# Manual on Wobble Analysis

In Swathed

Auke van der Werf November 2007 auke@omg.unb.ca

# Index

Index....2
Introduction....3
0.1 Recognize Artefacts....5
0.2 Unravel the data....6
0.3 Make a DTM....8
0.4 Open the data....8
1 Swath editor....10
1.1 Introduction....10
2 3.Cross plot analyse in TimeSeries....14
3 Photobook....23

# Introduction

The wobble analysis is an part of Swathed, the software of the Ocean Mapping Group. Swathed works under Linux.
I recommend to read lecture 26, written by John Hughes Clarke, before even start on the wobble analysis tool. Lecture 26 can be found on www.omg.unb.ca

To analyse data we've to make a few steps. In this manual I will explain which steps have to be taken to make an analysis. Working with Swathed takes some time. Without experience it is hard to recognize artefacts. That's why I will explain each step, how we can recognize artefacts and how we can solve artefacts.

Artefacts look like each other. But it is possible to recognize the difference artefacts. With the sun illumination technique, we can recognize artefacts better en sometimes we can even see what kind of artefact we're working with.
In Swathed we can look at factors as across profiles, DTM, scatter plots and correlations, and with that find the cause of the artefact, find the size of the error and solve the error.

From research we saw that the structure of the errors in lever arm definitions in across- and along track look like each other. The cause is different. In both cases the error, an induced heave error, will effect the whole swath. The whole swath will be (linear) lifted or lowered, depending on the motion of the ship like roll and pitch. On bigger ships is the chance on this kind of error bigger then on smaller ships.
With a time-delay of the motion sensor and an yaw-misalignment, the errors look like each other while the cause here also is different. In both cases the error will have the biggest weight on the outer beams of the swath and the lowest weight on the inner beams. We talk about a linear tilt of the swath; one half of the swath will measure to deep and the other half will measure to shallow. An yaw-misalignment will cause crosstalk between roll and pitch. We can prevent from this error, to line up the motion sensor to the ships reference frame when we measure the ships reference frame (boat geometry).

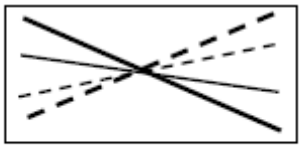
We also saw that artefacts caused by incorrect Surface Sound Speed or due to an incorrect Sound Velocity Profile have both a different character.

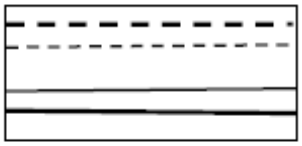
Artefacts caused by an incorrect Surface Sound Speed are not linear over the swath and make an linear tilt; one half of the swath will measure to deep and the other half will measure to shallow. With an incorrect Surface Sound speed the depth and across track error depends on the shape of the used multibeam echo sounder and on the motions of the ship at that moment.

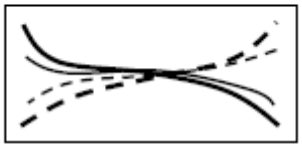
Artefacts caused by an wrong Sound Velocity Profile are also not linear over the swath, but are in phase! That will cause an ‘smiley’ or an ‘frown’. An ‘smiley’ is caused when there is used a to high sound velocity and a ‘frown’ when there is used an to low sound velocity.

## 0.1 Recognize Artefacts

In a DTM the Sun Illumination can come from different angles. We can recognize artefacts better or worse through different angles.
According to Hughes Clarke, there are different types of artefacts.

Type I:  Linear tilted

Type II:  Linear up and down

Type III:  Not linear tilted, out of phase

Type IV: Not linear tilted, in phase

*Types of Artefacts [Hughes Clarke, lecture 26]*

## 0.2 Unravel the data

We can unravel raw data with hand, or by using an unravel script.

If you're interested and want to learn the unravelling process, which I can recommend for the first times, unravel by hand. Guidelines to do this can be found on http://www.omg.unb.ca/~pimk/software/html/proc_pipeline.html

When you want to do it the easy way, you can use an unravel script. For the different multibeam systems we also need different scripts. Scripts made by Ocean Mapping Group can be downloaded on http://www.omg.unb.ca/~jonnyb/processing/new_unravel.html
Right mouse click on the buttons and save in the directory were your raw files are.
New_unravel.gz is for Simrad, new_xtf_unravel.gz is for Reson.

Here I also found the following recommendations:

A few rules, caveats and options that you'll have to customize in the script:

1. SIMRAD RAW FILES WARNING: You may need to modify the RT command for the sonar of choice (currently setup for EM3002). As of version 1.0.4, it will attempt to guess the model number, but the script is hardwired to support only a few sonars.
2. SIMRAD RAW FILES WARNING: You'll have to remove the **-force_swap** option from the RT command if the data was logged using the Unix based Merlin (instead of the new Windows based SIS, which is what this script assumes). As of version 1.0.4, this is no longer necessary as RT can decide the byte-ordering on it's own (but can still be forced to a certain order with -LE or -BE options).
3. RESON XTF FILES OPTION: You might need to change the sonar type for the xtf2omg_reson command (e.g. -sonar 8125)
4. RULE: It expects raw data to be in the 'raw' directory, all lowercase. It also expects a raw subdirectory, i.e. you can't yet shove the line data into the raw directory on its own (but this may be a useful future feature for quick n' dirty one day jobs).

To start unravelling simply type the next in your konsole or terminal in Linux:

- e.g. new_unravel raw/JD234/whatever*.all
- e.g. new_unravel raw/*/*.all
- e.g. new_unravel raw/*/*.all.gz

Directories will automatically be created.

## 0.3 Make a DTM

Start making a DTM. Then we can see if there are artefacts in the data.
Look where and if there is an flat area in the DTM, we like to use a flat area for the analysis in Swathed.
Area which we rather don't use for the analysis, are non flat area's or with objects like boulders or seegrass.

Please show the steps

## 0.4 Open the data

**Maps**

To read data in Swathed, the data should be in *.merged format. There is a procedure to make from an *.xtf file an *.merged file. This can be found on Jonnies homepage, www.omg.unb.ca/~jonnieb.
It is important to keep your maps organised, so you can easy work with them in Swathed. I would recommend to create make a folder with the following folders maps inside:

DTM
Maps
Merged
Raw
SVP

**Start Swathed**

To start swathed, we have to give the link to the folder with the data. After that we have to give the lines which we want to be opened. We always open a *.merged file in Swathed. This line can be opened in Swathed to type the following in the terminal or console (example):

Swathed –mini merged/1998_JDxxx/0013_19980907_185114.merged

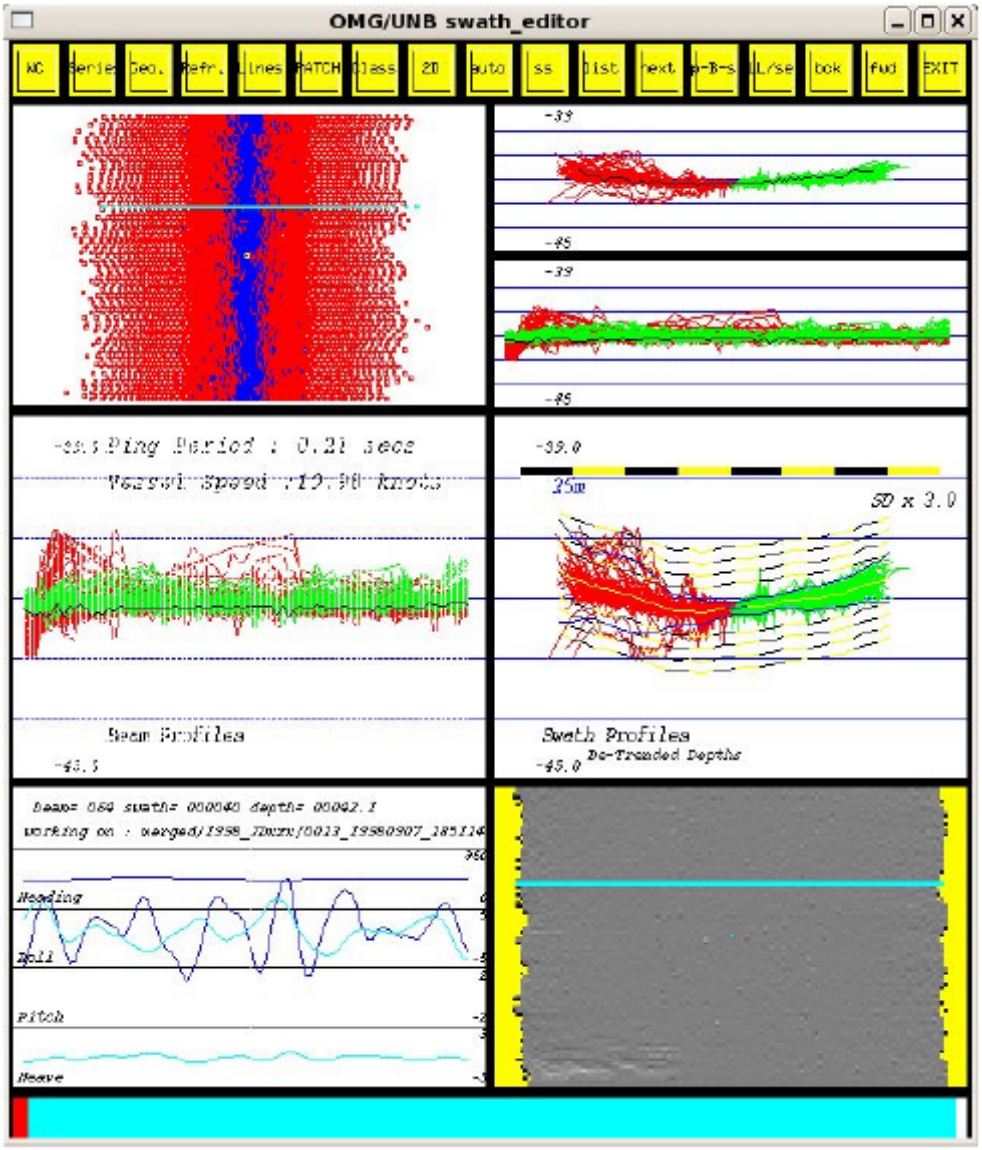
These commands mean:

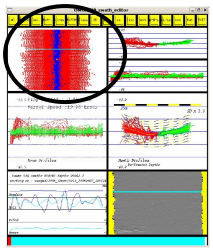
| | |
|---|---|
| swathed | start the program Swathed |
| -mini | gives a smaller screen (option) |
| Merged/1998_JDxxx | link to the correct folder we want to use |
| 0013… merged | link to the data we want to use |

# 1 Swath editor

## 1.1 Introduction

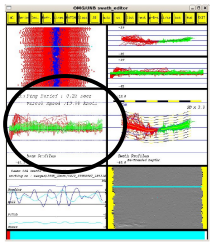
When we start Swathed, we will see the swath editor screen. In this screen there are 80 swaths visible. (figure)

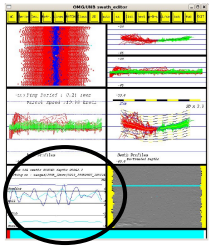




Top view, in which the red dots are phase measurements and the bleu dots are amplitude measurements. With the left mouse button we can edit the data. There is one black dot, which we can move up down and left right. With this we can see where we are in the swath, in the other screens.

