HYPACK
a xylem brand

Sounding Better!

Induced Heave: Correcting for Changing Sonar Draft Due to Vessel Motion

By Josh Sampey

It is becoming more and more common that the IMU/MRU (IMU henceforth) is not installed on the vessel at the center of rotation (COR/COG), especially for multibeam surveys. In this article, we will be focusing on subsea mountings for multibeam surveys.

If we are thinking about what we want to track the motion of, this makes perfect sense. When we are doing a multibeam survey, we want to know the motion of the multibeam, and in reality the motion of the boat is irrelevant. Let us think of it this way: if a multibeam is mounted on a flimsy mount off the side of the vessel, and the IMU is installed onboard the vessel. If the flimsy mount starts to flex or wobble, it will not be detected by the IMU and artifacts in the data will be evident. However, if we put the IMU on the pole and perhaps mounted to the sonar, that flex and wobble will be detected and therefore no motion artifacts (from pole movement) will be evident in your data.

Like all things, mounting the IMU at the sonar has some potential pitfalls; one of those is induced heave. In simplest terms, induced heave is the improper measurement of the vertical location (heave) of the IMU/multibeam. To think of it in other terms, the real-time draft of the sonar is incorrectly calculated.

NOTE: There is one exception to the rule for having offsets measured from the COR. If you have everything mounted on the same over-the-side pole, *and* you have an RTK antenna mounted on the same pole, *and* it is recording your vertical heights through RTK (min 10Hz, 25-50Hz recommended), then and only then will HYPACK® compensate for the “Induced Heave” by other means than those discussed here. With that said, you may want to enter COR offsets for the reason discussed at the end of this article.

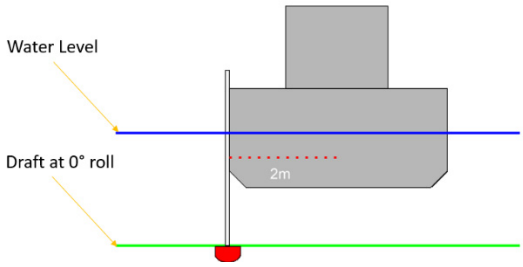
STATIC DRAFT

As stated above, induced heave is just the improper calculation of the real-time changes in sonar draft. To understand this further let’s take a look at how we typically measure *static* sonar draft.

When we initially measure the draft of the sonar, we are usually told to get the vessel at 0° roll and hopefully 0° pitch. While this practice/method is up for some debate, let’s just use this method for simplicity's sake.

Figure 1: Static Draft

For example, let's take a look at the induced heave as a result of roll only. For the vessel, we measure the draft, with the IMU indicating 0° roll to be 0.5m/1.64ft. The multibeam and IMU are mounted at the end of the pole 2m/6.56ft port of the COR. The actual draft of the sonar, in this case, is irrelevant as we are only examining the change in the draft due to roll.



HEAVE—WHY SO HARD?

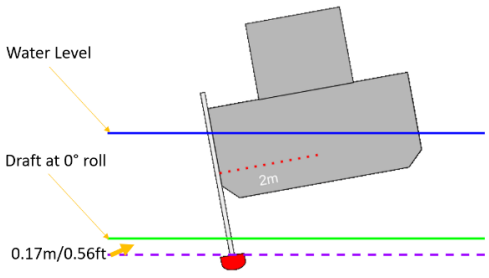
Now to understand how the draft is incorrectly calculated, we first must understand a bit about the measurement of heave.

First, heave is *always* the worst measurement that an IMU makes; it is the only measurement *not* related to gravity. So, while the zero point for pitch and roll are easy to determine due to a common reference (gravity), the zero point for heave has no reference and therefore it must establish its own zero. To do this most IMUs utilize a filter run in real-time to determine the instantaneous "0" point for the measurement. Delayed heave does nearly the same thing but examines the heave measurements over a longer duration and different filtering to reassess the zero point and provide for more accurate heave calculation. So for instance, if you are surveying on a rising/dropping tide the zero point of the heave must change with the tide. If the tide rose 2 meters during the survey, the heave value would continually trend up, even if the water was glass, throughout the survey. We have tide stations to measure the rise and fall of the water. All the heave should measure is the rise and fall of the boat with respect to the average water height.

