S-102 production possibilities/functionality October 13th, 2017

Author: Geir Gunleiksrud - Kartverket (Norwegian Hydrographic Service)

1. Introduction
   The intention is to look at the possibilities connected with S-102 modelling in an editor application.
   At the same time as we look at the possibilities connected with the modelling algorithms, there is additional information in connection with the classification regime, as well as the data density of the source data, which has been discussed at previous meetings.
   For the review, we have used three declassified data sets from Southern Sunnmøre, that were collected with several years in between and with different echo sounders, and which also represent different depths and bathymetry.
   This review does not mention future changes in either the functionality (multi variable grid) or changes in classification regime. It is based on current functionality and classification.

2. Source data
   2.1 Classification

"There are currently limits on general access to high resolution depth data for coastal sea areas. From the territorial limit and into the Norwegian coast, depth data with a point density of less than 50 metres between the points is defined as classified information under the Security Act. The Norwegian Mapping Authority is therefore not allowed to disclose more detailed data without the approval of the Norwegian Armed Forces. Such data is classified CONFIDENTIAL or higher. The security classification is conferred by the Security Act and applies to all activities within the scope of the Security Act.
The normal procedure is that the Hydrographic Service of the Norwegian Mapping Authority applies to the Norwegian Armed Forces at the Norwegian Joint Headquarters about the release of data on behalf of private legal entities that have a need for such data. The Norwegian Armed Forces have set out guidelines for enquiries about the declassification and disclosure of depth data, which follow the rules on declassification in the Security Act and associated regulations. As a general rule the Norwegian Armed Forces consent to the release if the data is to be used for a societally important purpose or if it is important or essential for business development. This is especially true if the data is limited to a smaller sea area. The Norwegian Armed Forces may set conditions in connection with the consent."
Source: https://www.regjeringen.no/no/dokumenter/prop.-86-l-2014-2015/id2405078/sec5

2.2 Data set

The following three data sets have been used for testing purposes for the report:

Assignment_id:	Hydrograf-4107
Positions:	Terrapos rask
Sounder:	EM 1002
Surveying:	main or secondary fairway
Type of waters:	Norwegian coastal
Collection:	multibeam
Digitalise:	Digitally measured
Approval:	approved navigation
S44_standa:	S-44 1
Area:	68
Start date:	28/11/2007
Finish date:	06/12/2007