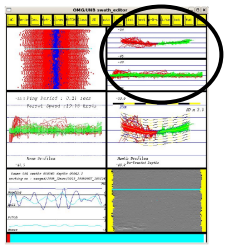
Side view of the swath. Left is west, right is east. With mouse and keyboard we can move through the swaths (80). With the mouse in this screen, and press "D" (detrend), we can change the view more from the side or more from the top. In the screen we can also see the mean ping rate of the multibeam echosounder en de mean velocity of the ship. In this screen an artefact can become visible.

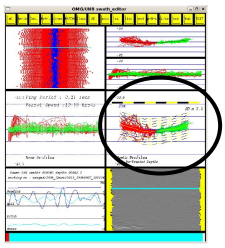




Here we can see the heading, roll, pitch and heave, of the visible 80 Swaths. Compare this screen with the screen above it. Then we can see if the swath correlates with the movements of the ship, like roll, pitch or heave.

Here we see the raw data.



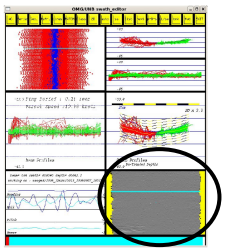


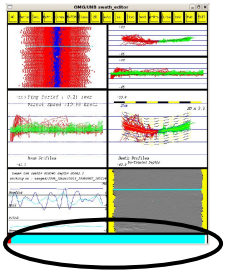
Back view of all swaths.

With the mouse in this screen + "V", IHO standards become visible. With the mouse in this screen + "K", QMS standards become visible.

Sun Illumination of the data.

With the mouse in this screen + "C", backscatter information becomes visible.



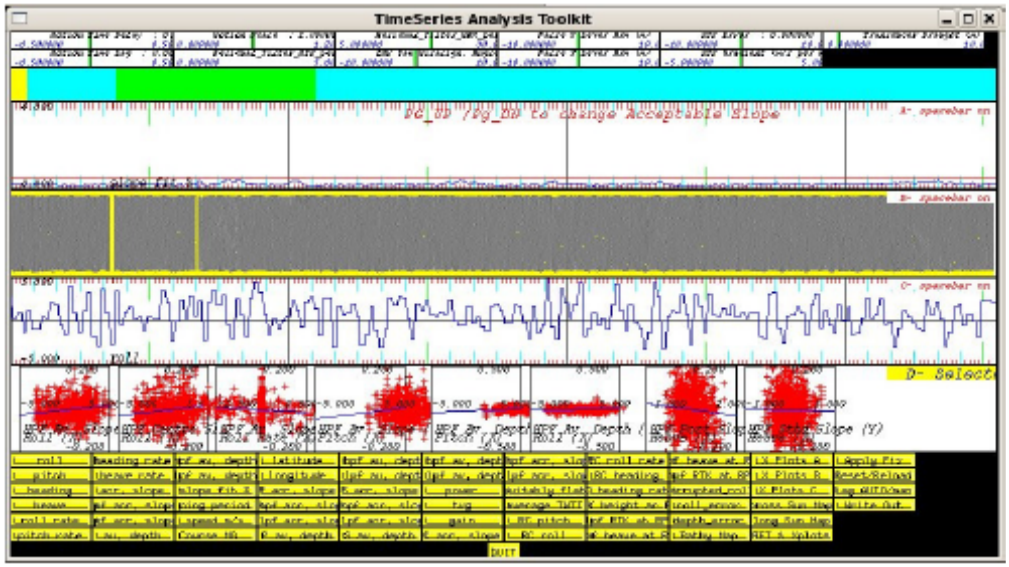


With the mouse in the mint green part, and press the spacebar, we're going through the Swaths.

**2.2 TimeSeries**

With the time series tool we can co an wobble analysis. I will explain this in …, but now first explain the main features in the time series tool.

In time series we can make an analysis of the errors/offsets which are in an dataset. In the time series toos we can select four features and plot them in the bars. In the figure I selected slope fit, along sun map, roll and X plots A.



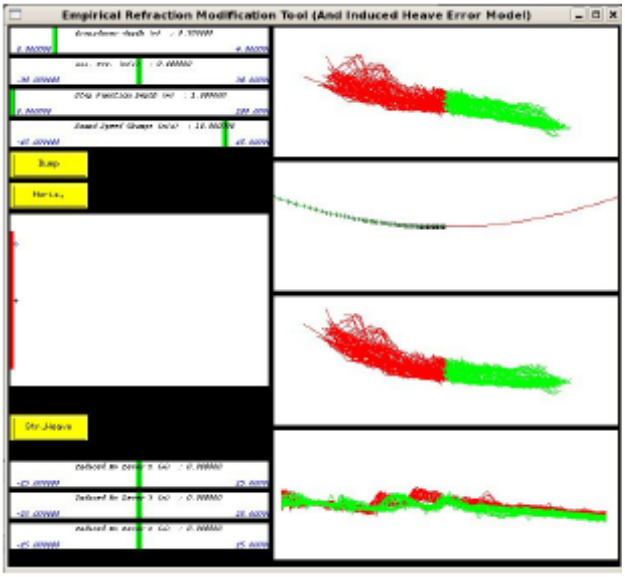

Down in the time series tool, we can see all the selection options in the yellow buttons. To select a bar, you have to put your mouse in the bar and press the space bar. Then the bar is selected, and you can choose an option to press a yellow button.

In the mint green bar you can select a part of the DTM at which you want to zoom in. This part you can select with your mouse.
To put the selected area back in the original scale, you can put your mouse in the mint green bar and press “A”. Or press “R” for rescaling.

In the graph bars, like for the roll, the vertical scale can also be edited. You can do this to put the mouse in the graph bar and press arrow up or arrow down on your keyboard.

### 2.3 Refraction Tool

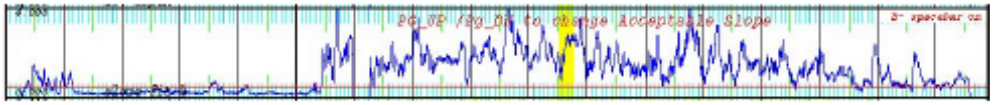
An error in sound velocity profile, can look like an frown or an smile. In the refraction tool (figure) we can recognize an frown or an smile. We can change the sound velocity, and see how big the sound velocity corrections should be to make a flat seafloor.



# 2 3.Cross plot analyse in TimeSeries

### 3.1. Select the following graphs/bars:

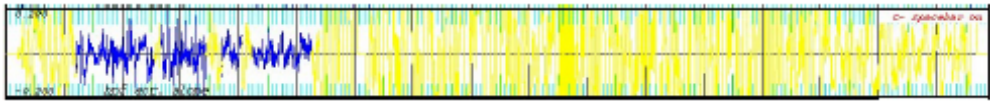
**Slope fit**



With ‘slope fit’ we can look for an area suitable for the analysis. The blue line should be under the red line to make an proper analysis. With ‘page up’ and ‘page down’ we can change the value of the red line. 0.25 is a lineaire regression, witch is calculated with a standart equation with least squares. It is an percentage of the depth.

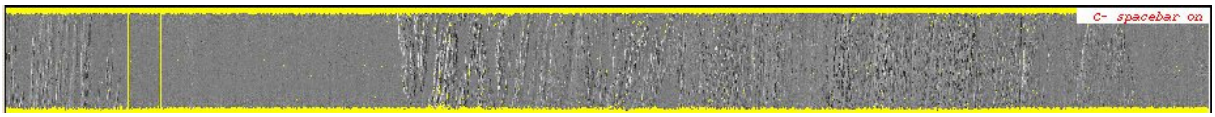
In the example in the figure we can see a suitable area for an analysis on the left side, cause the blue line is under the red line.

**Hpf across slope**



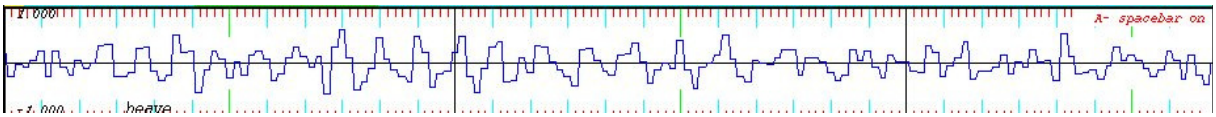
In the Hpf across slope bar (figure) the blue part is within 0.25 en thus is suitable for the analysis. Yellow is the part which in the slope fit bar above the red line, and thus not suitable for the analyse. So the blue part on the left side is suitable for the analyse.

**Sun illumination along track**



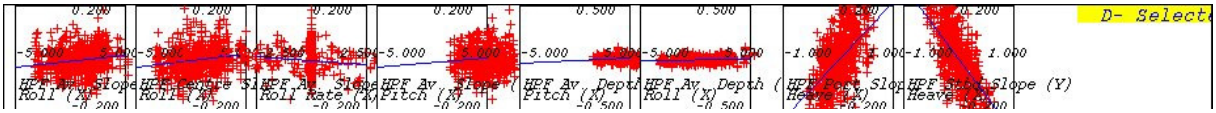

In ‘Along Sun Map’ (figure) we can select an DTM in sun illumination. This is the DTM of one line.

