Inertial Products

Application Note

Installation and Configuration for Seabed Mapping Measurements

IXBLUE
DEEP INSIGHT. SHARPER SENSES.

Document Revision History

Edition	Date	Comments
A	11/2011	First Edition
B	03/2012	Screen capture updated
C	04/2013	Graphical chart applied
D	10/2014	Version restrictions updated
E	03/2015	New style guide updated to the document
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Abbreviations and Acronyms

Abbreviations and acronyms are described in the document *Inertial Products – Principle and Conventions (Ref.: MU-INS&AHRS-AN-003)*

Table of Contents

1 OBJECT

This document is an Application Note for the INS generation III and OCTANS generation IV family. It describes how to use an iXBlue AHRS or INS for seabed mapping compensation.

Do not hesitate to contact iXBlue technical support for further information: support@ixblue.com.

2 Reference Documents

- *Inertial Products – Principle and Conventions (Ref.: MU-INS&AHRS-AN-003)*
- *Inertial Products - Web-based interface user guide (Ref.: MU-INSIII-AN-021)*
- *AHRS - Configurations & Operation with the Web-based User Interface (Ref.: MU-AHRS-AN-001)*
- *INS – Interface Library (Ref.: MU-INSIII-AN-001)*
- *AHRS – Interface Library (Ref.: MU-AHRS-AN-003)*
- For PHINS: *PHINS Interface Control Document (Ref.: MU-PHINSIII-AN-013)*
- For PHINS 6000: *PHINS 6000 Interface Control Document (Ref.: MU-PHINS6G3-AN-021)*
- For PHINS COMPACT C7: *PHINS COMPACT C7 Interface Control Document (Ref.: MU-PHINSCT7-AN-002)*
- For ROVINS: *ROVINS Interface Control Document (Ref.: MU-ROVINS-AN-021)*
- For HYDRINS: *HYDRINS Interface Control Document (Ref.: MU-HYDRINS-AN-013)*
- For OCTANS Surface: *OCTANS User Manual (Ref.: MU-OCTIV-AN-016)*
- For OCTANS 3000: *OCTANS 3000 User Manual (Ref.: MU-OCT3kG4-AN-007)*

3 VERSION RESTRICTIONS

This document is valid from:

- The following firmware versions:
  - For the INS family: **DSP 2.03** and **CINT 4.55**
  - For the OCTANS family: DSP4_INS_ALIX_6_10_0 and **CINT** 4.10
- The following Web-based User Interface version: Web INS 2.19K-1.35 and Web OCTANS 5.53-1.99
- The QNX version 2.10

4 USING HEAVE COMPENSATION ON SEABED MAPPING

4.1 Heave Definition

4.1.1 GLOBAL DEFINITION

Heave measurement is used (in AHRS and INS) to compensate for vertical movement due to sea waves in multibeam or sonar seabed mapping. Heave filter is designed to measure periodic movement of a surface vessel related to the average sea level. So, heave should not be used in subsea application to monitor tow fish.

4.1.2 HEAVE COMPOSITION

On a specific monitoring point, heave is made of three components (see simplified 2D schematic below):

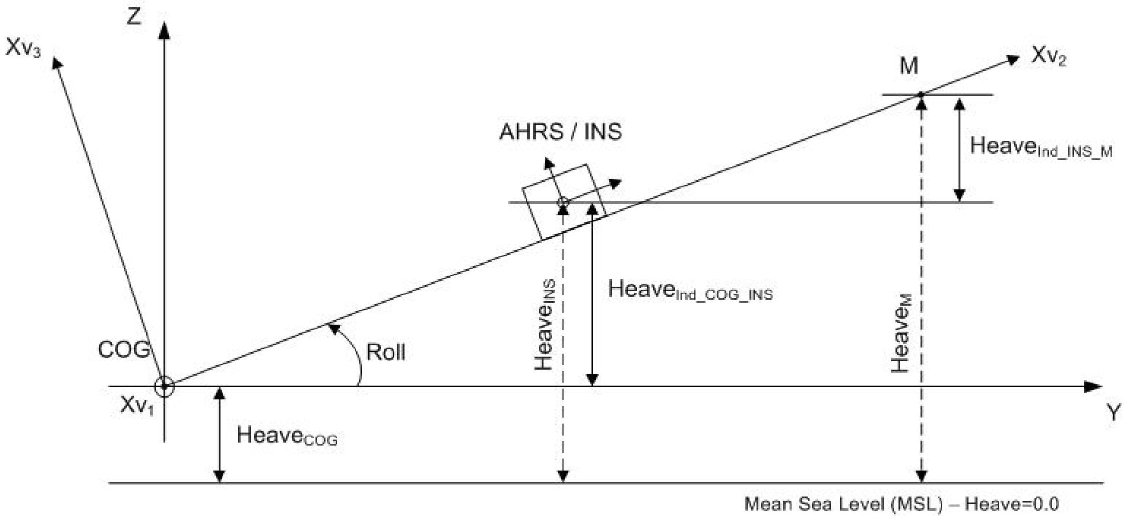


Figure 1 - Heave composition

- $Heave_{COG}$ seen by the center of gravity (COG) of the vessel. $Heave_{COG}$ exactly corresponds to vertical movement due to waves.
- $Heave\_ind_{COG\_INS}$, induced heave due to lever arm between COG and the (AHRS, INS) unit and vessel attitude (roll and pitch). It corresponds to the projection on the vertical axis of the lever arm between COG and the unit ($Heave\_ind_{COG\_INS}$ is null when vessel roll and pitch are null).
- $Heave\_ind_{INS\_M}$, induced heave due to lever arm between the unit and the monitoring point and vessel attitude (roll and pitch). It corresponds to the projection on the vertical axis of the lever arm between the unit and the monitoring point ($Heave\_ind_{INS\_M}$ is null when vessel roll and pitch are null).

