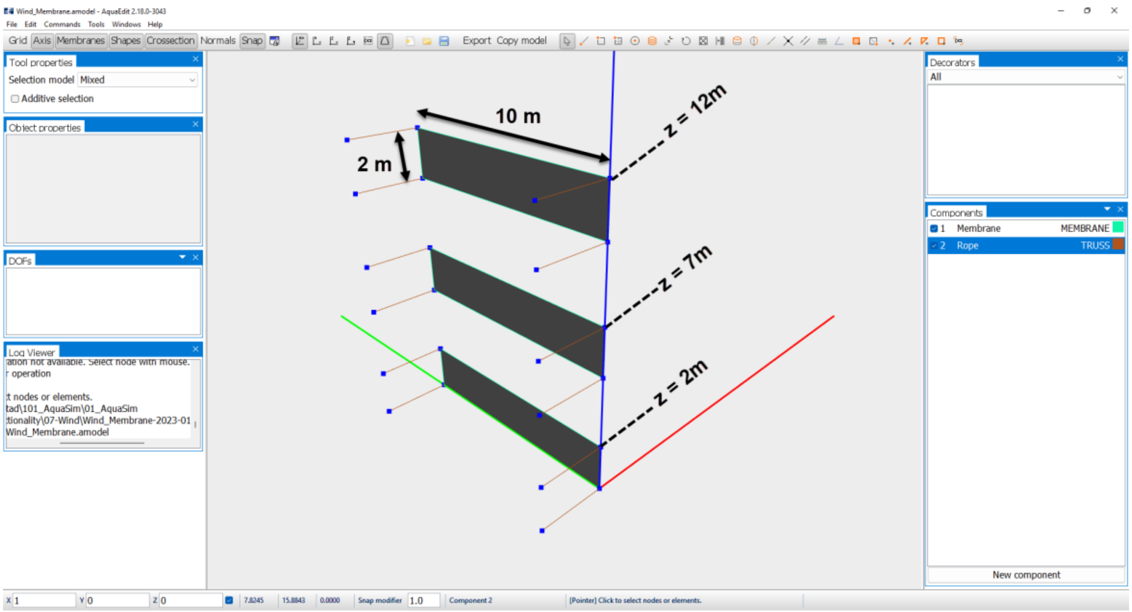

Figure 23

The panels are restrained from moving in all degrees of freedom, except from x-direction. In addition, the panels are restrained with ropes on the x-direction. When wind is applied along x-direction the wind forces on the panels are reflected in the ropes.

In AquaSim, mean wind is included for membrane panels of type Normal when the **Net in air** selection is toggled on. This is found the **Edit** Membrane window, in the **Load properties** tab.

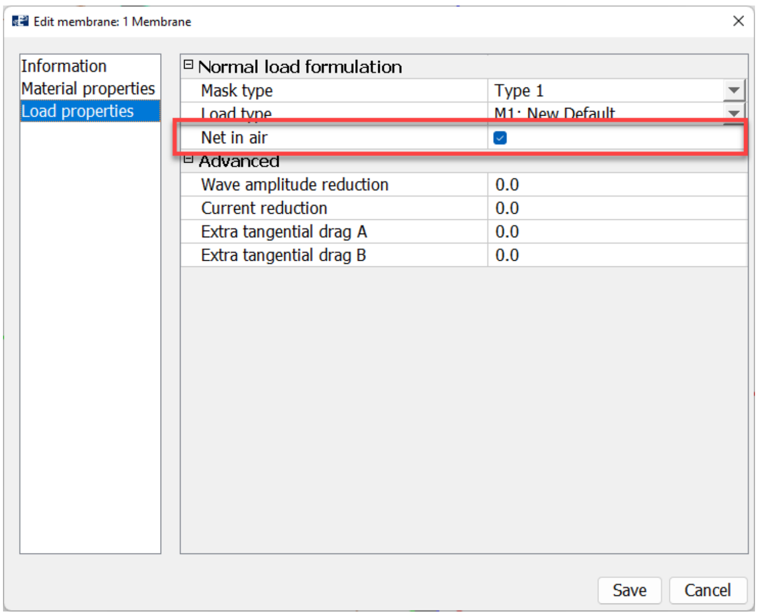

Figure 24

The properties of the membrane may be reviewed in the **Material properties** tab.