**Motion**

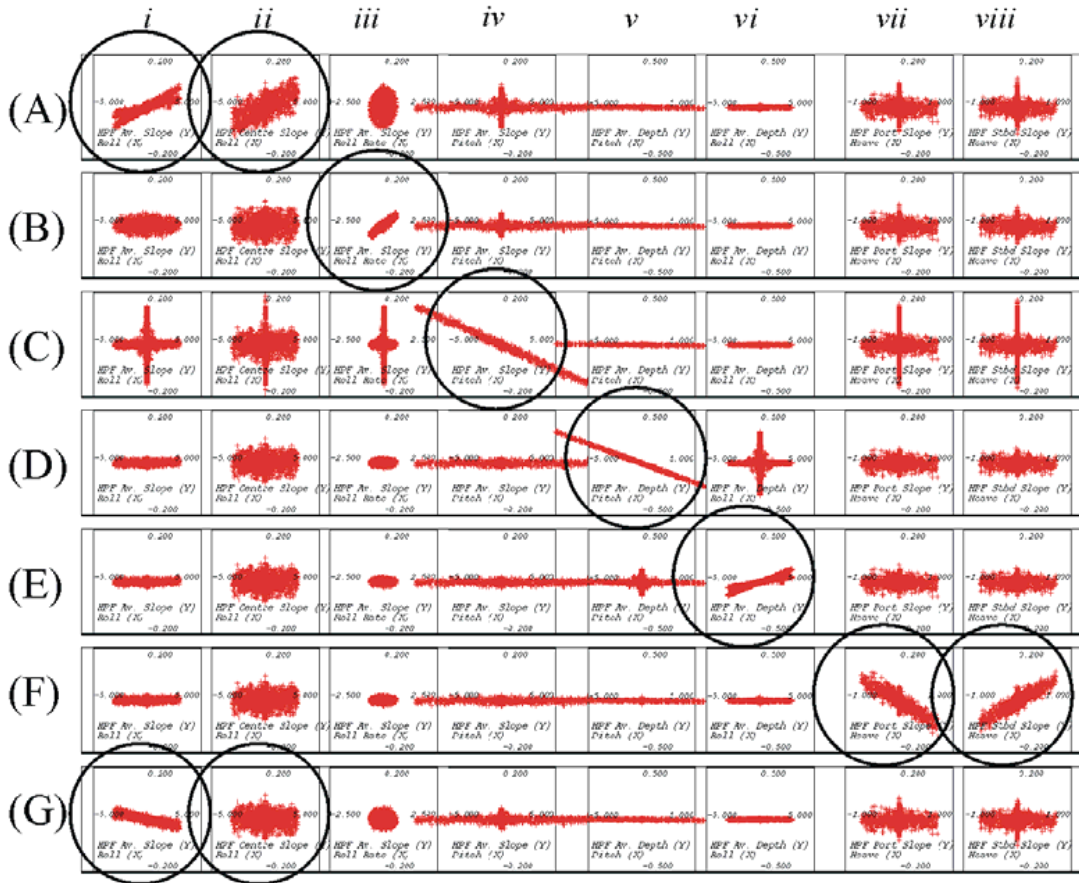



With a bar with the motion of the ship, like roll, pitch or heave (figure), we can compare the motion with ‘hpf across slope’, ‘hpf average depth’or the sun illumination along track, to see if there is any correlation between the motion and the artefacts.

**Cross plots**



With cross plots (figure) we can recognize what the cause of an artefact is. In the next figure we can see all cross plots given in lecture 26. The rows give the type of error (A till G) and the columns the type of movement at that moment (i till viii) roll, pitch, heave or roll rate. In every cross plot with a circle around in the figure, we can recognize an type of error. By every type of error we can see a change in one or two crossplots. There will exist a slope, except at Gii. To this slope we can recognize errors. I will now describe the different types of error.




In a cross plot we can see a linear regression which is made out of different scatter plots. The slope of the linear regression shows us the size of the error. In each cross plot there is a correlation with HPF across track slope or HPF mean depth. Which one is used in a cross plot is shown in the cross plot. In each cross plot is also horizontal shown how big the motion of the ship is in that cross plot. Vertical is shown how big the HPF slope or the HPF mean depth is.

### 3.2 Characteristics of errors shown in cross plots

*(A)Motion scale Type I*

An error in motion scale will cause artefacts of type I. The HPF (high pass filtered) across track error will correlate with the roll. So only when a ship has a roll motion, and there is an error in motion scale, there will occur artefacts. The slope of the inner beams is the same as the slope of the outer beams. An error in motion scale is not really 2007, so we won't see this much or not at all anymore.

*(B)Time delay Type I*

When there is an time delay, this will cause artefacts if there's also an roll rate. Then there can exist artefacts of type I. With an error in time-delay the HPF across slope will correlate with the roll rate.

*(C)Yaw Misalignment Type I*

An Yaw misalignment can cause artefacts of Type I. With an yaw misalignment the HPF accros slope correlates with the pitch. So only when the ship has a pitch motion, an yaw misalignment will cause artefacts.

*(D)X lever arm error Type II*

An error in the x-lever arm can cause artefacts of Type II. In this error the HPF mean depth will correlate with pitch. When the ship makes a pitch motion, and there is an offset in the X lever arm, this can cause artefacts.

*(E)Y lever arm error Type II*

An error in the Y lever arm can cause artefacts of Type II. In this error the HPF mean depth will correlate with the roll. When the ship make a roll motion, and there is an offset in the Y lever arm, this can cause artefacts.

*(F)Surface Sound Type IV*

Port and starboard HPF slope correlates the same in speed gradient and in opposite directions with heave (transducer depth)

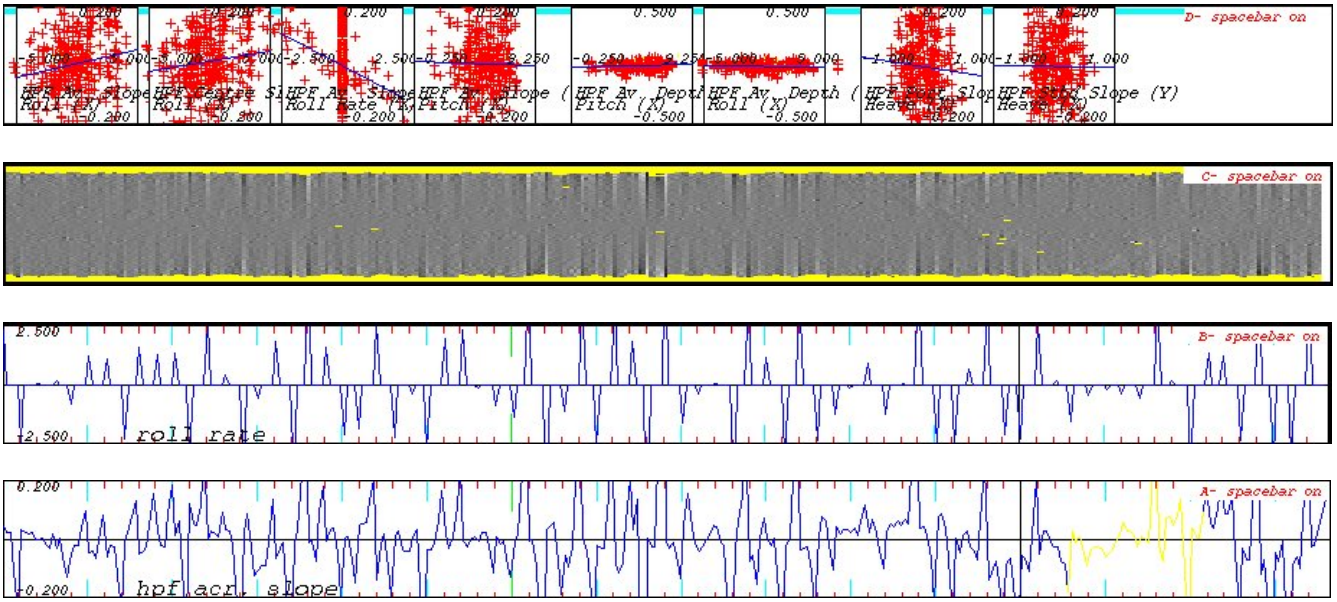
*(G) Surface Sound Type III*

A wrong sound velocity profile can cause artefacts of Type III. In this type of error the HPF across slope correlates with roll.

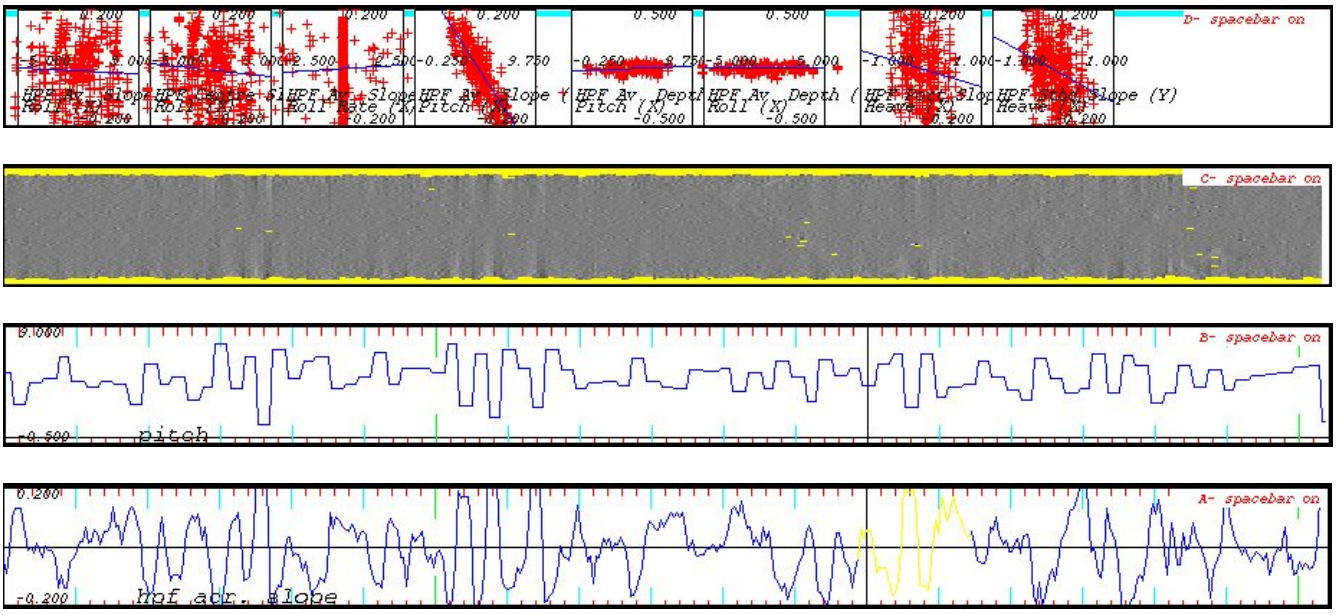
### 3.3 Correlations

Each type of error has to do with correlations. The correlations of each error will look like this:

