Spar Buoy Short Wave Issue

This note documents an issue that can arise when modelling near-surface spar buoys.

A random sea is modelled in OrcaFlex using a large number of regular component waves, whose periods and amplitudes are chosen to match the specified spectrum. You can see the wave components chosen and their wavelengths (In OrcaFlex 8.7 onwards) by clicking the 'View Wave Components' button on the Waves page of the Environment data form.

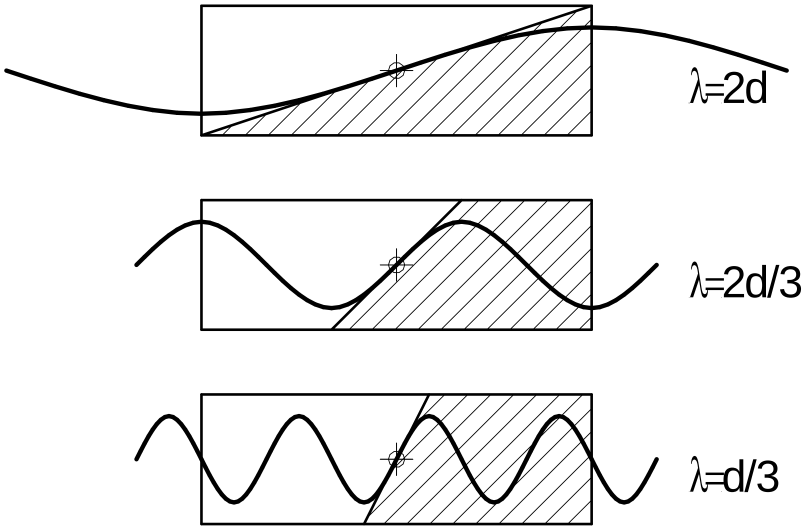
To cover the high frequency tail of the spectrum, the components include some short period waves. In some cases they can go down to a period whose corresponding wavelength is shorter than the diameter of a spar buoy in the model, and this raises a modelling issue. Note that the issue is only really relevant for near-surface buoys, since short waves do not penetrate far down in the water column.

A wave whose length is short compared with the buoy diameter will have effects that vary significantly across the diameter of the buoy. So to analyse a short wave's effects accurately OrcaFlex would have to calculate the fluid load contributions (buoyancy, drag etc.) at a number of points across the diameter of the buoy. But in OrcaFlex spar buoys cannot be subdivided in that radial direction - they can only be it subdivided in the buoy's axial direction, by dividing the buoy up into a stack of cylinders.

OrcaFlex calculates the fluid kinematics (velocity, acceleration, surface elevation, surface slope etc.) based on the sea surface and fluid kinematics at just one point on each cylinder of the buoy, and assumes that the values at that point apply right across the cylinder's diameter. This is fine for wave components a lot longer than the buoy diameter. But for waves shorter than about 3 times the buoy diameter the fluid kinematics, and hence the loads, average out since different parts of the buoy diameter are seeing different phases of the wave at any one instant.

The result of this is that the effects of the wave components shorter than about 3 diameters are exaggerated in OrcaFlex, since it cannot allow for the fact the effect of such components are averaged across the buoy diameter.

The figure below illustrates the point for the calculation of the buoyancy force and moment on an individual cylinder (similar problems arise for drag, added mass force etc.), for three cases where the wavelength is less than 3 times diameter.



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OrcaFlex determines the water surface slope at the volume centre of each cylinder of the buoy and assumes this slope is constant across that cylinder. Of course in a random sea the surface slope is a combination of the slopes of the various individual components that represent the random sea (and OrcaFlex allows for this), but longer waves have smaller slopes so the short waves tend to dominate the surface slope. So for simplicity the figure only shows the situation where there is just a single short wave component present, and it illustrates how its wavelength affects the buoyancy calculation on an individual cylinder.

OrcaFlex calculates the total buoyancy force and the centre of buoyancy (i.e. the point where it acts) by calculating the wetted volume and centre of wetted volume of each cylinder of the buoy. And each cylinder's wetted volume and wetted centroid is calculated by assuming that the surface through that cylinder is the tangent plane to the wave surface directly above or below the volume centre of that cylinder. The shaded section of the cylinder therefore indicates what OrcaFlex will assume for the immersed volume, and hence the magnitude and point of application of the buoyancy force on that cylinder, and so the size of the buoyancy moment applied.

As the wavelength reduces, so the discrepancy increases between the actual and the modelled righting moment. For example in the third case (shortest wave), the actual righting moment due to buoyancy will be small, since the wave crests and troughs are distributed fairly evenly across the cylinder, but the calculated buoyancy moment will be large since the shaded area is almost all on one side of the cylinder, so OrcaFlex will calculate that the centre of buoyancy is offset by nearly half a diameter from the cylinder centre.

You can work around this problem by removing (or scaling down) the short wave components. There are two ways to do this in OrcaFlex, as follows.

- Copy the wave components chosen by OrcaFlex, by clicking the 'View Wave Components' button and then copying the frequency, period, amplitude and phase lag columns. Then change the wave type to 'User Specified Components' and paste the wave components back into OrcaFlex. Finally, delete (or scale down) those components that are shorter than about 3 diameters.
- Alternatively you can copy the spectral density values, by clicking the 'View Spectrum' button, then right clicking and selecting Values, and then copying the table of spectral frequencies and density values. Then change the wave type to 'User Specified Spectrum' and paste the spectral frequency and density values back into OrcaFlex. Finally, delete (or scale down) the last few entries to truncate (or reduce) the spectrum for wavelengths less than about 3 diameters.

Note that these two methods will not give exactly the same results, since in the latter OrcaFlex will rediscretise the truncated spectrum. But they should give statistically equivalent results.

We hope that the information in this article is useful, but do contact us if you have any comments or questions.

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