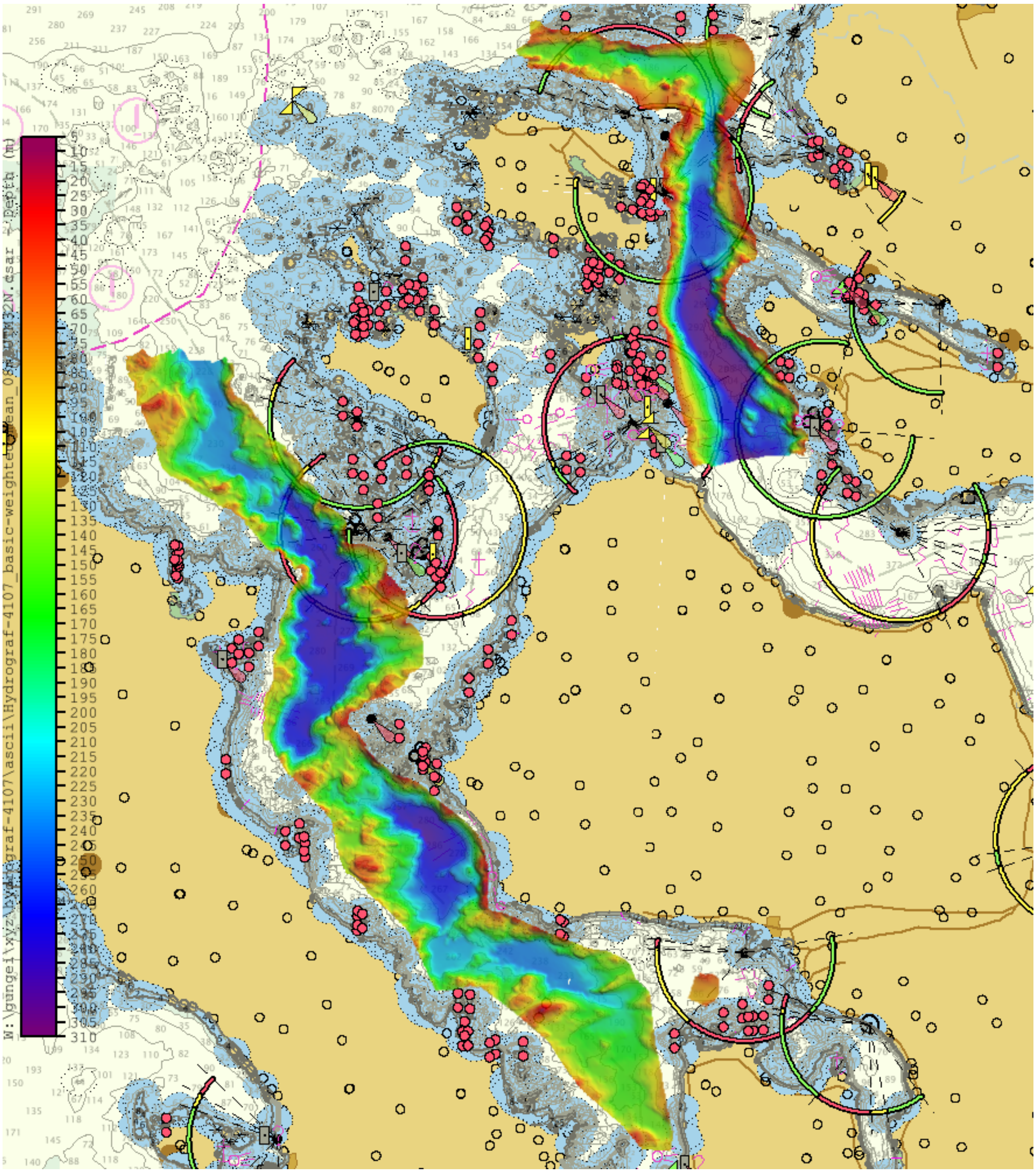

Fig. 1: Hydrograf-4107 8 × 8 metres Scale 1:127000

Assignment_id:	Hydrograf-2012-023
Positions:	Terrapos endelig
Sounder:	EM 3002 Double
Surveying:	general surveying
Type of waters:	Norwegian coastal
Collection:	multibeam
Digitalise:	Digitally measured
Approval:	approved navigation
S44_standard:	undefined
Area:	78