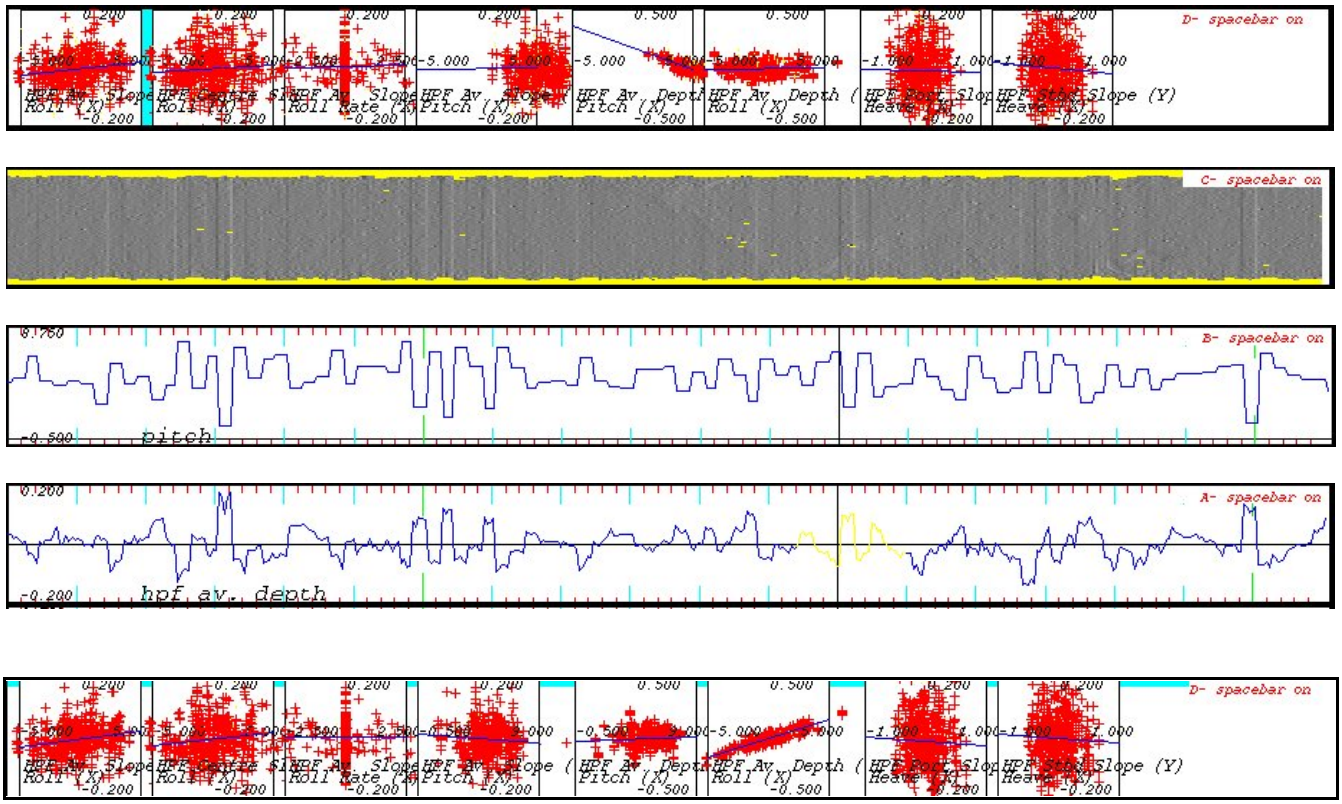
**(B) Time-delay Type I, HPF across slope correlates with roll rate**




**(C) Yaw Misalignment Type I, HPF across slope correlates with pitch**



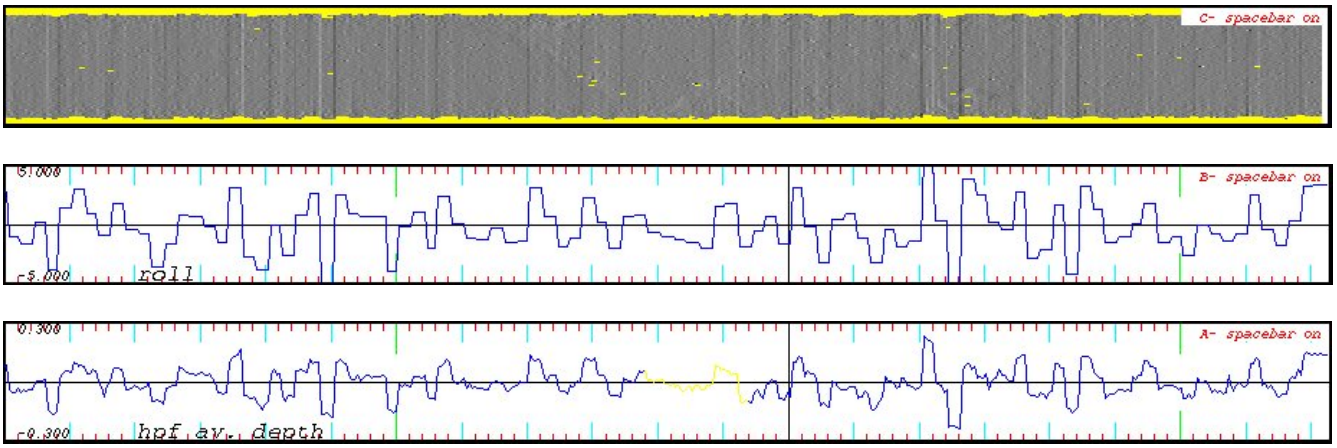
**(D) X lever arm error Type II, HPF mean depth correlates with pitch**



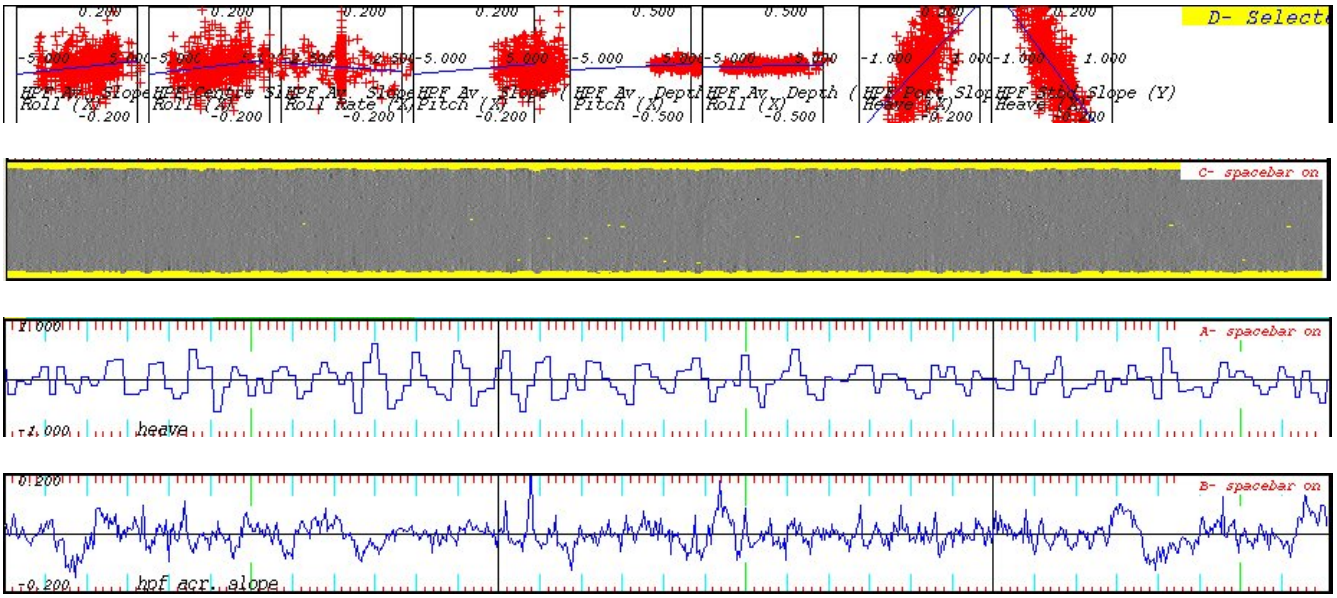




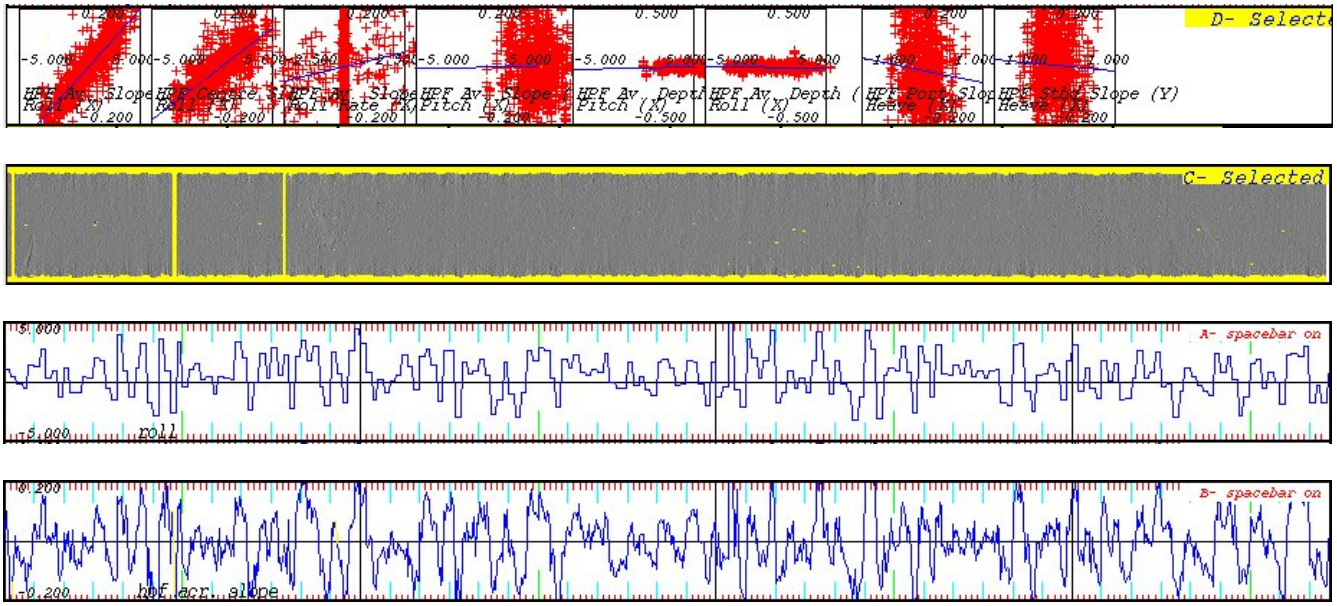
**(E) Y lever arm error Type II, HPF mean depth correlates with roll**



**(F) Surface Sound Type IV, correlation with heave**




**(G) Surface Sound Type III, HPF across slope correlates with roll**



### 3.4 Remove an artefact

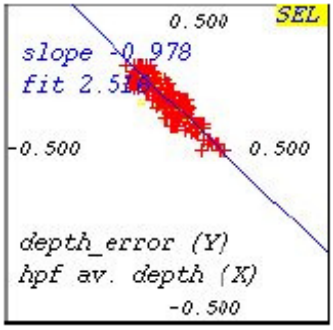
I explained now how we can recognize an artefact in Swathed. We can now try to get rid of the artefact or mimimize the artefact.