4.2 Measured Heave

4.2.1 General Case

In the general case:

$$Heave_M = (Heave_{COG} + Heave\_ind_{COG\_INS} + Heave\_ind_{INS\_M})_{FILTERED}$$

Heave measured on a specific monitoring point M is the addition of:

- The Heave measured and filtered by the unit $(Heave_{COG} + Heave\_ind_{COG\_INS})_{FILTERED}$
- The Heave induced by lever arms from the unit to the external monitor point M $(Heave\_ind_{INS\_M})_{FILTERED}$

4.2.2 Using Vessel Center Of Gravity

To avoid the effect of vessel transient movement on heave measurement, induced heave $Heave\_ind_{COG\_INS}$ should not be filtered (like $Heave\_ind_{INS\_M}$). It is possible in two different cases:

- Place the unit as close as possible to the COG. In this case $Heave\_ind_{COG\_INS} \approx 0$.
- Indicate the COG position by entering lever arms between the unit (AHRS/INS) and the COG of the vessel. In this case, the unit will compute heave at the COG.

$$Heave_M = (Heave_{COG})_{FILTERED}$$

The figure below is an extract of the Web-based User Interface (Mechanical Parameters) used to set up the lever arms between the INS and the vessel center of gravity:

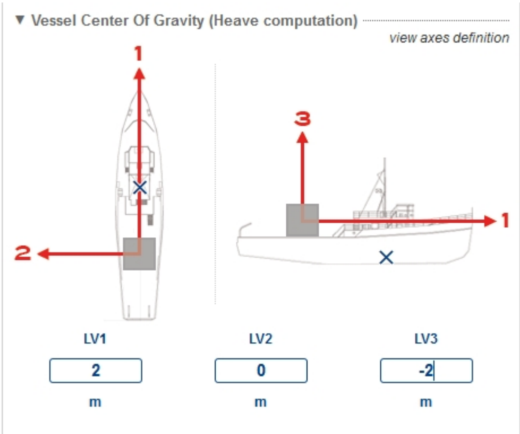


Figure 2 - Vessel Center of Gravity entering point

4.2.3 CONCLUSION

In all cases, the aim is to suppress the effect of vessel transient movement (roll and pitch) on heave measurement output and what we call “heave” is the addition of:

- Heave due to waves
- Elevation due to vessel attitude

To have more information on the effects of vessel transient movements, see *section* 5*.*

4.3 Heave Filters

AHRS and INS can output two distinct heave measurements:

- Real Time Heave
- Smart Heave TM

4.3.1 REAL TIME HEAVE

Real time heave provides heave in real time mode.

4.3.2 SMART HEAVE™

4.3.2.1 Definition

Smart Heave™ provides a measurement of heave with a 100s fix delay and offers a precision on heave measurement largely greater than Real Time heave one. You can use Smart Heave™ to replay the multibeam data in case the Real Time Heave is not good enough.

4.3.2.2 Output Protocol

Smart Heave™ is available in specific output protocols (selectable on both AHRS and INS):

- POSMV GRP111 protocol compatible with applications using APPLANIX systems. This protocol can be directly sent in RESON multibeam systems that can output delayed multibeam pictures (Seabat 7111, for example) . This data can also be logged in the navigation package (i.e., QUINSY). Refer to the definition of the POSMV GRP111 protocol in the Interface Library document (ref. MU-AHRS-AN-003 for AHRS product or *MU-INSIII-AN-001 for INS product*).
- SEATEX DHEAVE protocol to be compatible with KONGSBERG multibeam. Refer to the definition of the SEATEX DHEAVE protocol in the Interface Library document (ref. MU-AHRS-AN-003 for AHRS product or *MU-INSIII-AN-001 for INS product*).
- IXBLUE_STD_BIN. Refer to this protocol definition in the Interface Library document (ref. MU-AHRS-AN-003 for AHRS product or *MU-INSIII-AN-001 for INS product*).