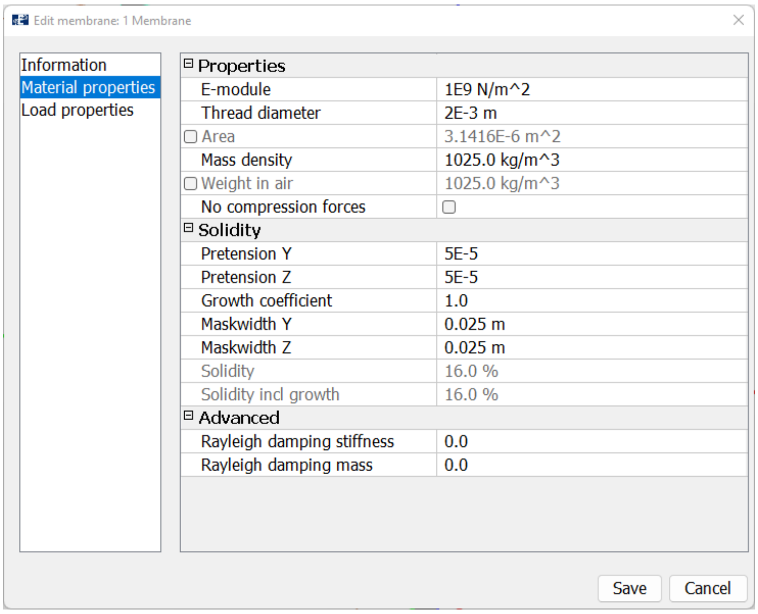

Figure 25

We are satisfied with the defined values and select **Save**. The cross sectional properties of the ropes are found in the figure below. It is assigned some stiffness, but the volume and weight are set equal to 0. In that way, the ropes will only contribute to restrain the panels and to take up axial forces. They will not contribute to aerodynamical forces.

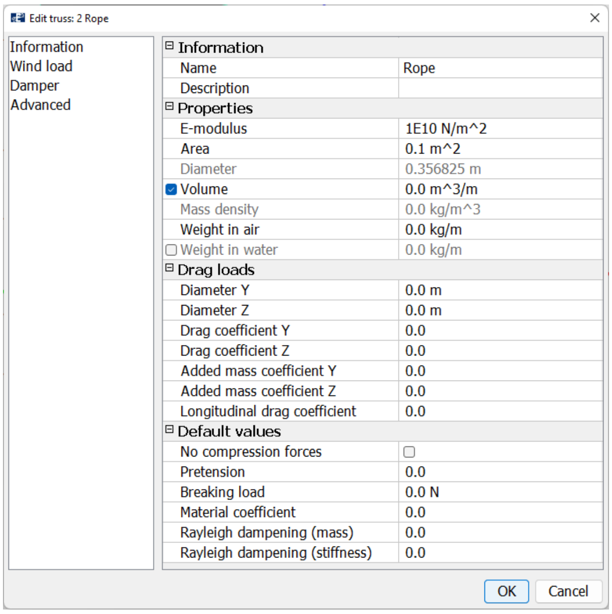

Figure 26

The wind velocity itself is defined in the **Environment** window in the **Export** menu.

2.7.1 Analysis

Select Export and navigate to the Normal-tab. The setup is equivalent to what was presented in the first case study with the Beam exposed to mean wind, only that the wind is applied along the x-direction. Hence, **wX[m/s]** =30.