When we now in which scatter plot the artefact is, we can change the error with the upper bars.

We can remove an artefact like this. Make sure you opened the bar with the crossplots. And open with the yellow buttons the menu FFT & Xplots (figure). With this menu we can determine how big the error is.
For example if there is an error in the x –lever arm, then we've to make the value of the x-lever arm so that the slope in the FFT & Xplots -1 is, or as close as possible to -1. When the slope (almost) -1 is, that will be the correct value of the x – lever arm.

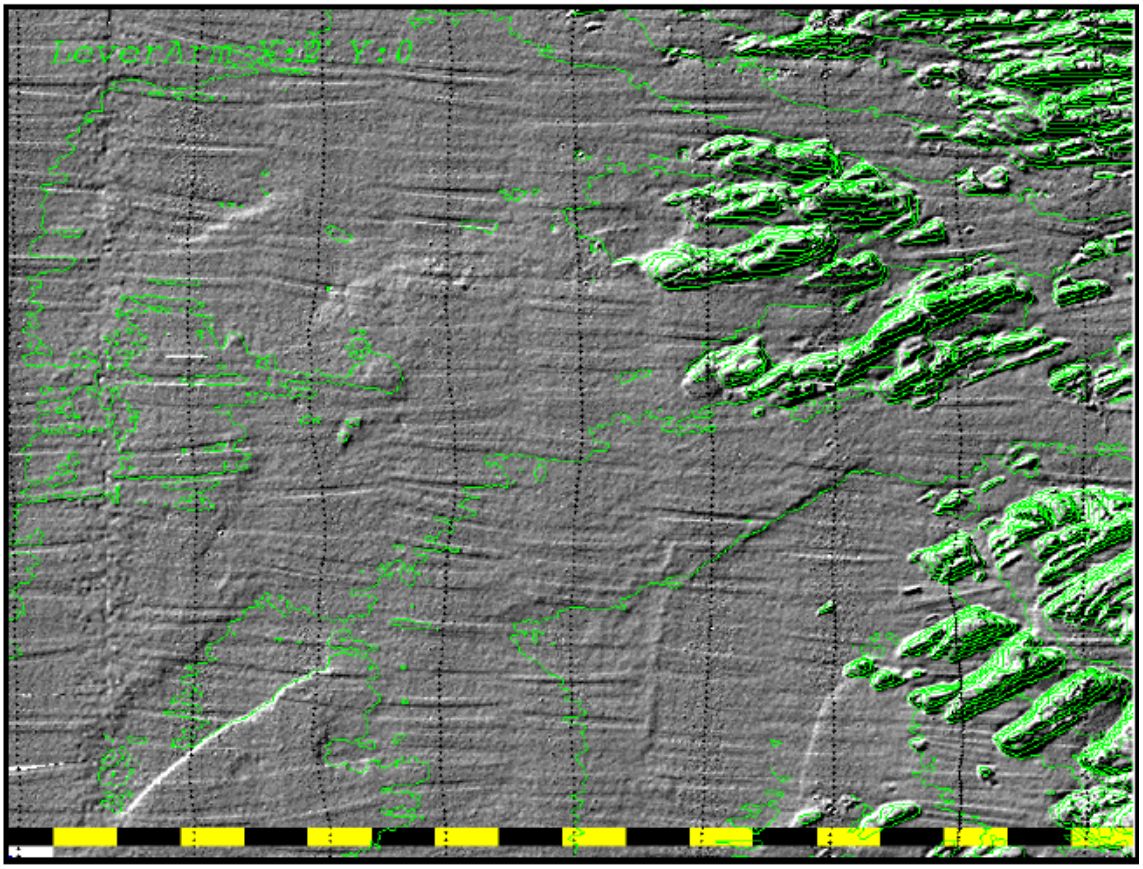
The slope has to be -1 to remove or minimize an error, is for an error in the x – lever arm, an error in y – lever arm, a time – delay, an SSS error and a SSS gradient. For an error in yaw – misalignment the slope should be -0.70 to remove or minimize this error.

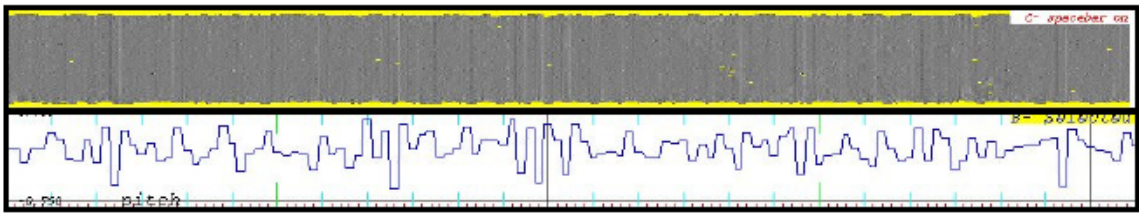
With 'apply fix' the change is applied, and we can control this to see in the DTM if the artefacts are gone or minimized.

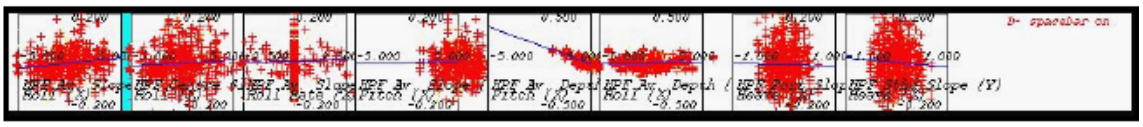


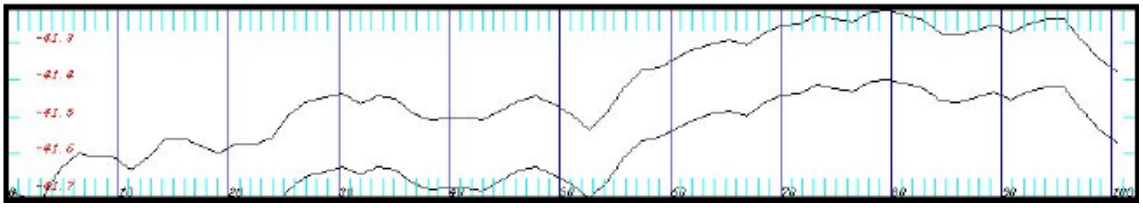
# 3 Photobook

### 4.1 Error in X-lever arm of 2 meters





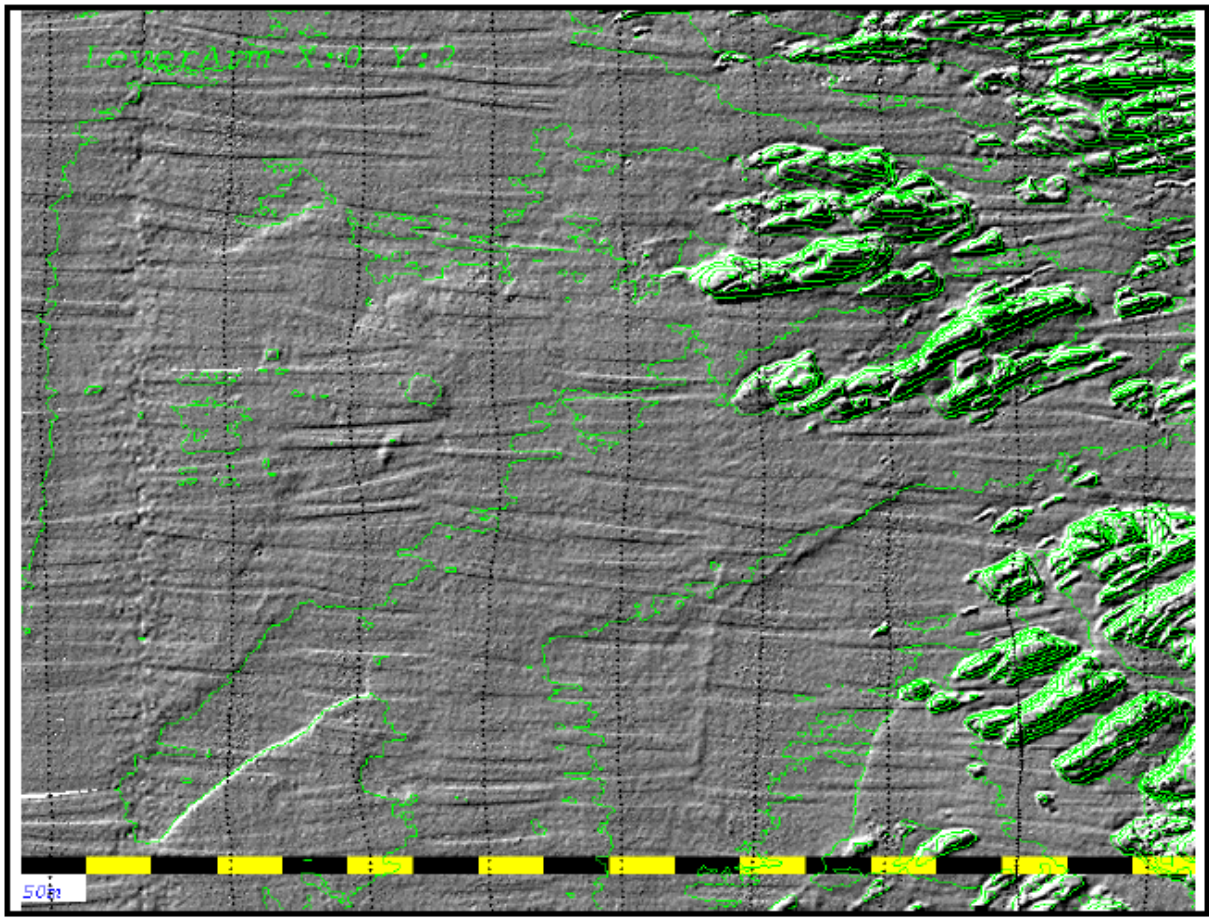
This figure shows us an DTM with nine sailing lines. The sailing lines are shown with the dotted lines. In the DTM we introduced an systematic error in the x – lever arm of 2 meters The effect of this error is an artefact over the whole width of the swath (type II). The whole swath will be lifted or lowered.
This error becomes more clear with pitch motions and a flat seafloor.