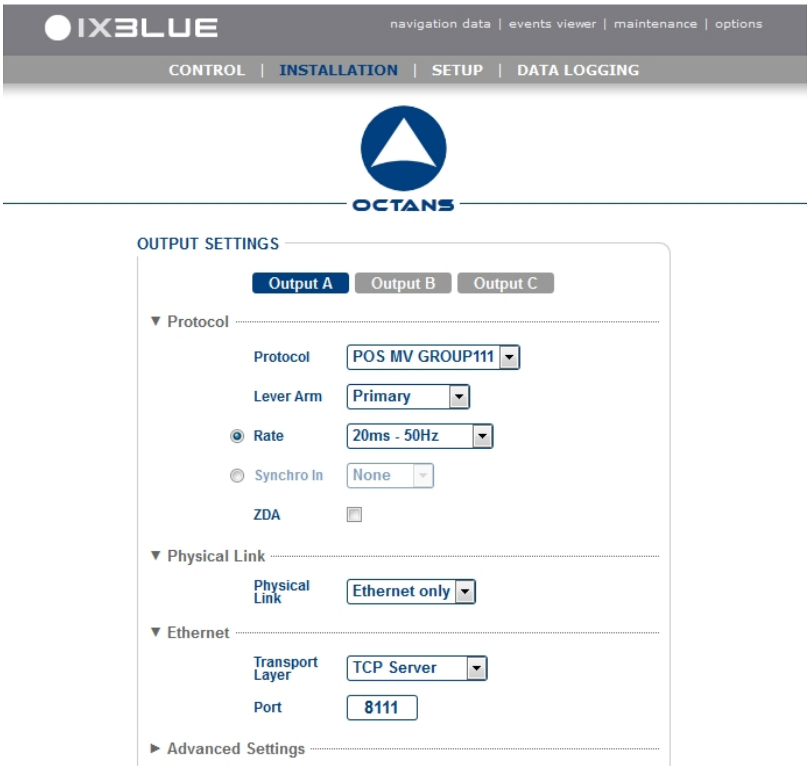


Figure 3- APPLANIX delayed heave protocol

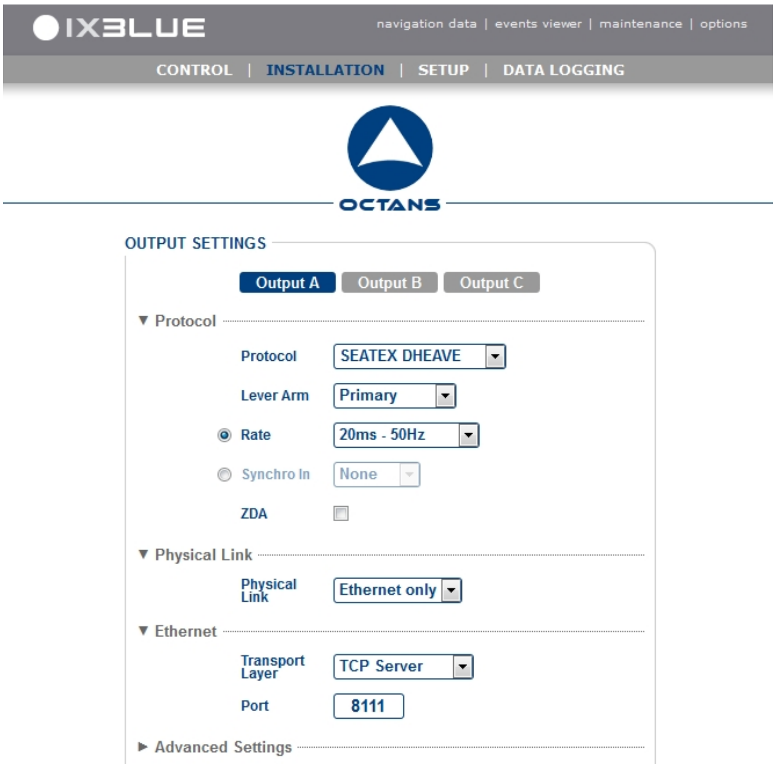
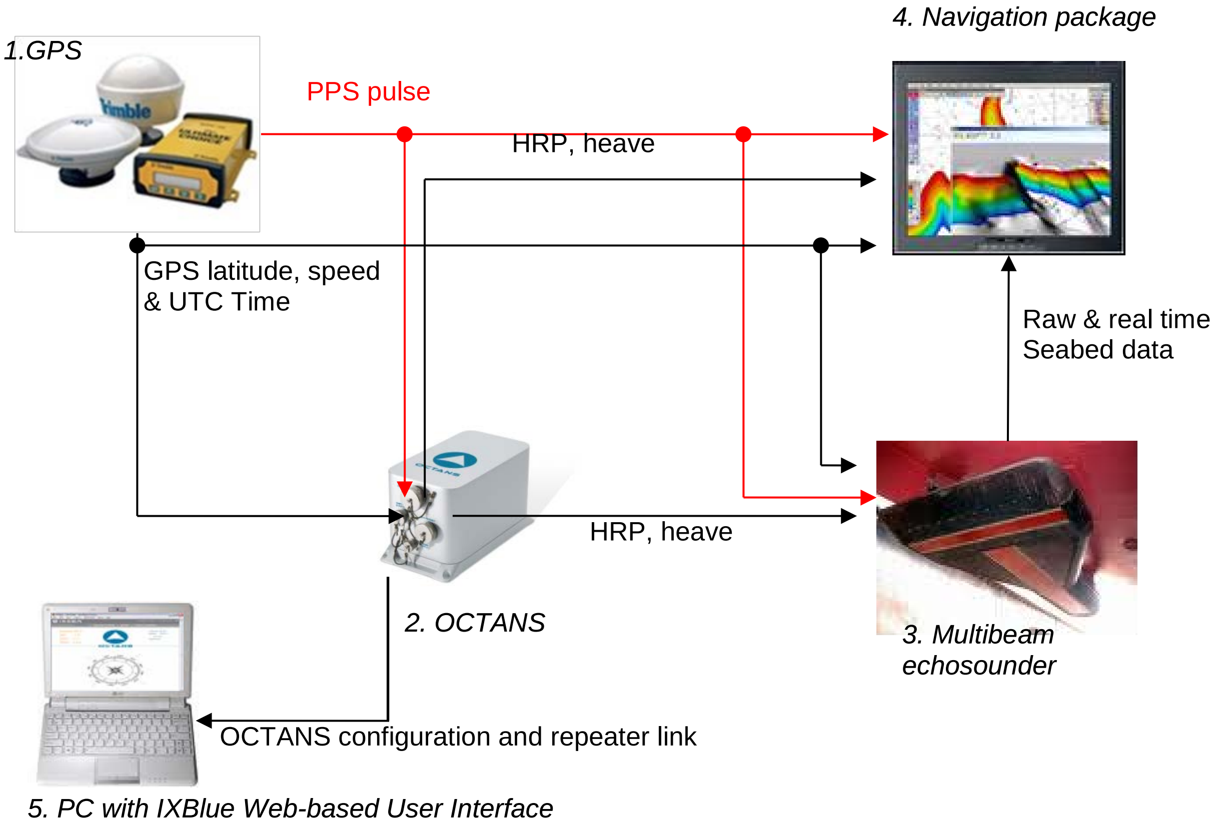


Figure 4 - KONGSBERG delayed heave protocol

4.4 Typical Multibeam Set up with OCTANS

In this configuration an AHRS is used and hence heave is sent to the multibeam to compensate for vertical movements of the ship.



