Aanderaa Data Instruments AS
Sanddalsringen 5b, Postboks 103 Midtun, 5843 Bergen
Tel +47 55 60 48 00   Fax +47 55 60 48 01   aanderaa.info@xyleminc.com

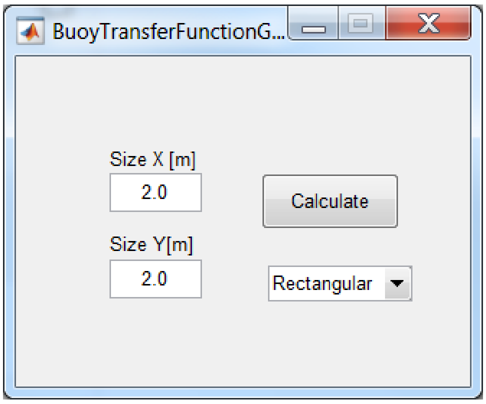
MOTUS Stand-Alone: MOTUS Buoy Integration Consideratons

Is my buoy suitable for measuring waves?
The accuracy of a wave measurement from a buoy depends on the buoy and the types of waves in the area it will measure. If there are small, higher frequency coastal waves, you may want to utilize a smaller buoy to get an accurate measurement. For navigation where the bigger waves affecting vessels are of interest, a large buoy can also measure these well.

What buoy and mooring features affect the accuracy of the wave measurement?

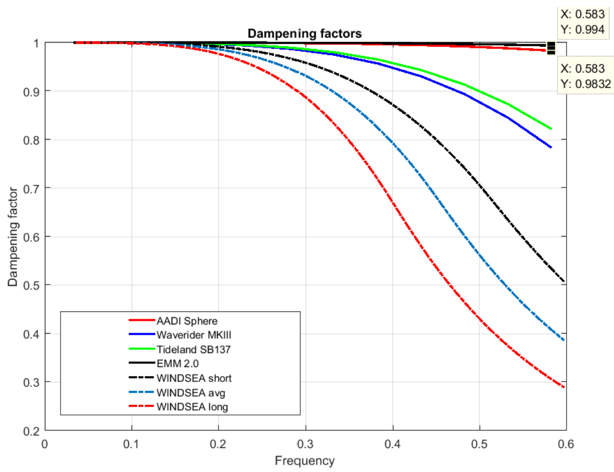
Buoy size

A larger buoy will dampen smaller waves. In order to get an idea of the accuracy possible from different buoys, a tool has been developed to aid integrators.



By inserting buoy size and shape into the tool, it outputs an overview of the dampening from the buoy on waves of different frequencies. Ideally, there would be no dampening on the wave, and a dampening factor of 1.

All buoys will have some dampening and this will have a dampening factor between 0 and 1. A dampening factor of **0.9 means a 10% dampening** of the waves of this frequency.

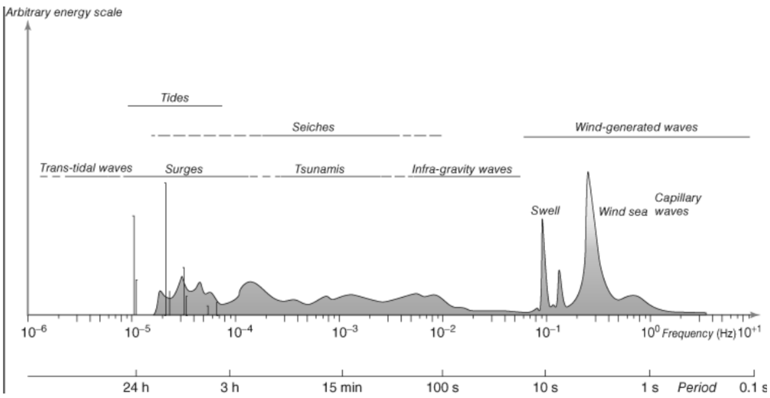


In the example graph, the **WINDSEA long** buoy has a dampening on waves starting at about 0.2Hz, or 5 second wave period. This means that any waves with a higher frequency than 0.2Hz will be dampened by this buoy.

If the WINDSEA long buoy was in an area with 0.3Hz/3.33second waves, it would dampen these by about 10% per the red graph in the curves.

Aanderaa Data Instruments AS
Sanddalsringen 5b, Postboks 103 Midtun, 5843 Bergen
Tel +47 55 60 48 00   Fax +47 55 60 48 01   aanderaa.info@xyleminc.com

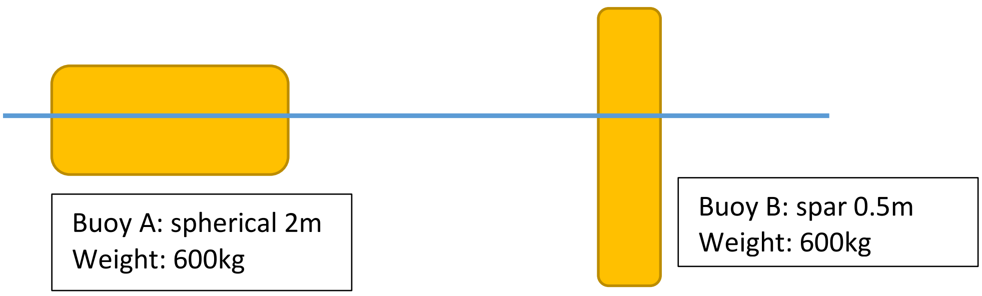
Wind driven waves along the coast, are centered on 0.3Hz/3.33secons as can be seen in the graph below. This means that if you look at the waves in a typical coastal area these will in many cases have a frequency of predominately 0.3Hz. The WINDSEA long buoy will be dampening these waves with about 10%, meaning that it will have less accuracy for these smaller coastal waves. For typical ocean waves including swell, this buoy will have no damping on these based on size.