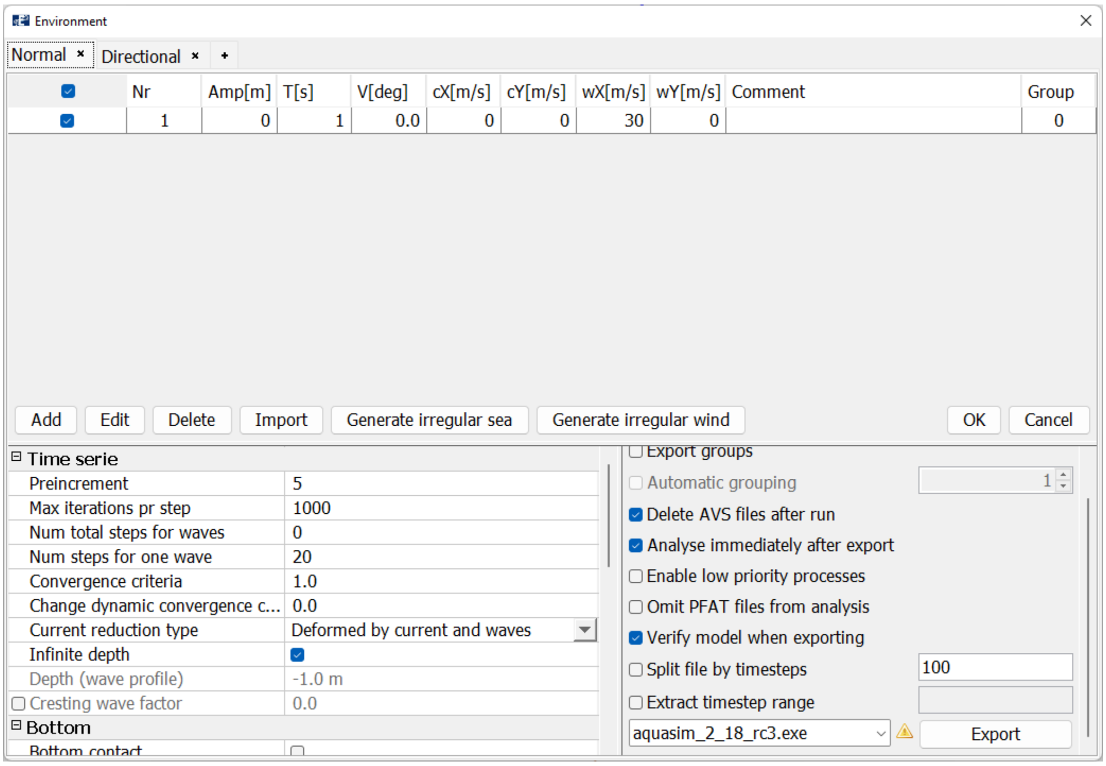

Figure 27

Only the static part of the analysis is considered. **Preincrement** is set to 5 and **Num total steps for waves** are equal to 0.

2.7.2 Analysis

Export the analysis and save it a suitable place. We have named the analysis *membrane_mean_*. **Start** the analysis.

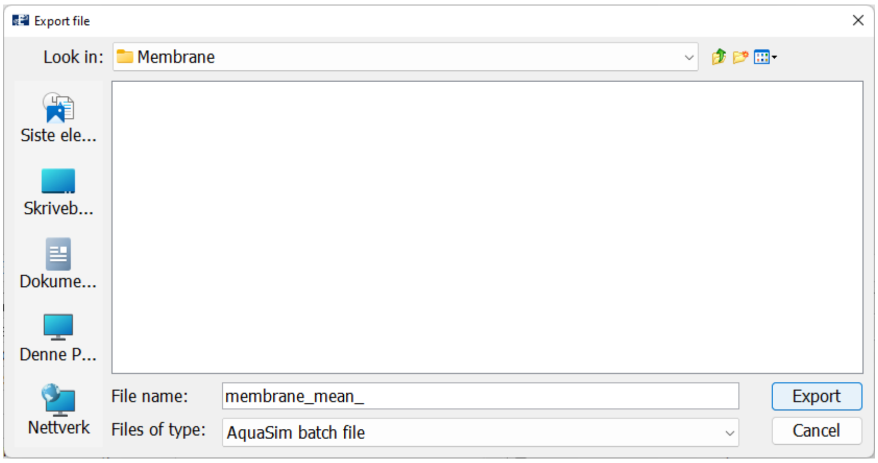

Figure 28

When the analysis is finished, **Open** it in Aquaview.

2.7.3 AquaView

We should plot the axial forces in the trusses, select **Result** > **Local section forces** > **Axial forces [N]** and select the truss elements in the 3D window.

AquaSim apply a logarithmic wind profile. This will result in different values of wind loads at different elevations. This is seen by the axial forces in the ropes vary with the panels. The highest panel is exposed to a higher wind load than the lower ones.