1. GPS is used to synchronize the time of the AHRS by sending ZDA telegram and PPS pulse. AHRS will also use the latitude of the GGA string to update the initial startup latitude. It is recommended to also send speed data (i.e., VTG telegram) to compensate for "north speed" error on heading. Any quality GPS can be used here.
2. AHRS: Data links can be managed through serial or Ethernet. The AHRS is time-synchronized with the GPS time (ZDA+PPS). The unit can send real time heave or delayed heave (Smart Heave™) if the multibeam can support it. Delayed heave can also be sent and stored by the navigation package for data replay for possible further enhancement.
3. Multibeam echo sounder: this equipment is time-synchronized with the GPS time (ZDA+PPS). It receives heading, roll, pitch and heave from the AHRS. It sends real time and raw data to the Navigation software package.
4. The Navigation package displays real time bathymetry and can replay data since it does log all data from AHRS, GPS, and multibeam echo sounder.
5. Web-based User Interface installed on a PC is used both to configure the AHRS and INS as a data repeater.

4.5 Time Stamping of the Data

If the INS or AHRS is time-synchronized with the UTC time of the GPS then all data coming out of the INS or AHRS is time stamped (depending on the choice of the output message).

If not, data is time tagged at the time of reception by the navigation package data logger. In this case the following latencies should be accounted for:

Specification(*)	**Value**
Time stamping accuracy	< 100 µs
Jitter	< 200 µs on all serial ports < 400 µs on Ethernet high priority port < 800 µs on all other Ethernet ports
Fixed latency	2.35 ms on all serial ports 2.95 ms on Ethernet high priority port (**) < 5 ms on all other Ethernet ports

(*) Valid for Firmware version starting from FrmWCINT v3.80.

(**) Highest priority port is defined by the highest output data rate and first in alphabetical order.

4.6 Location of the Heave Measurement Unit

As described in *section 3*, you should place the unit as close as possible to the center of gravity of the vessel or compensate for lever arms between the unit and the COG. This will considerably reduce heave measurement errors due to vessel attitude, especially when turning.

4.7 Lever Arms and Alignment to Vessel Frame

The AHRS should be aligned to the vessel frame since the lever arms are measured in the vessel reference frame centered at the location of the AHRS. If not, this can induce an error in the lever arm taken into account by the AHRS.

4.8 Example of A Multibeam Picture Produced Using Attitude and Smart Heave™ Data

4.8.1 Example 1

The equipment used here was the following:

- IXBLUE PHINS generation III
- Reson PDS2000 multibeam
- IFREMER Techsas navigation package

The swell amplitude (p-p) was 0.5 m and swell period 7 seconds.

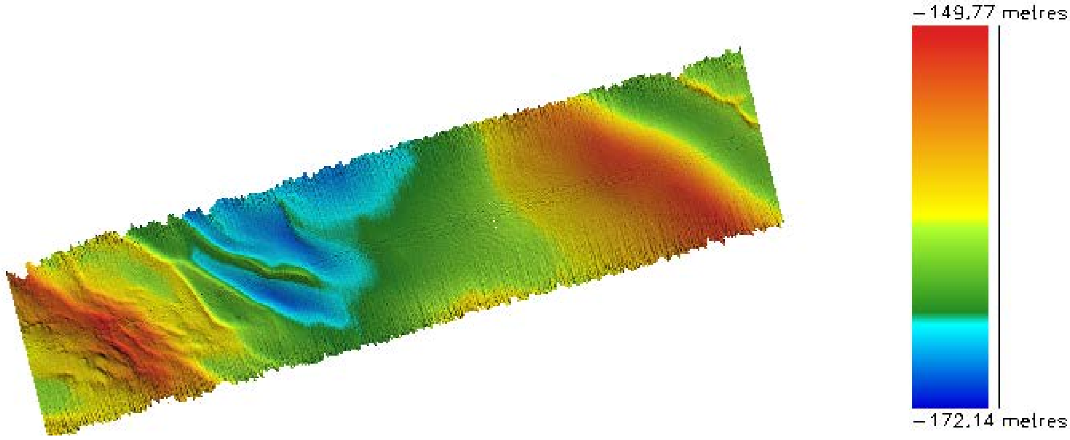


Figure 5 - Multibeam picture using Smart Heave™
(Courtesy of IFREMER, France)

4.8.2 Example 2

The equipment used here was the following:

- IXBLUE PHINS generation III
- Kongsberg EM 302 (30 kHz) multibeam
- IFREMER Techsas navigation package