Start date: 18/05/2012
Finish date: 27/05/2013

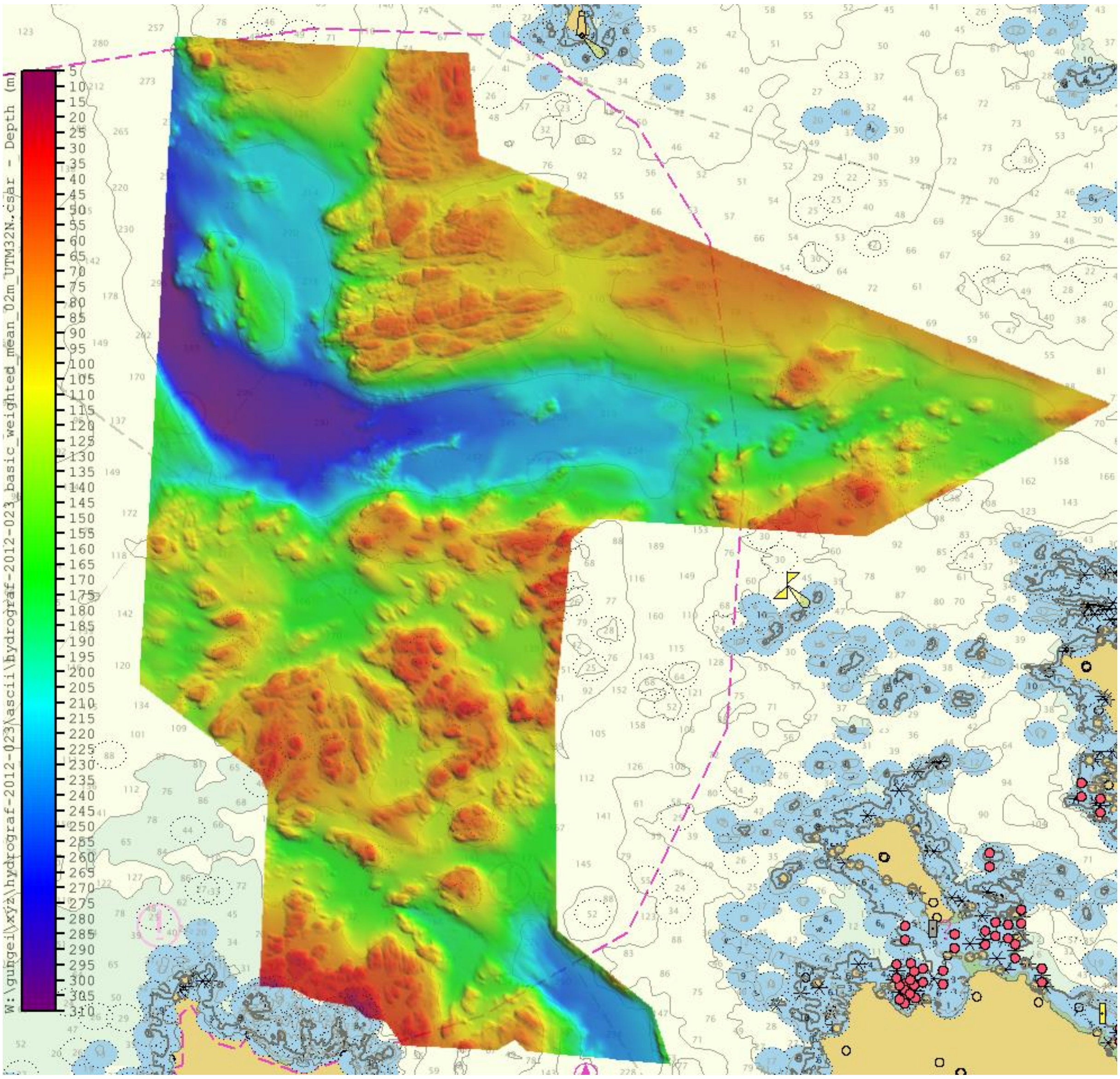

Fig. 2: Hydrographic chart-2012-023 2 × 2 metres Scale 1:54 000

Assignment_id: Hydrograf-0208
Positions: Terrapos quick
Sounder: EM 3002 Double
Surveying: main or secondary fairway
Type of waters: Norwegian coastal
Collection: multibeam
Digitalise: Digitally measured
Approval: approved navigation
S44_standard: S-44-1
Area: 17