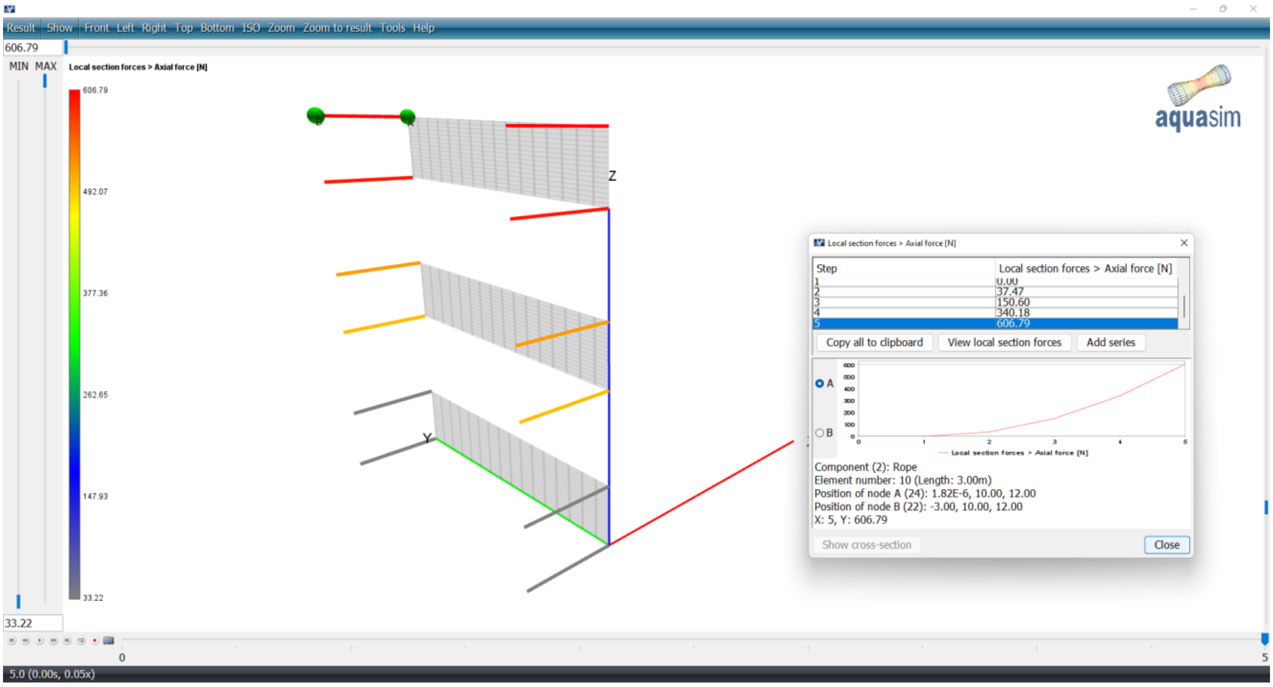

Figure 29

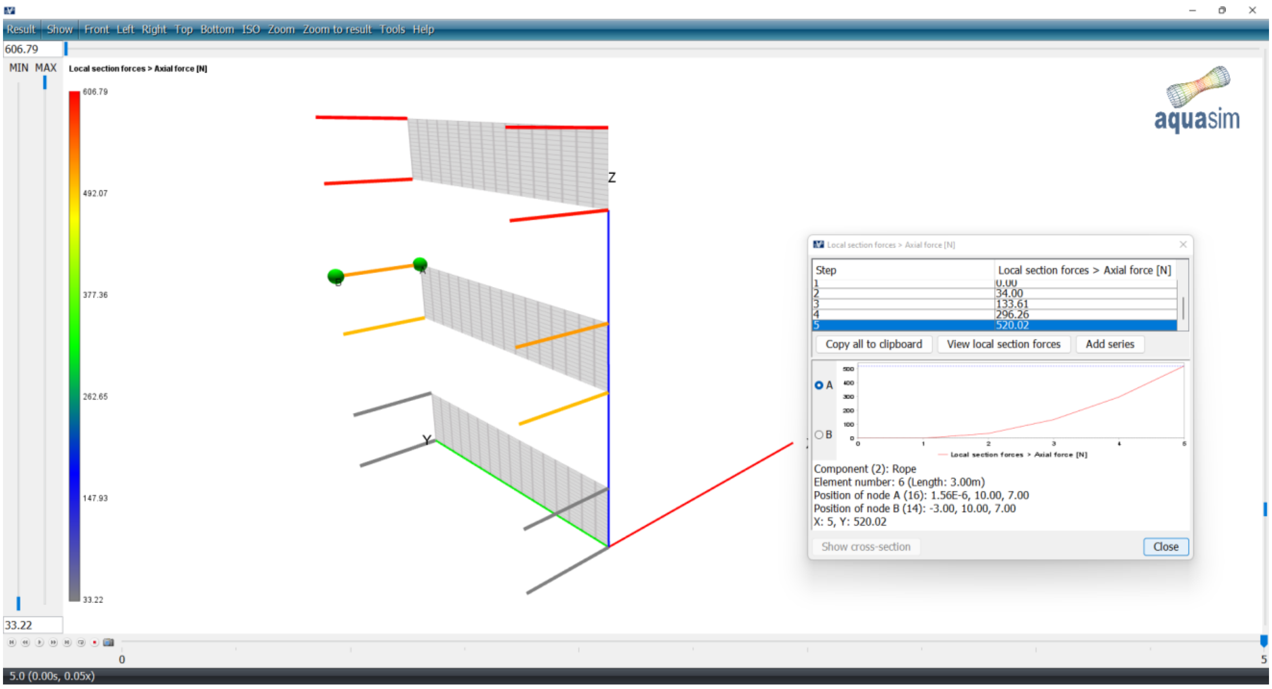

Figure 30

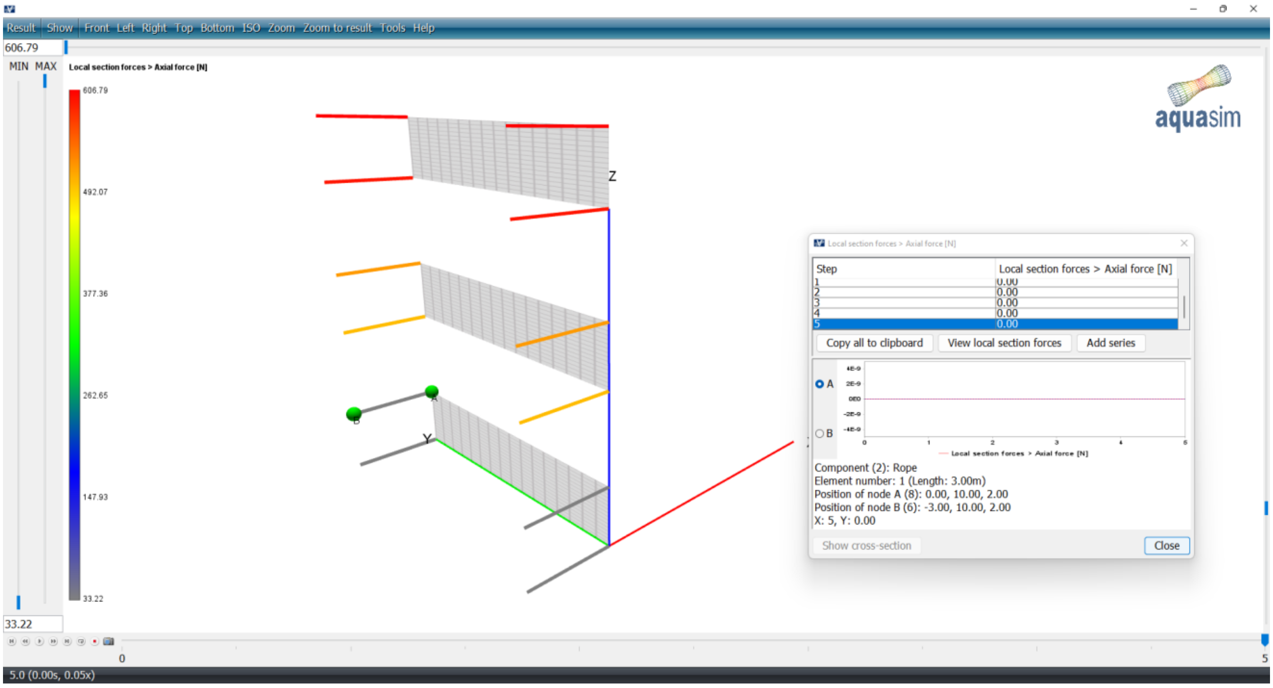
Result Show Front Left Right Top Bottom ISO Zoom Zoom to result Tools Help
606.79
MIN MAX
Local section forces > Axial force [N]
606.79
492.07
377.36
262.65
147.93
33.22
aquasim
Z
Y
33.22
Step
Local section forces > Axial force [N]
1 0.00
2 0.00
3 0.00
4 0.00
5 0.00
Copy all to clipboard
View local section forces
Add series
A
B
Component (2): Rope
Element number: 1 (Length: 3.00m)
Position of node A (8): 0.00, 10.00, 2.00
Position of node B (6): -3.00, 10.00, 2.00
X: 5, Y: 0.00
Show cross-section
Close
0
5
5.0 (0.00s, 0.05x)