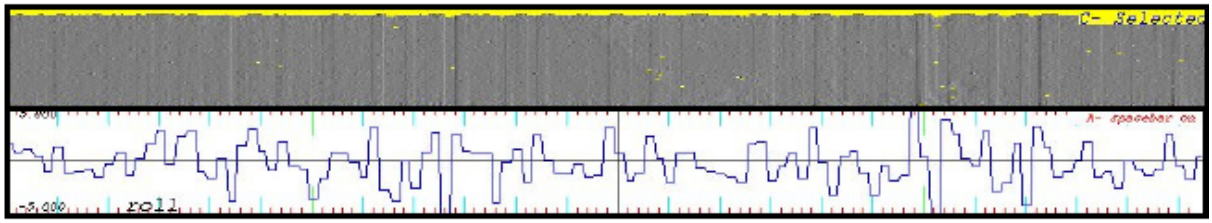
Here are two profiles of the line given; the lowest line gives the profile without error in the x – lever arm. In the upper line is with an error of 2 meter in the x – lever arm. Just like as in the DTM we can see that an error in the x – lever arm affects the whole swath. This effect is everywhere in the swath the same. The difference in depth between these two swaths is about 20 cm.

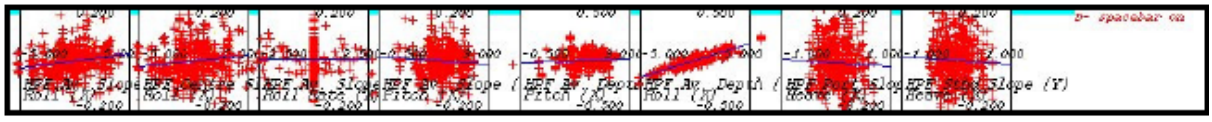
In the scatter plots we can see that the line in the scatter plot has a slope: HPF average depth correlates with the pitch. This means that there is an error in the x – lever arm

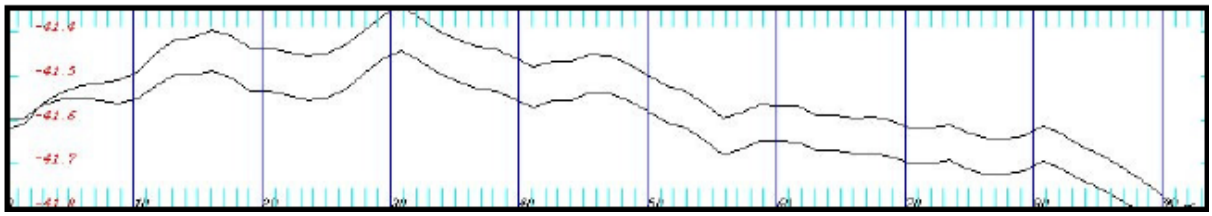
Here is a part of one line given. This DTM uses sun-illlumination. Under the DTM is the pitch given at the same moment of the DTM. In this DTM we can see the influence of the pitch on the x – lever arm. Because

**4.2 Error in Y-lever arm of 2 meters**



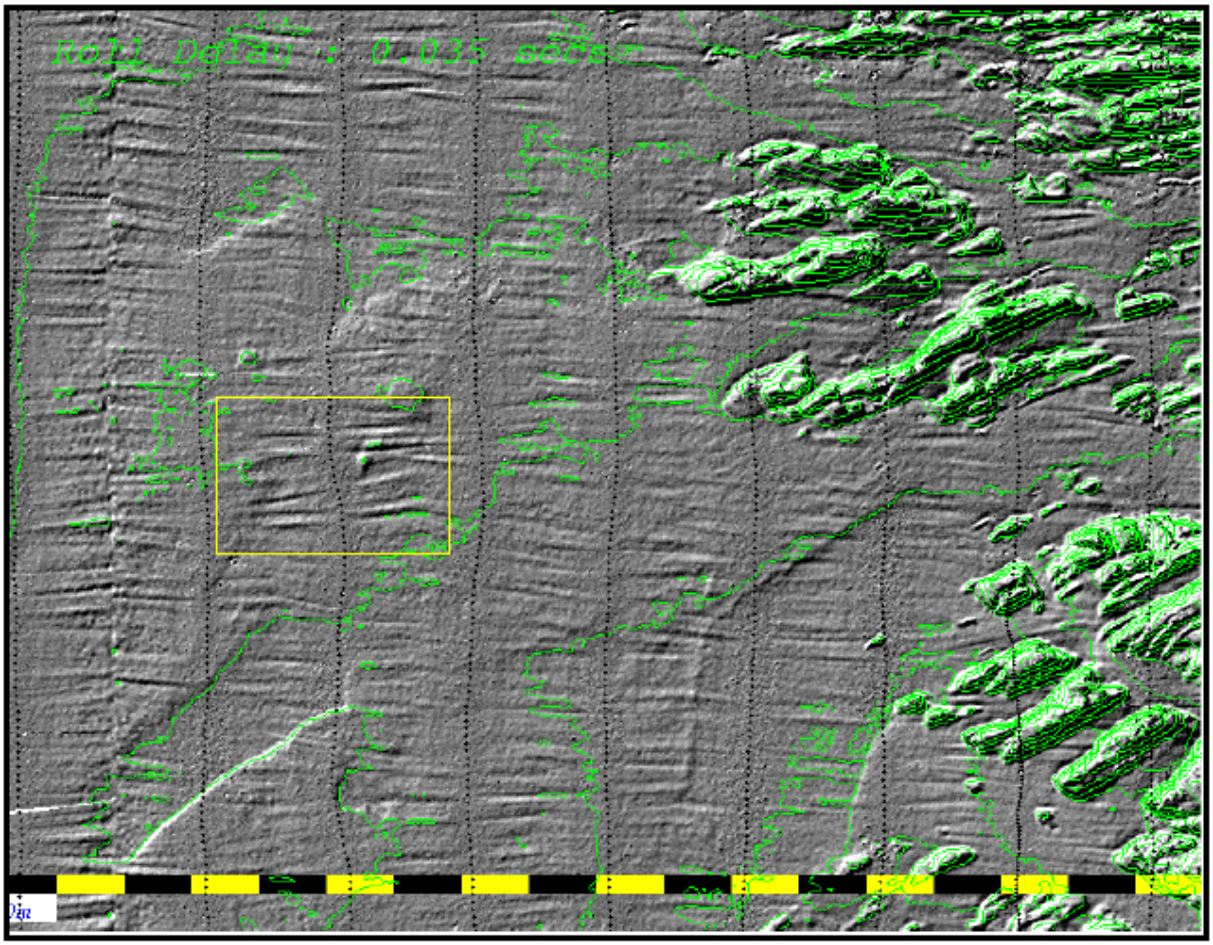
In this DTM we introduced a synthetic error in the y – lever arm of two meters. The effect of this error is an artefact over the whole width of the swath. The whole swath is lifted or lowered. This means that the artefact is of type II.
This DTM looks like the DTM with the error in the x – lever arm. Only this error becomes visible with a roll motion.

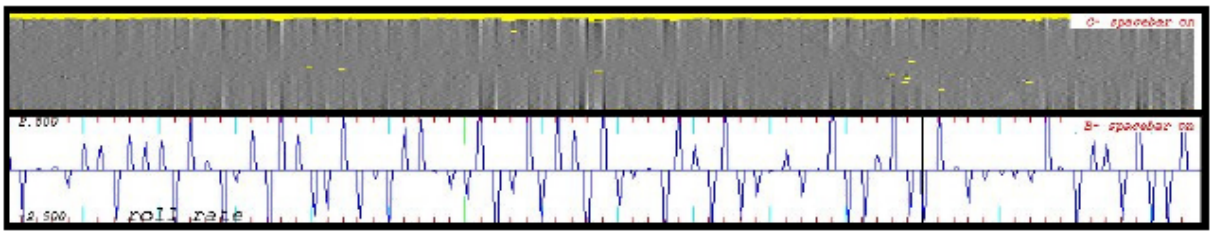
Here is one line out of the DTM in sun illumination given. Under the DTM the roll is showed at the moment of the DTM. In the DTM we can see the influence of the roll on the y – lever arm. When there is roll, we can clearly see artefacts in the DTM.

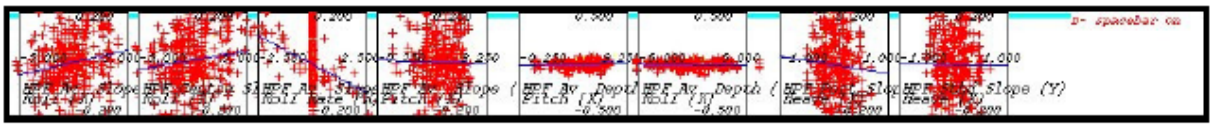
In the scatter plots we can see that the line in the scatter plot has a slope: HPF average depth correlates with the roll. This means that there is an error in the y – lever arm.

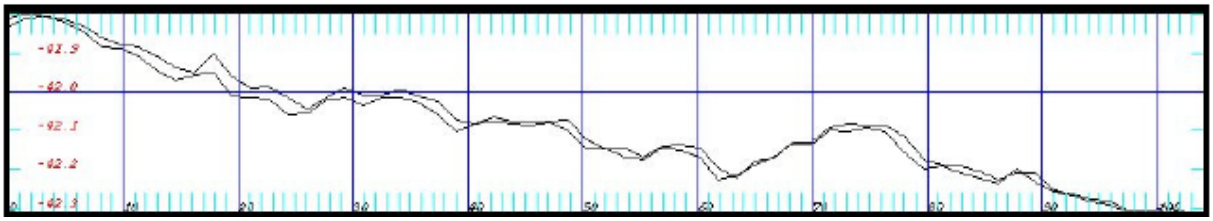
Here are two profiles of the line shown; one gives a profile without error in the y – lever arm, the other gives a profile with an error of 2 meters in the y – lever arm. Which profile is deeper depends on the roll (if the roll is positive or negative). Just as in the DTM we can see that an error in the Y lever arm affects the whole swath. The effect is the same everywhere in the swath and the difference in depth is about 10 cm.

**4.3 Roll delay of 35 ms**





In this DTM we introduced an synthetic time-dealy of 35 milliseconds. Effect of this error are linear artefacts with a slope over the swath (type I). The outer beams have the biggest error. We can see this in the DTM; the more the swath comes to the outer beams, the more the artefacts are visible. One half of the swath is measured to deep and the other half to shallow. In the yellow border we can see this through the shadow.