Start date: 28/10/2008
Finish date: 27/12/2008

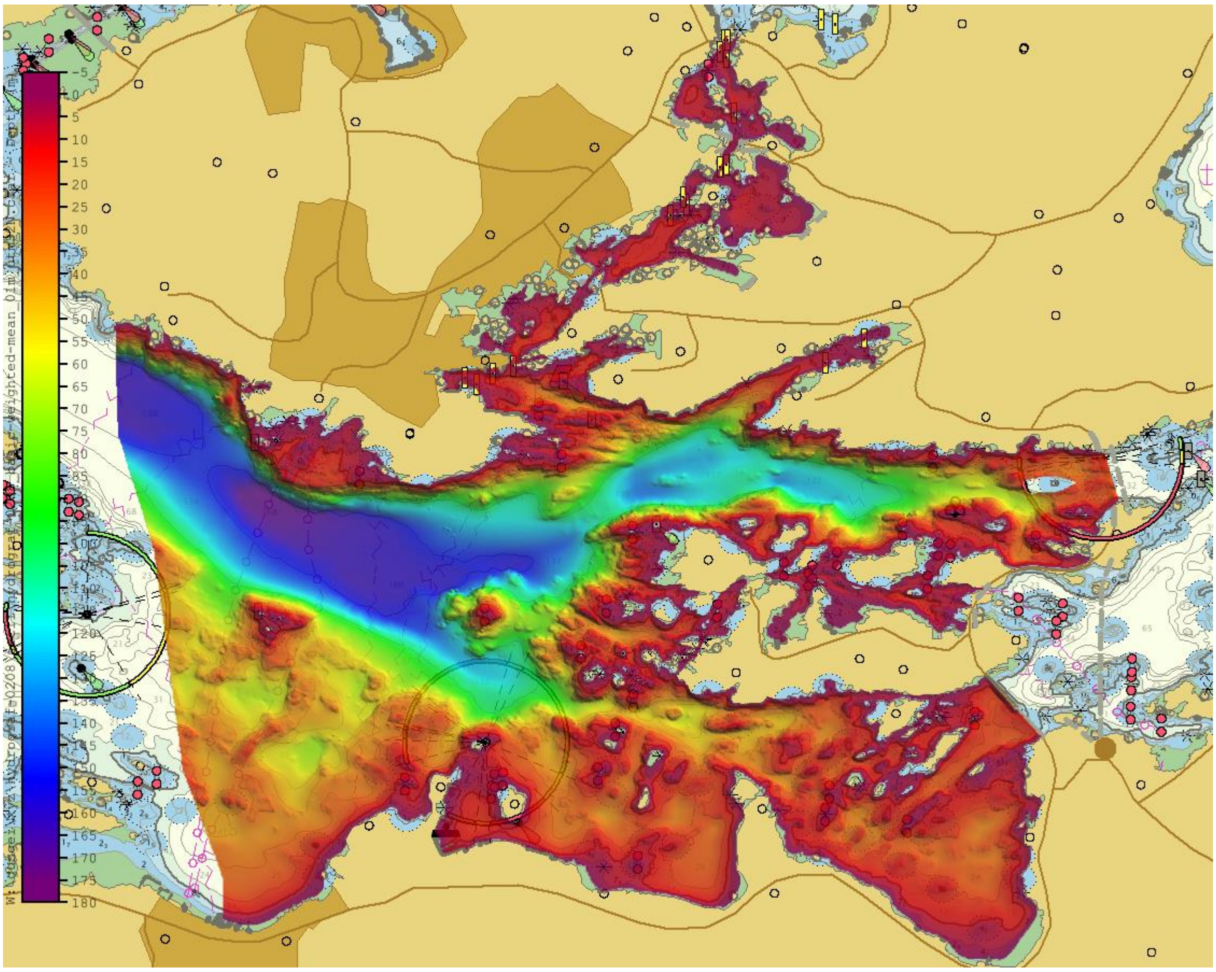

Fig. 3: Hydrograf-0208 *1 × 1 metre* *Scale 1:23 000*

2.3 Format (source data)

```
62.13942625 5.32874250 107.86 3.53 0.41
62.13942695 5.32877540 108.68 3.52 0.41
62.13942985 5.32880640 109.66 3.51 0.41
62.13943280 5.32883920 110.57 3.49 0.42
62.13943615 5.32887530 111.41 3.47 0.42
62.13943945 5.32891160 112.25 3.46 0.43
62.13944235 5.32894290 113.33 3.45 0.43
62.13944550 5.32897750 114.42 3.43 0.43
62.13944940 5.32902000 115.19 3.41 0.44
```

```
62.13945345 5.32906460 115.89 3.39 0.44
62.13945690 5.32910200 116.86 3.37 0.45
```

Table 1

Total horizontal uncertainty (THU)
The component of total propagated uncertainty (TPU) calculated in the horizontal plane.