Figure 31

2.8 Membrane (wind gust)

Let us now investigate the opportunities for wind gust on the membrane panels. Go back to your AquaEdit model and return to the **Export** menu. Navigate to the prepared **Wind Gust** tab. When a wind gust spectrum is applied the sections **wX[m/s]** and **wY[m/s]** will come out grey in the load condition line.

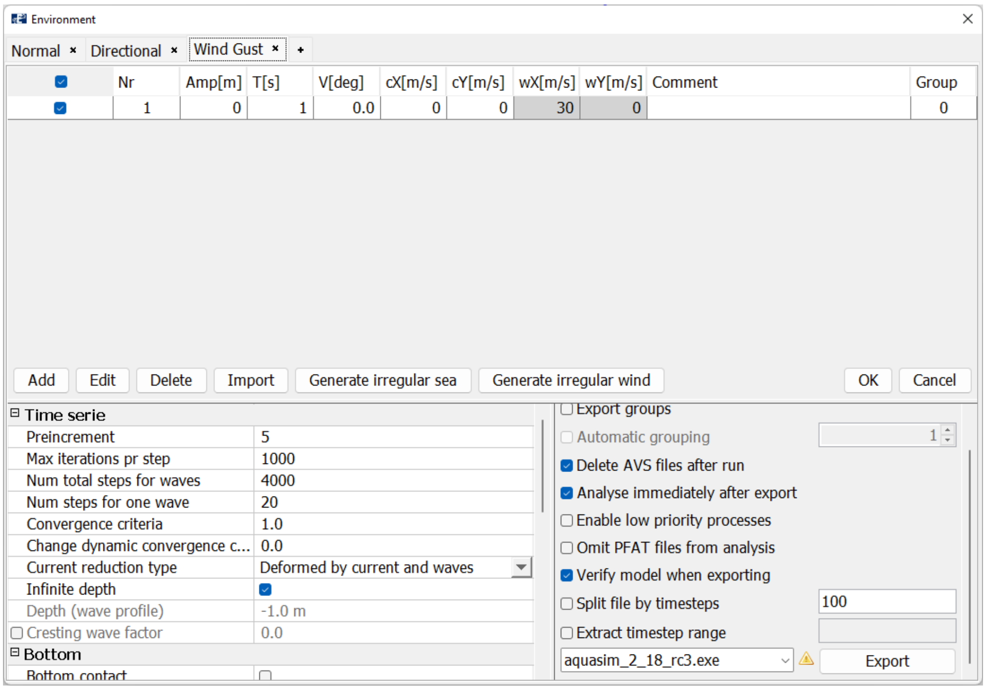

Figure 32

You may review the wind gust spectra through first click on the load line so it become blue, then select **Edit**. In the **Edit load 1** window, go to the **Irregular wind** tab and select **Plot windstate**.