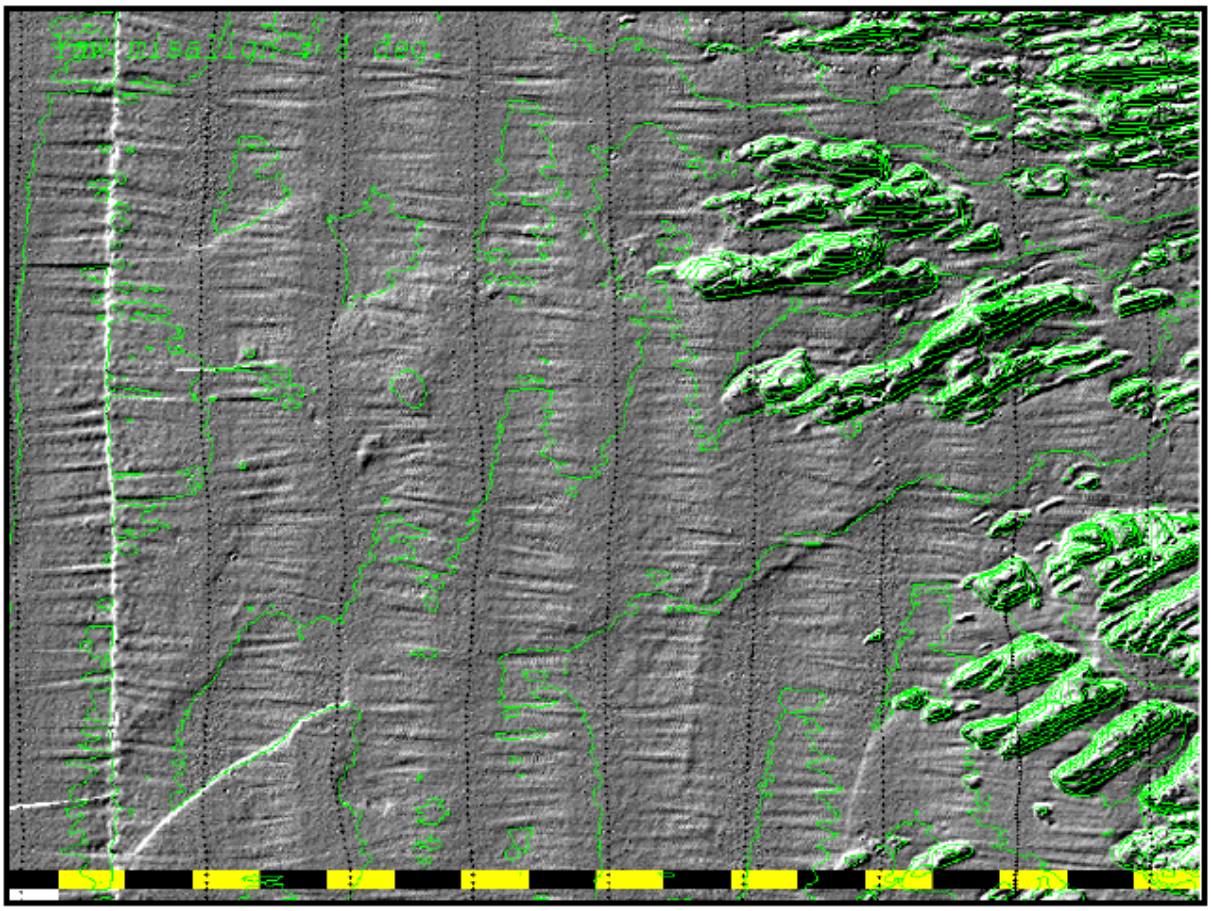
The error becomes visible by changes in roll rate and a flat seafloor.

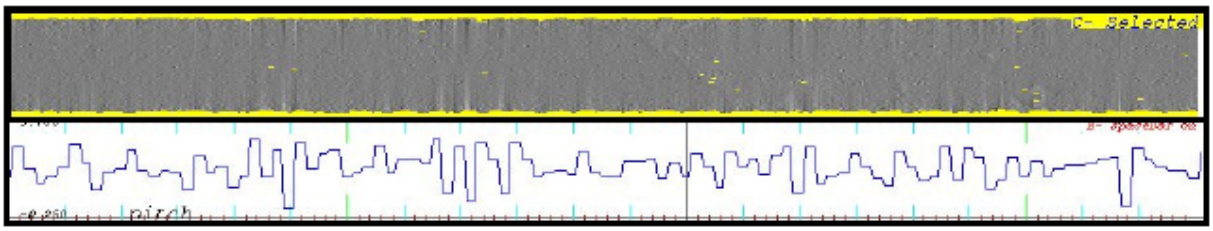
Here is an DTM given. It is an zoomed part of the sailing line. Under the DTM is the roll rate given at that moment. In the DTM we can see that the roll rate influenced the Y – lever arm. When the roll rate gets bigger (positive or negative), we can clearly see artefacts in the DTM.

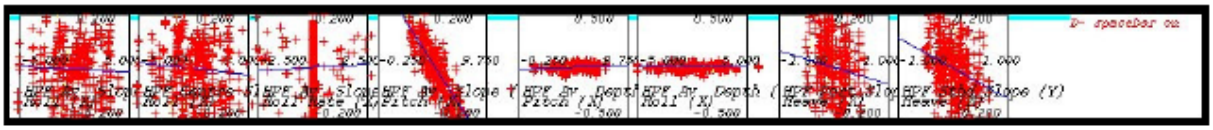
In the scatter plot we see that the (graph of the) scatter plot has an slope: HPF average slope correlates with the roll rate. This means that there is an error in the x – lever arm.

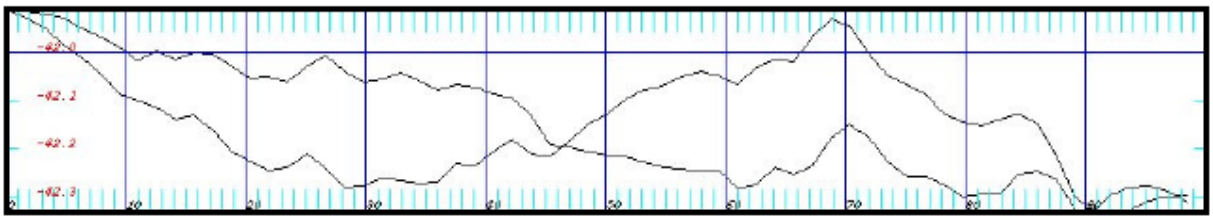
In this profile of the sailing line is is not so clear to see that the artefact is an type I. We can see in the profile that both swaths cross each other several times. This means that the error has to be an type I of an type 3. Because the swaths are linear, it has to be type 1.

### 4.3 Yaw misalignment of 4 degrees





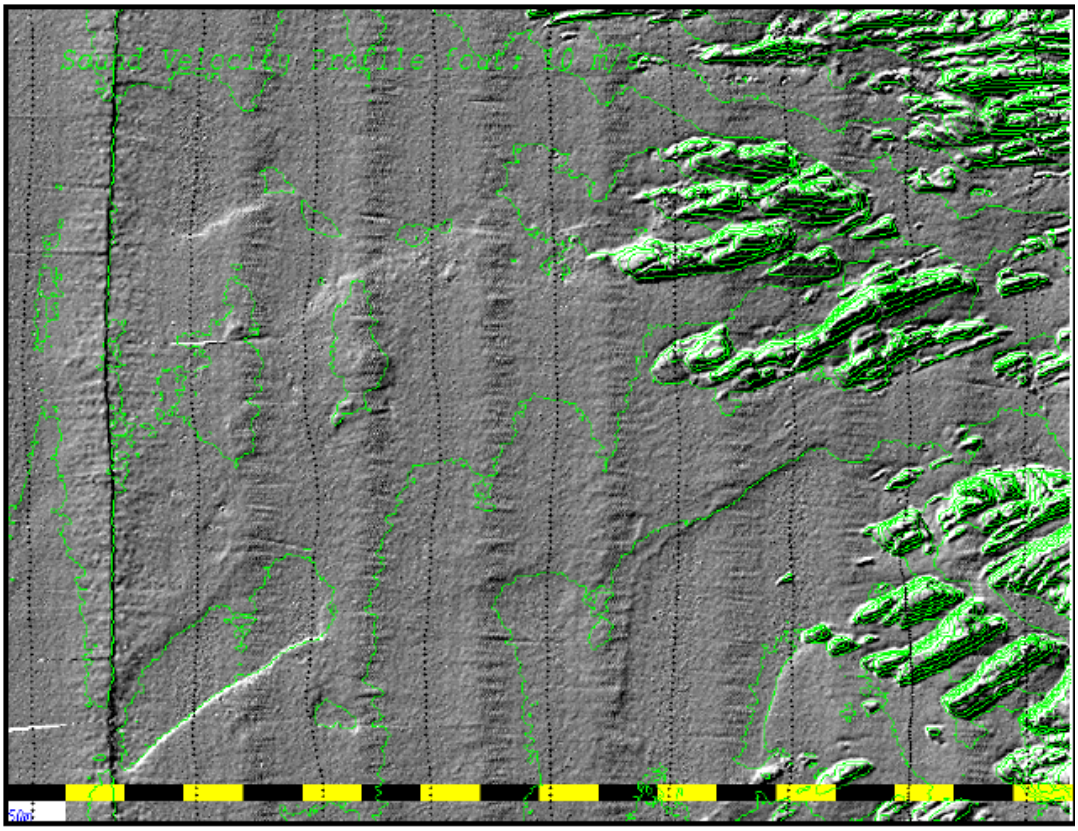
In this DTM we introduced an synthetic yaw misalignment of 4 degrees. A yaw misalignment can be caused through crosstalk. The effect of yaw misalignment are artefacts which are lineair and have a slope over the swath (type I). The outer beams have the biggest errors. We can see this in the DTM; the more to the outside of the swath, the more visible are the artefacts. One half of the swath is measured to deep and the other half is measured to shallow. We can see this at some point through the shadow. This error becomes visible by changes in pitch and a flat seafloor.

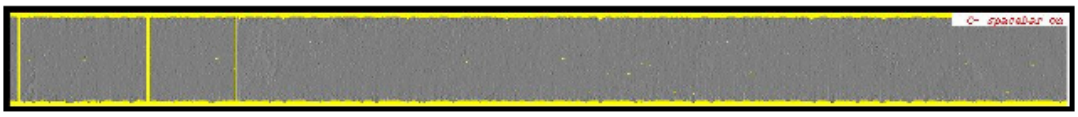
Here is an DTM given. It is an zoomed part of the sailing line. Under the DTM is the pitch given at that moment of the DTM. In the DTM we can see that when the pitch is bigger (positive), artifacts also appear.