Buoyancy

The buoyancy of a buoy determines how the buoy follows the surface. The waves will change the amount of displaced water and give a change in the buoyancy force. This is depends on the change of waterline and the area of the waterline (volume).

The larger the area at the waterline is vs. the mass of the buoy, the quicker the buoy will compensate for the waves hitting the buoy moving the waterline. Buoy A below will “correct” for waves much quicker than buoy B. It is also possible to calculate this by looking at the areas of the waterline and weight of the buoy.



The area at the waterline of A is $r^2 \times \pi = \mathbf{4 \times \pi}$ The area of B is ***0.25 x π***
This means that the area of A is 16 times larger than B.

Aanderaa Data Instruments AS
Sanddalsringen 5b, Postboks 103 Midtun, 5843 Bergen
Tel +47 55 60 48 00 Fax +47 55 60 48 01 aanderaa.info@xyleminc.com

Looking at the formula for the *resonant frequency* which is how quickly a buoy responds, the formula is:

$\omega_o = \sqrt{(a\rho g)/m}$, ρ is the density of sea water, and g is the gravity constant.

ρ = 997kg/m3 fresh water, 1030kg/m3 salt water
g = 9.81m/s2

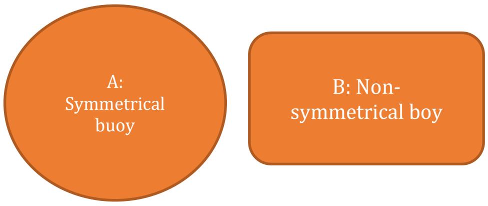
Buoy A: ω_o = ~14
Buoy B ω_o = ~4

Buoy A will work well for wave measurements, while Buoy B will not

Ideally, a buoy would have a ω_o higher than 8. Tideland SB138P has a ω_o = ~8.7.

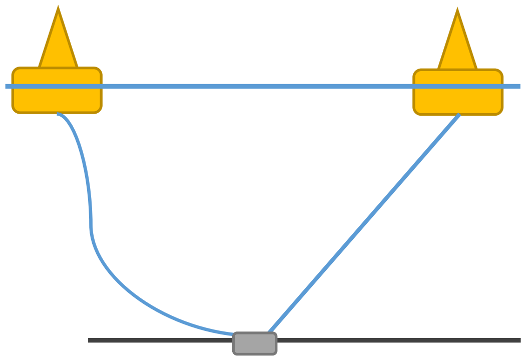
Shape

Ideally, the hull should be symmetric with regard to the vertical axis in order to have a correct wave direction measurement. Buoy A and Buoy B to the right are seen from above. Buoy A will give a better result, particularly for wave direction.



Mooring configuration, current, water depth

When installing a wave sensor on a buoy, it is important that the mooring does not limit the motion to capture.



In the case of strong current, the buoy will normally have less freedom to move in the directions parallel to the mooring line compared to the directions normally to the mooring line. This may influence the wave direction property.

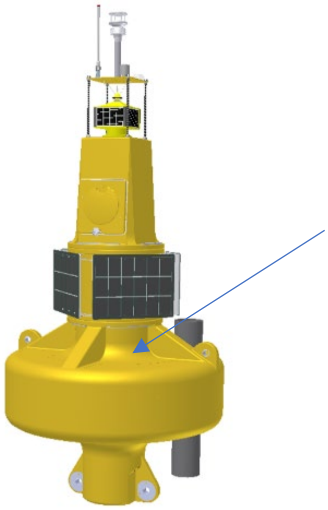
Buoys with large ω_o (refer to section on buoyancy) will have less problems with wave height in strong currents than buoys with small ω_o

Aanderaa Data Instruments AS
Sanddalsringen 5b, Postboks 103 Midtun, 5843 Bergen
Tel +47 55 60 48 00 Fax +47 55 60 48 01 aanderaa.info@xyleminc.com

Sensors placement

Ideally, the MOTUS wave sensor should be installed in the centre (rotational origin) of the buoy. The vertical offset has less impact compared to the horizontal offset.

If the ideal installation position cannot be used, than the installation offset of the sensor can be configured at the sensor, and the Off center compensation can be enabled.



Buoy weight distribution

Ideally, the weight distribution should be selected in order to have a stable buoy.

Adding heavy weight at a high position above the waterline is normally not a good idea.

Marine Growth

Marine Growth will increase the friction between the buoy surface and the wave induced orbital water current. This will increase the forces that makes the buoy follow the orbital current which is an advantage for a wave measurement buoy.

Even though the effective mass of the buoy will increase somewhat, marine growth is normally not a disadvantage for the buoy itself due to the increased friction and force. On the other hand, if the mooring is heavily fouled, the drag on the mooring line will increase significantly in case of a steady current on the mooring line. This will reduce the quality of the wave measurement.

Aanderaa Data Instruments AS
Sanddalsringen 5b, Postboks 103 Midtun, 5843 Bergen
Tel +47 55 60 48 00   Fax +47 55 60 48 01   aanderaa.info@xyleminc.com

I am interested in looking at waves in the time domain, what is the parameter of interest?

$H_{1/3}$ is a time domain parameter where all waves hitting the buoy are measured and sorted. $H_{1/3}$ is the average of the highest 1/3 of all waves.

What is the most common parameter to measure waves in the frequency domain?

Significant wave height Hmo looks at the frequency spectrum and the energy of different wave frequencies. The significant wave height reflects what wave frequency has the most energy.

In reality, it is only about 5% difference between Hmo and $H_{1/3}$