Total vertical uncertainty (TVU)
The component of total propagated uncertainty (TPU) calculated in the vertical dimension.

Source: IHO Standards for hydrographic Surveys (S-44) 5th Edition February 2008

Source data: total file size

Hydrograf-2012-023	5.76 GB
Hydrograf-4107	476 MB
Hydrograf-0208	36.1 GB

NB! The total amount of data will vary considerably, and on many occasions exceed 100 GB.

2.4 Density

The density varies with depth and collection method (sounder). The density will further affect what resolution we can use when modelling. The purpose of the illustrations below is to show the variations.

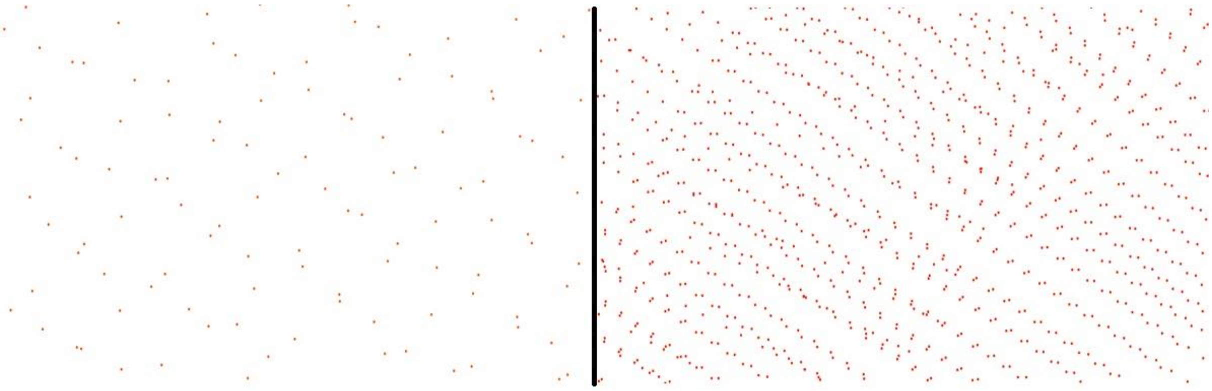

Fig. 4: Illustrates soundings for hydrograf-4107 on the left and hydrograf-2012-023 on the right, both at a depth of around 50 metres. *The density of the soundings determines the resolution we can generate the model in. For this test purpose, hydrographic chart 4107 was modelled to 8 × 8 metres, while hydrographic chart -2012-023 was generated at 2 × 2 metres. Measured depth point/sounding (true position) is the source data for the S-102 models. This is the same data that is used for primary data production in the Norwegian Hydrographic Service. The data is quality approved in line with the developed specifications for the processing of data. The reference level of depth data is sea chart zero, it the same as for other Norwegian Sea charts.*