The swell amplitude (p-p) was 7 m and swell period 15 seconds

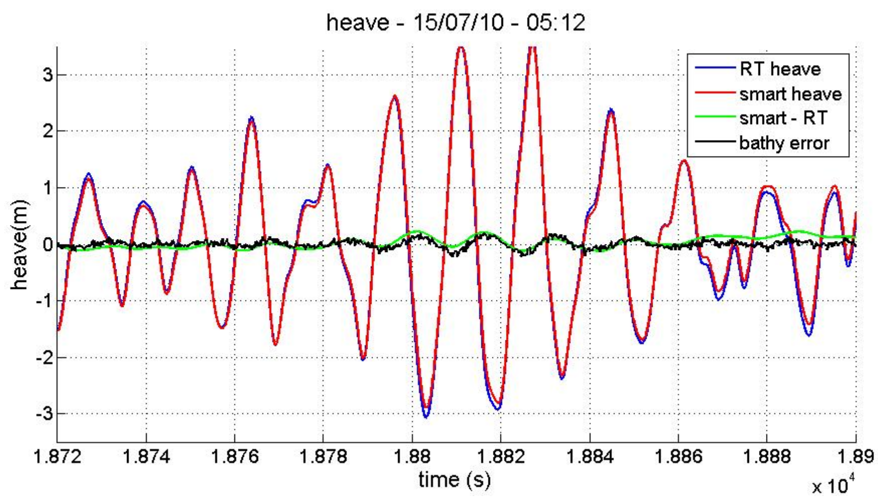


Figure 6 – Heave measurement

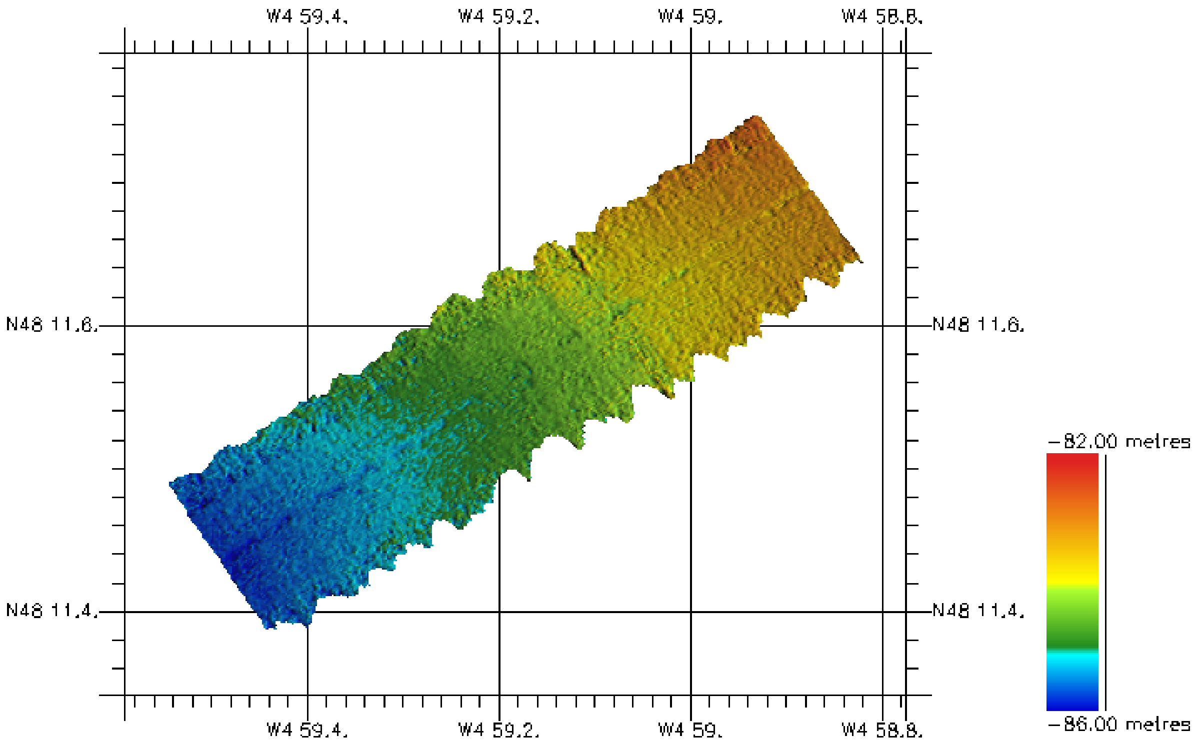


Figure 7 – Multibeam picture using Smart Heave™

5 EFFECT OF VESSEL TRANSIENT MOVEMENTS

5.1 Description of Transient Heave Observations

The aim of this part is to show the effect of vessel transient movement (roll and pitch) on heave measurement and the importance of placing unit as close as possible to the vessel COG or indicating to the unit the position of the COG (next part).

Indeed, the unit cannot distinguish $Heave_{COG}$ from $Heave\_ind_{COG\_INS}$ and both components are filtered through heave high-pass filters. During turns, roll and pitch change and induce filter impulse response.

As an example: a vessel on a glassy sea ($Heave_{COG} = 0$) for which roll goes up from 0 to 10° in 10 s and an unit placed at 10 m of the COG along the XV2 axis.

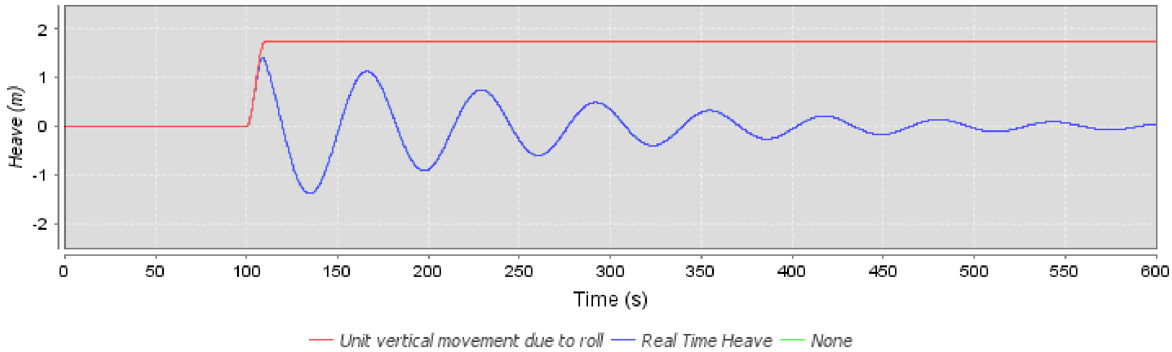


Figure 8 - Real time heave filter response with roll transition due to turn

In this case, heave filter output does not correspond to the real vertical movement of the unit. On top of that, the filter output is not null (so heave not valid) while the filter adjusts itself and settles back. Settling time can be quite long (up to 300 s for real time heave).

5.2 Location of the Heave Measurement Unit

5.2.1 PLACING THE UNIT AT THE COG OF THE VESSEL

The first and easiest fix to avoid the effect of vessel movement on heave is to place the unit as close as possible to the COG of the vessel. In this case $Heave\_ind_{COG\_INS}$ is null.