INDUCED HEAVE = INCORRECT DRAFT

Figure 2: Change in Draft Due to 5° Roll

So to understand how induced heave produces incorrect draft, let's examine a simplified case. Let's say that, midway through the survey day, there is a crew change on the boat and some jugs of fuel were taken onboard the boat for the generator. During the change, the system was left on. Once everything was loaded and everyone was on board, the boat now has a static 5° roll to port and, for simplicity's sake, the water is glass.



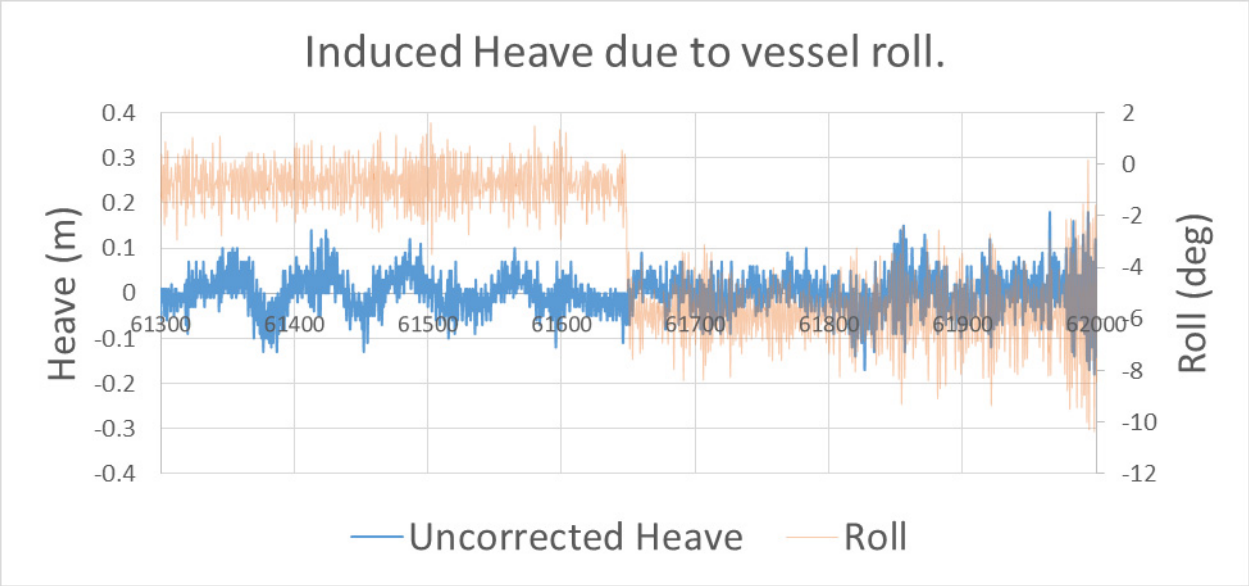
Now, because we have the IMU mounted on the sonar, the only offset we have is the static draft entered into HYPACK®/HYSWEEP® so that we can properly apply our tide file. However, the boat is now listing, so our sonar is now 0.17m/0.56ft deeper in the water (2m x Tangent 5°). If we apply a tide file, we will see a vertical bust of approximately 0.17m/0.56ft.

If we recall (from the previous section) that the IMU must define its zero through the use of a filter, we can start to understand what is going on here. When the boat listed over, fairly quickly, a new zero point is defined within the heave filter. So the zero point for heave moves

with the IMU and does not stay at the static draft level meaning that the new draft is not taken into account.