Scale 1:60

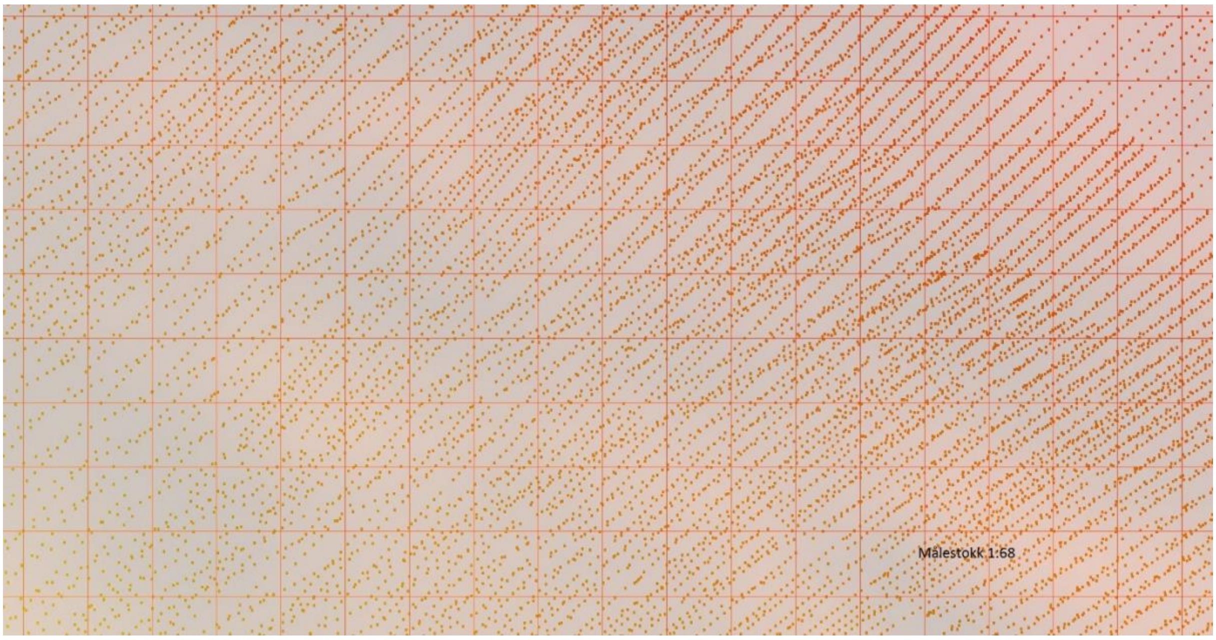

Fig. 5: If we are generating an S-102 terrain model, we first specify a resolution that is in accordance with the source data/soundings. The resolution will vary with the depth and echo sounder used during collection. In the illustration above a 2-metre resolution is specified, and every route in the network is 2 × 2 metres.

3. Modelling

3.1 Algorithms

The following 4 algorithms are possible in the current solution NHS use.

A) Basic Weighted Mean

- «Use the distance from the sounding to node as the weight to compute the mean depth for each node»

Comments

We have so far used this method to generate S102 models, with some exceptions.

Each grid cell in the model is calculated based on an algorithm that weights soundings, and further calculates a mean value. This algorithm renders the bathymetry, which is presented in the best possible manner, as all the soundings will be included in the calculation.

According to the S-102 standard, the "Tracking List" is described as a possibility the organisation that produces the S-102 data has to override the values in the model with manually selected depth points. In order to promote navigation safety it will often make sense to replace the value in the model with the shoalest value. However, this functionality is not yet available in the application.

Also suitable for data sets where the data is more limited.

B) <u>Shoalest Depth</u>

-«Find the shoalest sounding near the node and assign the depth to the node.»

Comments Find the shoalest value in the grid cell and assign the same depth value to the cell. One ensures greater safety for navigation-critical depths. This modelling method is otherwise generated in a different way than other navigation products, and in some cases differences will arise from this.

With this algorithm large amounts of multibeam data are excluded, as the horizontal uncertainty that is brought about by assigning the cell the shoalest value increases with the coarser resolution (Fig. 6).

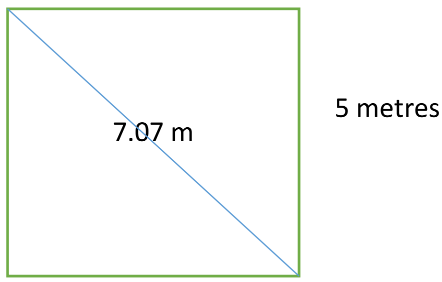

Fig. 6. Displays the horizontal uncertainty within a 5 × 5 meter regular grid cell. The maximum horizontal uncertainty in from the centre of the cell would then be the hypotenuse divided by two, 3.535 m.

Only suitable for data where the source data is sufficient to generate a two-metre resolution model or better. There may be a problem with more empty pixels/cells and more NoData where the data set has a large depth variation (Fig 7).