$Heave_M$ is the addition of:

- $Heave_{COG}$ seen by the unit
- $Heave\_ind_{INS\_M}$ that is the projection of the lever arm between the unit and the monitoring point on the vertical (using roll and pitch)

5.2.2 USING COG POSITION

The second solution to avoid the effect of vessel transient movement is to indicate the COG position by entering levers arms between the unit (AHRS/INS) and the COG of the vessel.

In this case, the unit will compute and output heave at the COG of the vessel as shown in figure below:

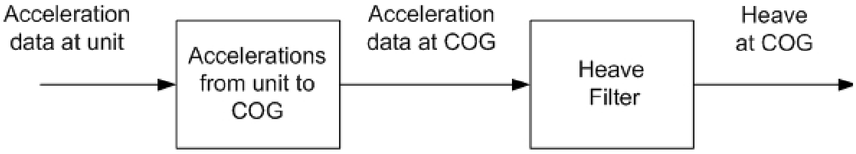


Figure 9 - Principle of heave computation at the COG

So, $Heave_M$ is the $Heave_{COG}$ computed by the unit from accelerations at unit level and levers arms between the unit and the COG.

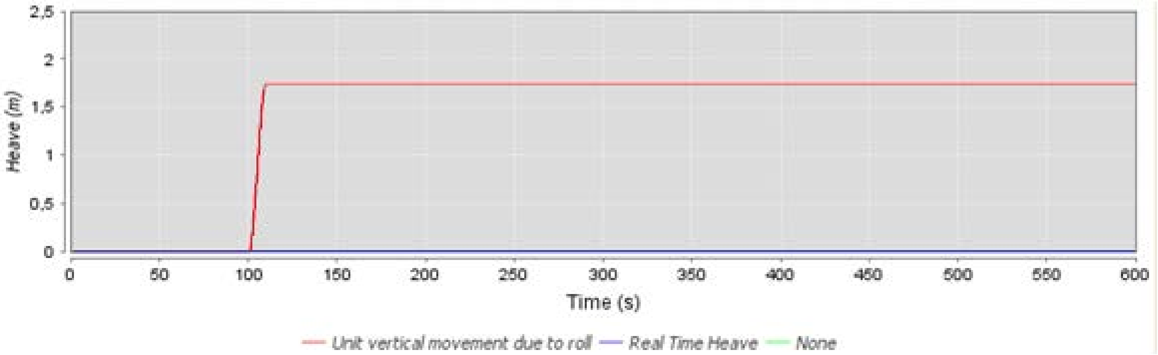


Figure 10 - Real time heave filter response with roll transition and use of COG

In this case, the heave filter output is zero because the vertical movement of the unit is only caused by roll. It demonstrates that using the COG is the best way to reduce the error caused by roll and pitch.

5.3 Illustration Example

The figure below shows theoretical heave measurement to illustrate previous explanations, based on a vessel on a sea with regular swell and roll transition. We observe a settling time on $Heave_M$ after the roll transiant:

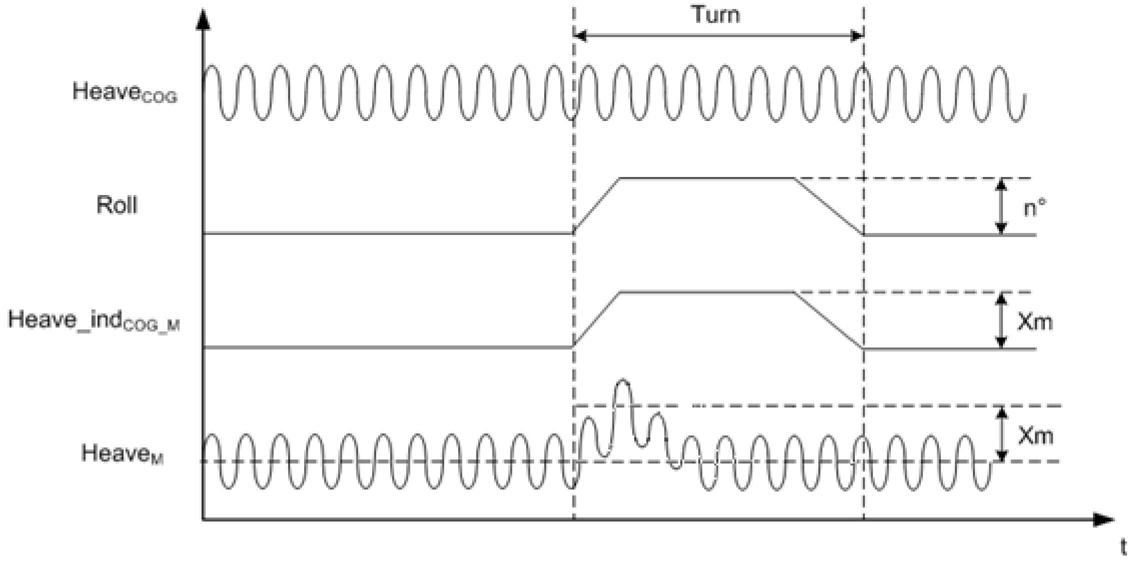


Figure 11 - Heave measurement illustration

5.4 Impact of COG Lever Arms Accuracy

In any case, if the unit is not located at the COG, indicating COG lever arms will always reduce heave output errors due to vessel transient movement, no matter the precision of the COG levers arms is.

If the COG levers arms are entered with a precision of NN% (20% for example), output errors induced by the vessel transient movement will be reduced of 100-NN% (80% for example).