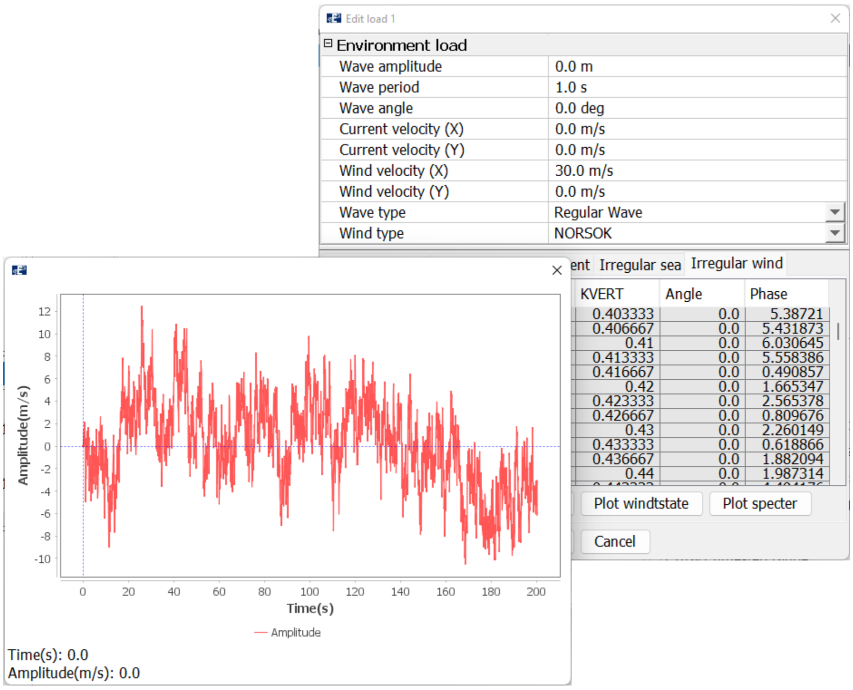

Figure 33

Exit the Edit load 1 window. We should run an analysis with 5 initial steps (**Preincrement**), **Num total for waves** = 4000 and **Num steps per wave** = 20.

2.8.1 Analysis

Export the analysis and save it a suitable place. We have named the analysis *membrane_gust_*. **Start** the analysis.

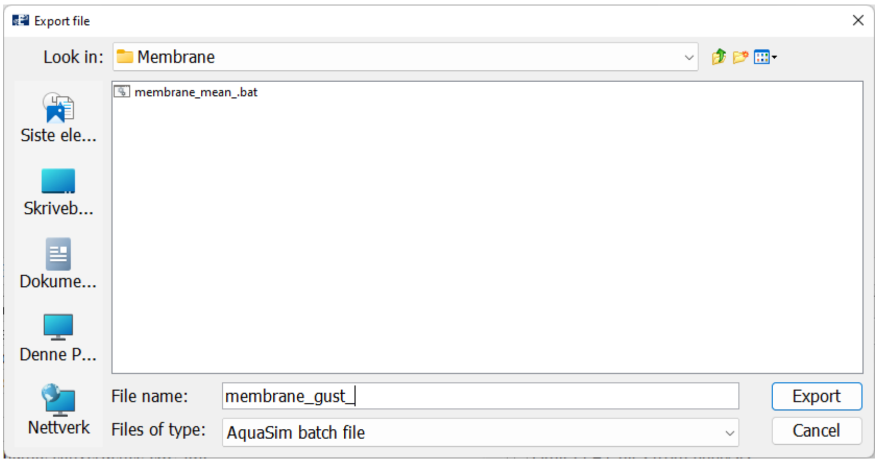

Figure 34

When the analysis is finished, **Open** it in AquaView.

2.8.2 AquaView

We should plot the axial forces in the trusses, select **Result** > **Local section forces** > **Axial forces [N]** and select the truss elements in the 3D window.

As seen when plotting the axial forces in the trusses for the different panel location, it increases with the height. This is consistent with how the wind varies with height.