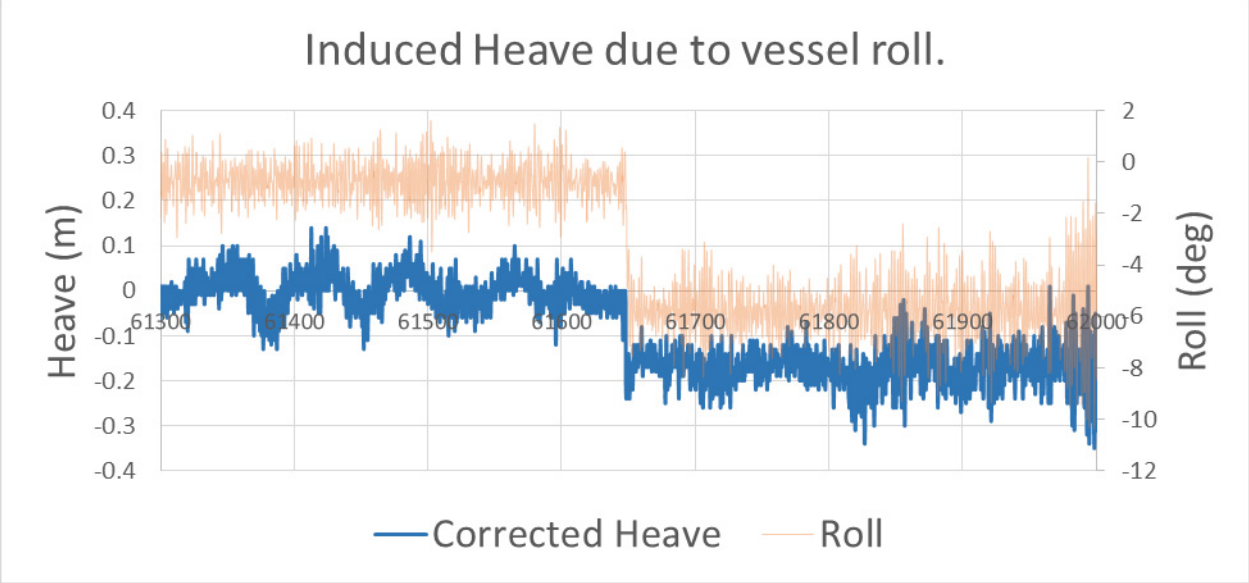
If we take a look at the plot (in Figure 3) of a simulated induced heave, we see that when the roll occurs there is little or no indication in the heave measurements that any large change in vertical motion occurred. So the heave is still calculated properly with respect to the new zero point; however, it is this zero point that is wrong.

Figure 3: Uncorrected Heave



If we have properly corrected heave, then the zero point does not move with the change in the draft of the sonar and that increase in the draft is properly measured. Figure 4 shows what the heave signal looks like when this occurs. When the roll occurs, we see a simultaneous shift in the heave indicating an increase in the draft of the sonar.

Figure 4: Corrected Heave



CORRECTING INDUCED HEAVE

To correct for induced heave, we have to inform the IMU system or HYPACK® that the IMU is not located at the vessel center of rotation. Many of the INS systems today have a Reference to COR offset. These offsets do not impact the position at all and are only for heave.

For instance, if we take a look at an Applanix system with the IMU mounted off the side of the boat on the sonar head, when we put in the lever arm offsets, we want to fill in the Ref to COR. We want to include all XYZ measurements.

The easiest way to do this is to measure the static draft of the IMU, or sonar reference depending on how the system is set up, and the forward and starboard offsets to the COR.