5.5 How to Obtain $Heave_{COG}$?

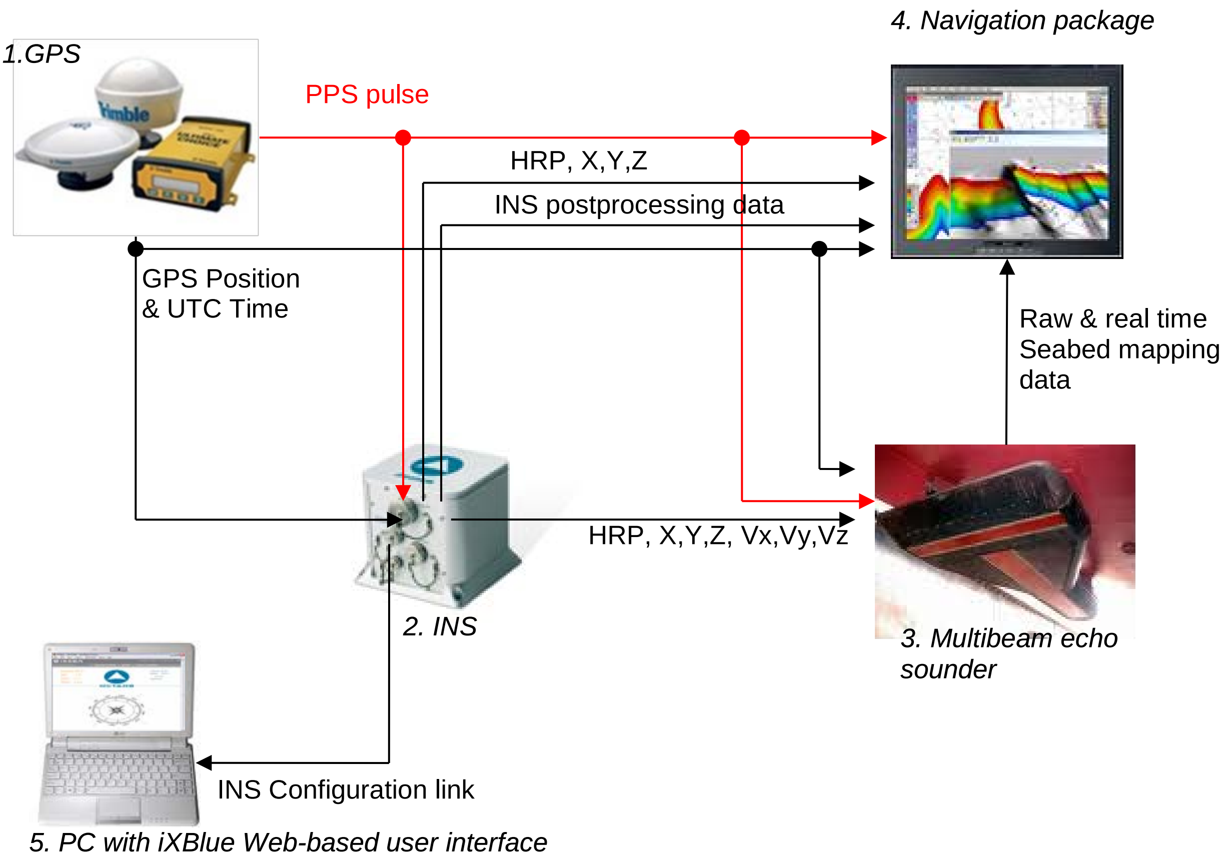
To measure $Heave_{COG}$, you can:

- Place the unit at the COG.
- If the unit is not located at the COG, you should enter the same lever arms between the unit and the monitoring point than between the unit and the COG. In this case, the monitoring point corresponds to the COG.

6 Using Absolute Altitude Compensation for Seabed Mapping

6.1 Typical Multibeam Set up with an INS

In this setup, absolute altitude is used instead of heave to compensate for vertical movements of the ship.



1. GPS mode 4 is requested here. This is achievable using RTK or Augmented DGPS (Veripos, Starfix). Following telegrams will be sent to the INS: GGA (position), GST (SD on position), ZDA (UTC time). PPS pulse is distributed to all equipment for time synchronization.

2. INS: HYDRINS or PHINS. Data links can be managed through serial or Ethernet. INS is time synchronized with GPS time (ZDA+PPS). INS post processing data can be logged on a PC for further DELPHINS post processing. Altitude mode should be set to “HYDRO altitude”. INS compared to AHRS has the ability to also send speed data to a multibeam echo sounder. This is a key feature for use with the latest multibeam system that can use speed, for Doppler shift compensation.

3. Multibeam echo sounder equipment is time-synchronized with GPS time (ZDA+PPS). It receives heading, roll and pitch data from the INS. Position is also sent for geo-referencing of the seabed mapping data. Absolute altitude is also sent to compensate for the vessel movements. Real time and raw data are sent to the Navigation package.
4. The Navigation package displays real time bathymetry and can be used to replay data since it logs all data from INS, GPS, and multibeam echo sounder.
5. Web-based User Interface installed on a PC is both used to configure the INS and as a data repeater.

6.2 Location of the Heave Measurement Unit

Here since we use absolute height from the INS there are no issues regarding transient heave so the unit can be located anywhere on the ship. Preferably in a temperature controlled room free from any heavy vibrations.

6.3 Lever Arms and Alignment to Vessel Frame

The INS should be aligned to the vessel frame since lever arms are measured in the vessel reference frame centered at the location of the INS. If not, this can induce an error in the lever arm taken into account by the INS.
Lever arms values must be entered into the system. The lever arms are a point coordinates expressed in the INS reference frame. There are two types of lever arms:

- An external point from the INS where the user wants data calculated. Lever arms affect the following physical parameters:
  - ❑ Acceleration
  - ❑ Speed
  - ❑ Heave, Surge, Sway
  - ❑ Position

  Rotation rate, Heading, Roll, Pitch are not affected by lever arms.