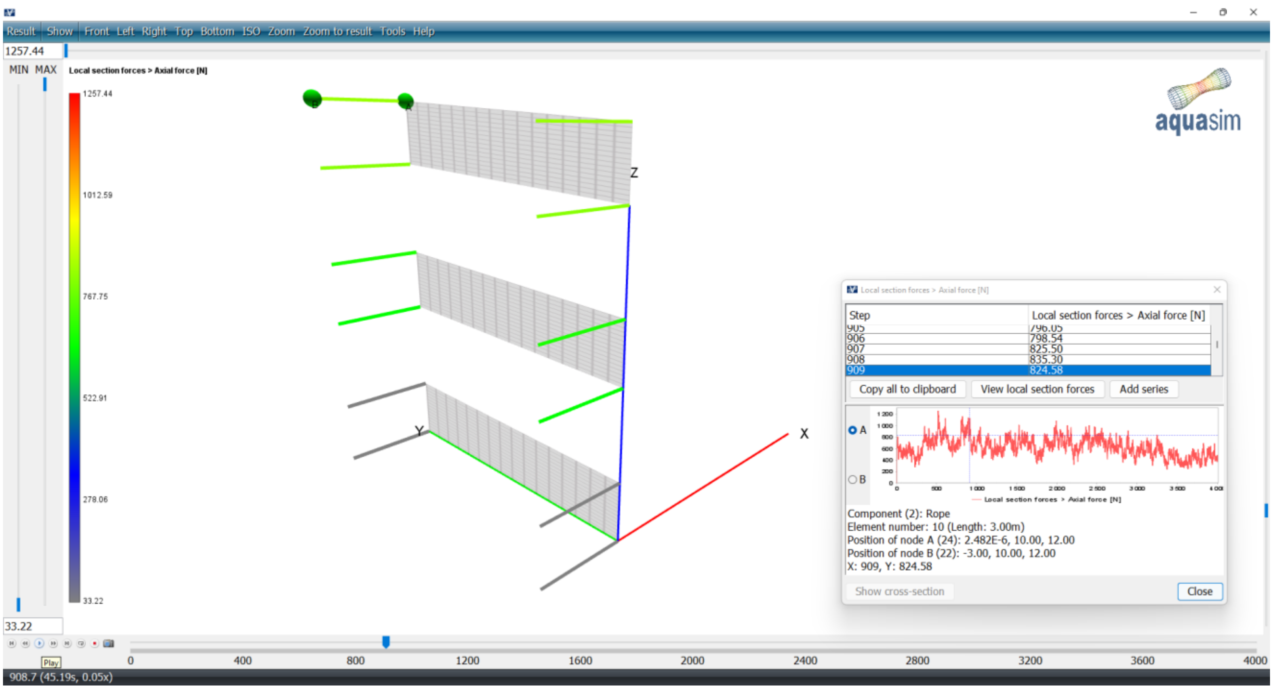

Figure 35

2.9 Summary

In this tutorial you have been given an introduction to how wind can be applied to beams, truss and membrane. Both mean (regular) wind and a wind spectrum can be applied for most components in AquaSim.

By establishing simple models and apply the wind stepwise one can check that the wind loads are as expected. In general, it is advised to first establish simple models to check how the options works, and then implement it to more complex models. In that way you keep control of the different load contributions in the analysis.

At last, it is noted that other membrane load formulations (other than type Normal) includes wind forces in a different way. The option Net in air is not available for General impermeable net, Morison free plat, Lice skirt, Closed compartment and surface tarpaulin. Instead, wind loads are included automatically when the Water volume correction **With slamming** is activated.

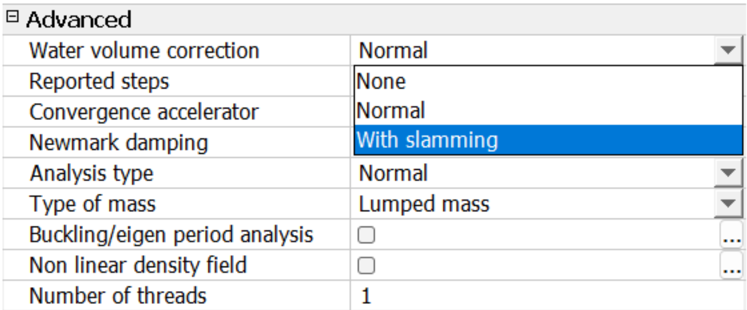

Figure 36

This option is found in the **Advanced** section in the **Environment** window.

3 Revision comments

Revision no.	Comment
1.0	First publication

--- End of document ---