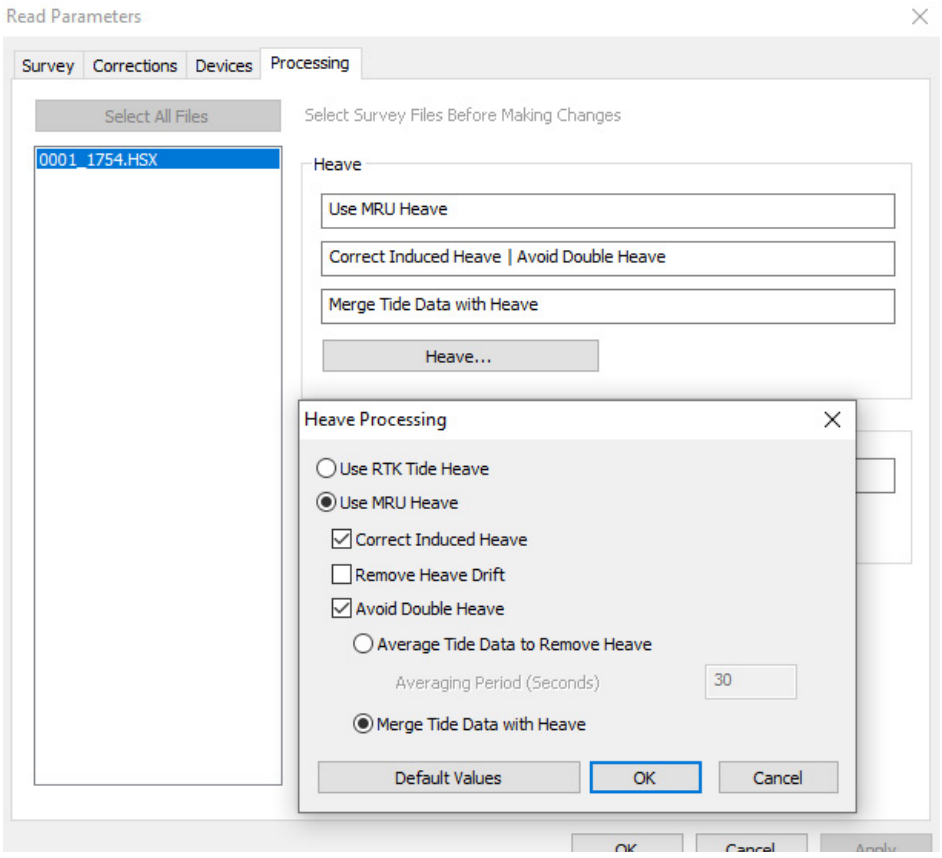
Tip: In general, on small boats, the COR is at the waterline and approximately ¾ of the way down the vessel from the bow.

Once the COR is determined, you will enter those offsets. They can be entered into your INS/MRU or they can be entered into HYPACK®.

NOTE: It is worth noting that if the offsets are entered into some systems *and not in HYPACK®*, there may be no way to recover should an error occur during the installation.

If you have entered these offsets into HYPACK® and have kept them out of the motions system, then you will want to select to correct induced heave during processing (Figure 5).

Figure 5: Correcting Induced Heave MBMax



INDUCED HEAVE AND RTK

When you are surveying with RTK, there is usually no need to worry about heave at all because the RTK is tracking the vertical motion of the system to a much higher accuracy than the heave sensor can. However, there are a couple of instances where you will still want to consider correcting for induced heave even when using RTK:

- **Your GNSS receiver cannot output position at a minimum 10hz (25-50Hz preferred).** If the output rate is not high enough, then vessel motion will occur between position fixes and may import artifacts into your data between position fixes.
- **You are surveying in an area where the loss of RTK fix is expected.** If you are surveying a bridge, there is a strong possibility that you will lose the RTK fix. When you do, the heave sensor will have to take over the measurement of vertical motion until the RTK fix is restored. If there is not proper COR offset entered, you will have improperly calculated real-time draft and will likely see heave artifacts in your data.

If you have entered your COR offsets into your INS/MRU, do not check the Correct Induced Heave option in HYPACK®.

If these offsets are not in your motion measurement system, select the Correct Induced Heave option.

In all cases, you will select the Use MRU Heave, Avoid Double Heave and Merge Tide Data With Heave options. While this sounds scary, what is happening is that between RTK position fixes, HYPACK® utilizes the IMU heave for proper vertical corrections.

CONCLUSION

In this discussion, we only examined the case of a change in the static list of the vessel and how that failed to calculate the change in sonar draft.

This discussion is a much more simplified version of what happens throughout the survey as the boat rocks around. Without informing either the motion system or HYPACK® of the location of the IMU with respect to the vessel COR, you are surveying without proper real-time changes in sonar draft So remember, keep your stick on the ice and enter in those COR measurements.