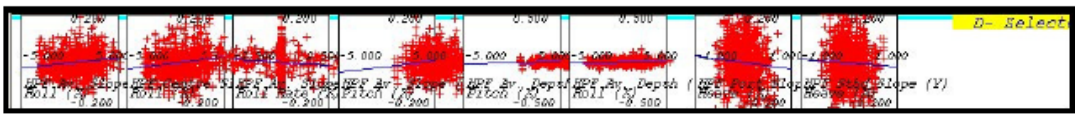
In the scatterplot we can see that the (graph of the) scatterplot has a slope: HPF average Slope correlates with pitch. This means that there is an yaw – misalignment.

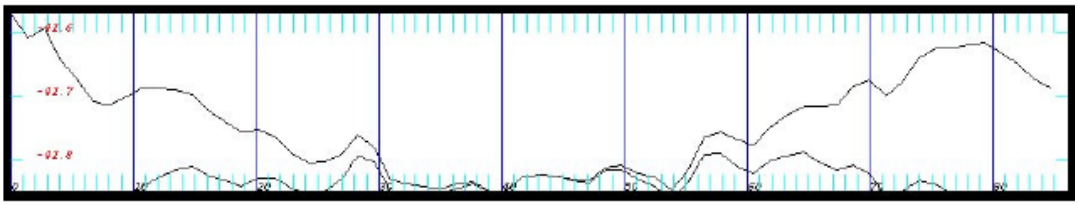
Here are two profiles given of the sailing line; one fives the profile without yaw – misalignment, the other gives a profile with yaw misalignment of 4 degrees. The swaths cross each other in the middle of the swath. This is correct, because at the swath with an yaw – misalignment is the middle of the swath the only point that measures the correct depth. One half is measured to deep, the other half measured to shallow

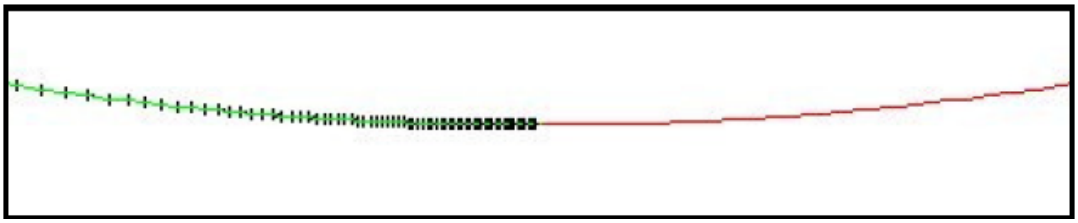
**4.5 Systematic error in Sound Velocity Profile of 10 m/s s**



Auke van der Werf November 2007 auke@omg.unb.ca

In the DTM we introduced an synthetic error of 10 m/s in the sound velocity profile. The effect of this error are artefacts which are not linear and not in phase over the swath (type IV). The outer beams have the biggest errors. We can see this in the DTM; the more the swath comes more to the outer beams, the better we can see the artefacts.

This error becomes visible with changes in picth and a flat seafloor.

With an error in the sound velocity profile the whole bottom can be lowered of lifted. We can see this on the contour lines.

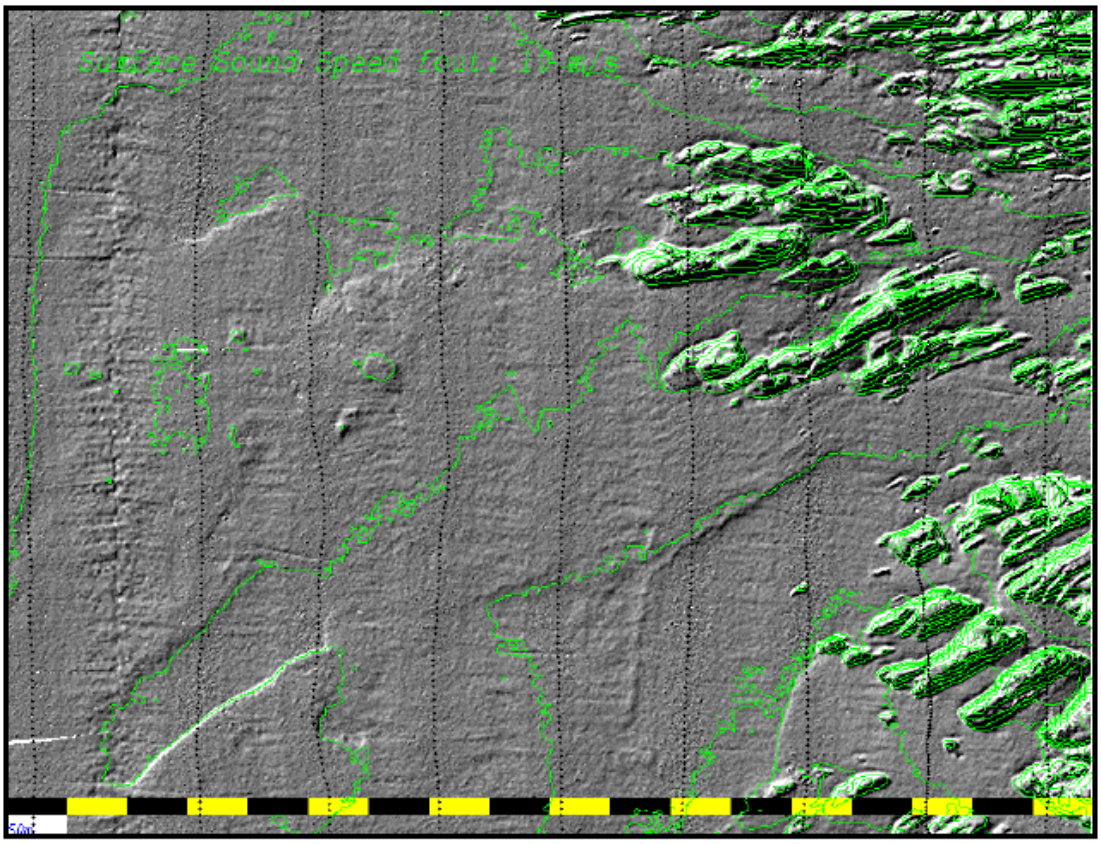
This is an zoomed part of the sailing line. We can see ribbles on the outer sides of the swath.

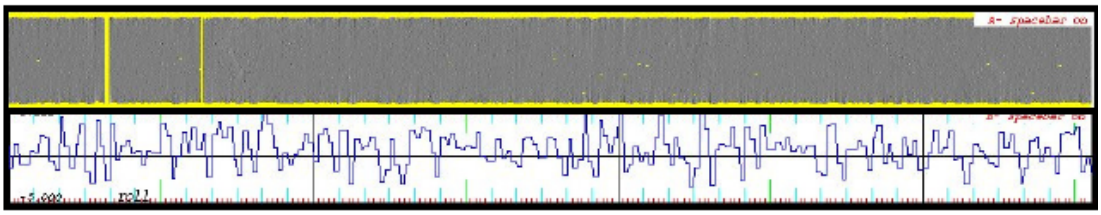
From the scatter plots we cannot see clearly an error; all plots are more ore less horizontal. So it could be an error in the Sound Velocity Profile.

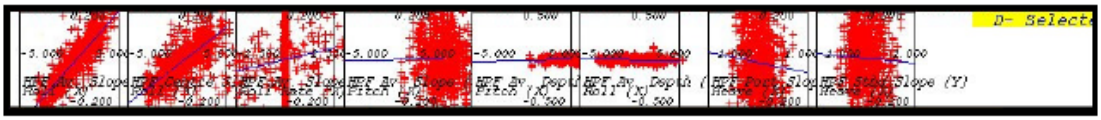
Here are two profiles given; the lower line is the swath without error in SVP, the upper line is an error in SVP of 10 m/s. It is clear that there is quite a big ‘smiley’.

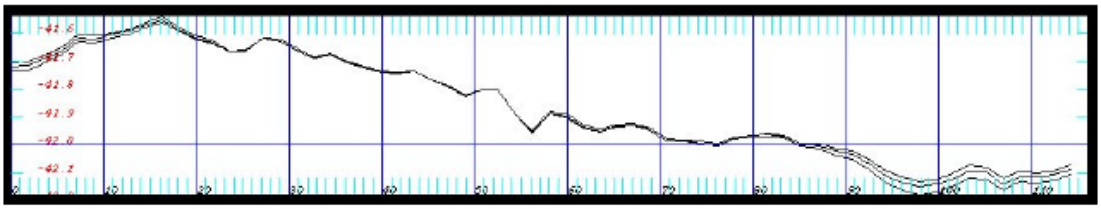
In the refraction tool, when we look at the swath from the front, we can clearly see an smiley. So it could be an error in the SVP. When we try an higher value in the refraction tool, the smiley even gets bigger. When we try an lower value the smiley disappears. This means that the used SVP is too high. We can replay the measurement with an corrected sound velocity profile..

### 4.6 Surface Sound Speed error of 10 m/s


Surface Sound Speed (cut: 1500 m/s







In this DTM we introduced an synthetic error om 10 m/s in the surface sound speed. We can see small ribbles on the outer sides of the swath, which get smaller to the middle of the swath.

This data is measured with an EM3000. The EM3000 is an flat array. This means that all beams are steered. When there is an error in the SSS with an flat array, this should be visible over the whole width of the swath. The error should theoretical be bigger at the outer beams and smaller at the inner beams.

When the next layer in the sound velocity profile was correctly used, we introduce the Don Dinn effect; the error won't bet bigger or even gets minimized.

Here is an DTM given. It is an zoomed part of the sailing line. Under the DTM the roll is given for that moment. In the DTM we can see that the ribbles come to the middle of the swath. Also we can see that there is correlation with the roll.

Here are two profiles given; the lower line is the swath without error in the SSS, the middle line has an error in SSS of 10 m/s and the upper line has an error in SSS of 20 m/s. We can see that the outer beams go up, but the difference is minimal.

The swath in the refraction tool. The swath is quite flat. The conclusion is that an error in SSS has a minimal influence on the swath when there is measured till a depth of 20 meters with an error in SSSS of about 10 m/s.

In the scatterplot we can see that the (graph of the) scatterplot has an slope: HPF average slope an HPF centre slope. Both have correlations with the roll. This means that there is an error in the surface sound speed.