- Sensor lever arms. The INS needs to know the position of the external aiding sensor (i.e., GPS, EM LOG, DVL, DEPTH SENSOR) in its reference frame.

The error on lever arms has two main possible impacts:

- Error on absolute position calculated by the INS due to lever arm error with GPS. A rule of the thumb is that the lever arm accuracy should be 1/10 of the required absolute accuracy. For example if you want to position the vehicle with an 1-meter accuracy, your GPS lever arms should be measured with a 10-cm accuracy.
- If lever arms are not sufficiently accurate with respect to GPS accuracy the INS can reject the GPS when the ship is performing accelerations or turns. As a rule of the thumb the accuracy of the measurement of the lever arm in this case should be 1/10 of the accuracy of the GPS. As an example we present accuracy of GPS lever arm with respect to GPS accuracy:

GPS Mode	STD on position	Accuracy required on lever arm measurement
RTK GPS	5 cm	5 mm

When lever arms cannot be measured with sufficient accuracy to avoid GPS rejection the GST telegram should not be sent to the INS. In this case the INS will use and convert the quality factor 4 received in the GGA string into position SD of 0.3 m which is much greater than the SDs sent in the GST string.

6.4 Example of a Multibeam Picture Produced Using iXBlue INS Attitude and Height Data

The following multibeam picture was obtained using the following equipment:

- IXBLUE HYDRINS generation III
- R2Sonic 2022 multibeam
- QPS QINSy navigation package
- Trimble GPS 5700 in RTK mode

This area is in a city with GPS masking due to buildings with a bridge masking in a curve. This zone is on Oise River at Pont Saint Maxence (60), France, in shallow water (a few meters).

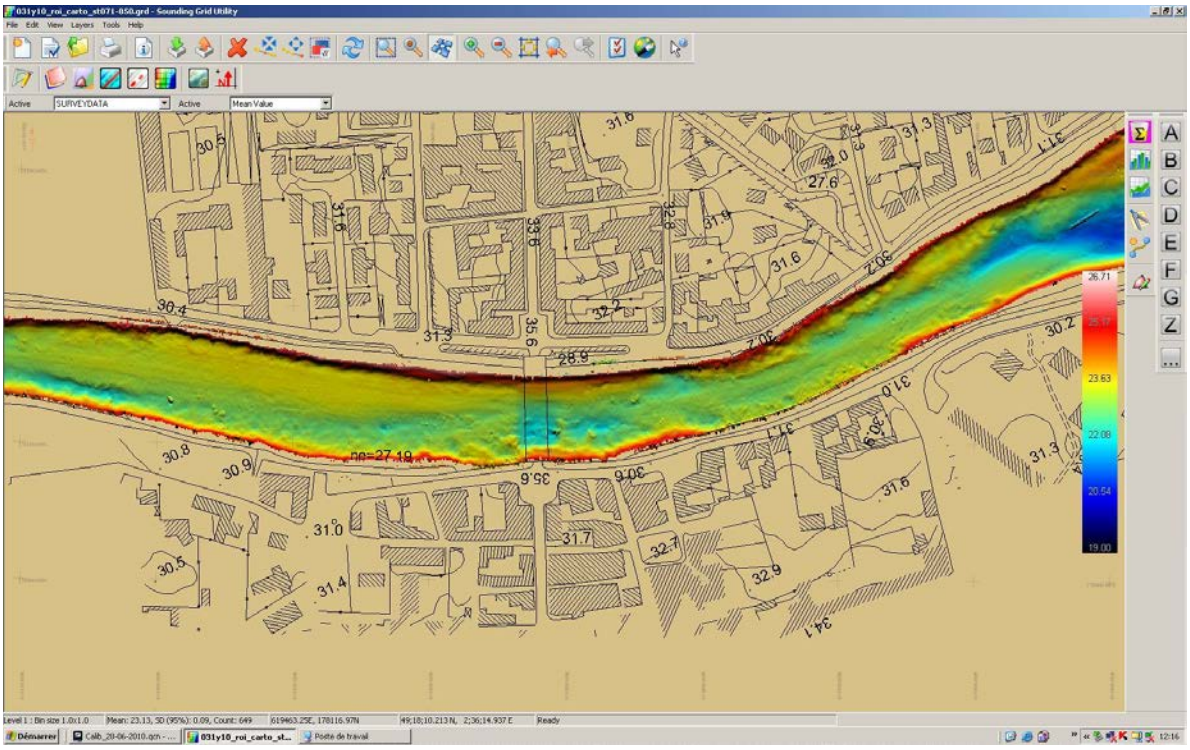


Figure 12 - Multibeam survey using IXBLUE INS

(Courtesy of VNF, France)

7 SURGE AND SWAY

7.1 Definition

7.1.1 SURGE

The surge is similar to the heave and is the forward position of the vessel referenced to the mean position. The surge is the addition of:

- surge due to forward movement (filtered by the unit)
- surge due to vessel attitude (induced by lever arms)

7.1.2 SWAY

The sway is similar to the heave and is the starboard position of the vessel referenced to the mean position. The sway is the addition of:

- sway due to starboard movement (filtered by the unit)
- sway due to vessel attitude (induced by lever arms)

7.2 Surge and Sway Filters

AHRS and INS only provide surge and sway measurement in real time. Filtering method used for surge and sway measurement (high pass filtering) is different from the one used for heave (adaptation of an altitude filter centered on mean sea level). So, the sea state selection used to optimize the accuracy of the real time heave filter has no effect on surge and sway accuracy.

7.3 Using the Center of Gravity

The description of heave measurement (see section 4) is also applicable for surge and sway measurements. Indeed, the vessel transient movements have effect on surge and sway measurements and the recommendations given for heave (place the unit as close as possible to the COG of the vessel or indicate the COG position) are also valid for surge and sway.