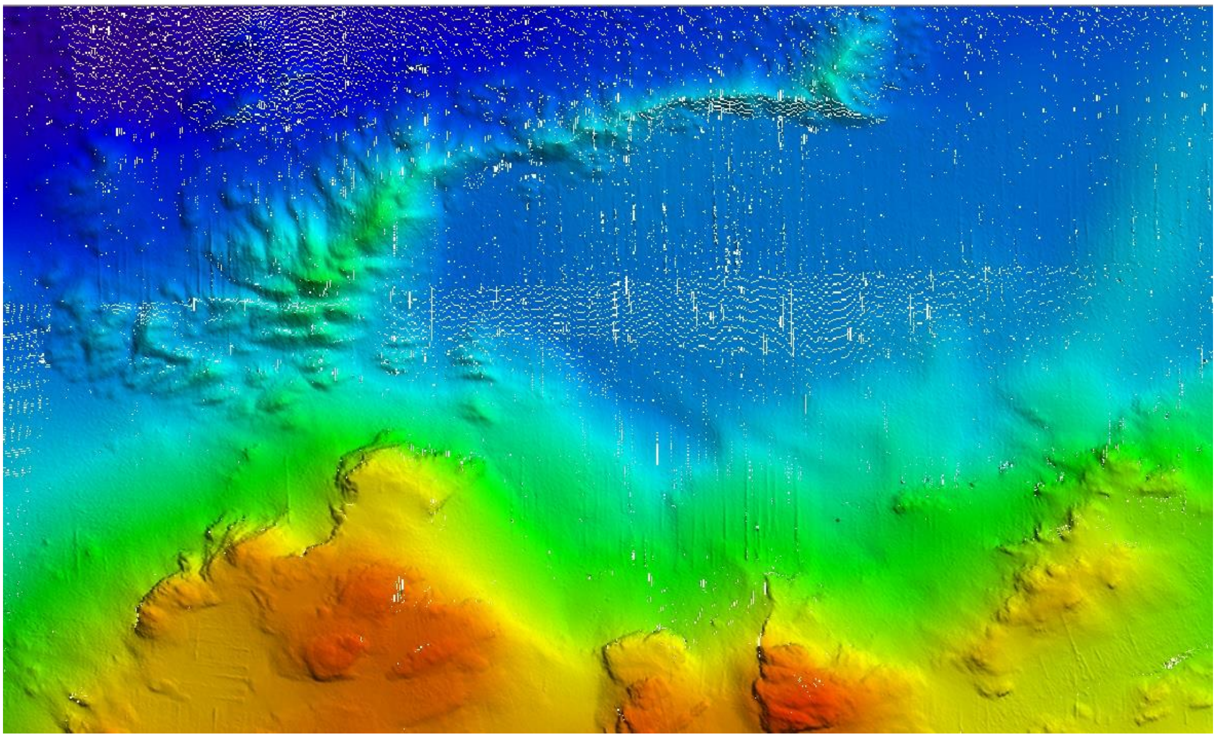

Fig. 7. Shows hydrograf-2012-083 (2 × 2 metres) modelled with the "shoalest depth" algorithm, where grid cells without data occur Fewer soundings are included in the calculation of the cell.

C) <u>Shoalest Depth True Position</u>

-«Find the shoalest sounding near the node and assign the depth to the node. The sounding's original position is recorded."

Comments Same as above with "Shoalest Depth", but the proprietary *. CSAR file saving at the same time "true position" depth value and position. In addition, this information is not included with the Bag/S102 export.

D) <u>TPU Weighted Mean</u>

-«Use The Propagated Uncertainty (TPU) values for the soundings to compute a TPU-weighted mean depth for each node."

Comments Weights the uncertainty information (horizontally (THU)/vertically (TVU)) associated with the node to generate an average depth. Soundings with lower uncertainty will be weighted to a greater extent than soundings with greater uncertainty.

Some data sets do not contain TPU information. Little experience with this form of modelling.

3.2 Uncertainty surface

Essentially 2 possibilities, using either the standard deviation or by using TPU values.

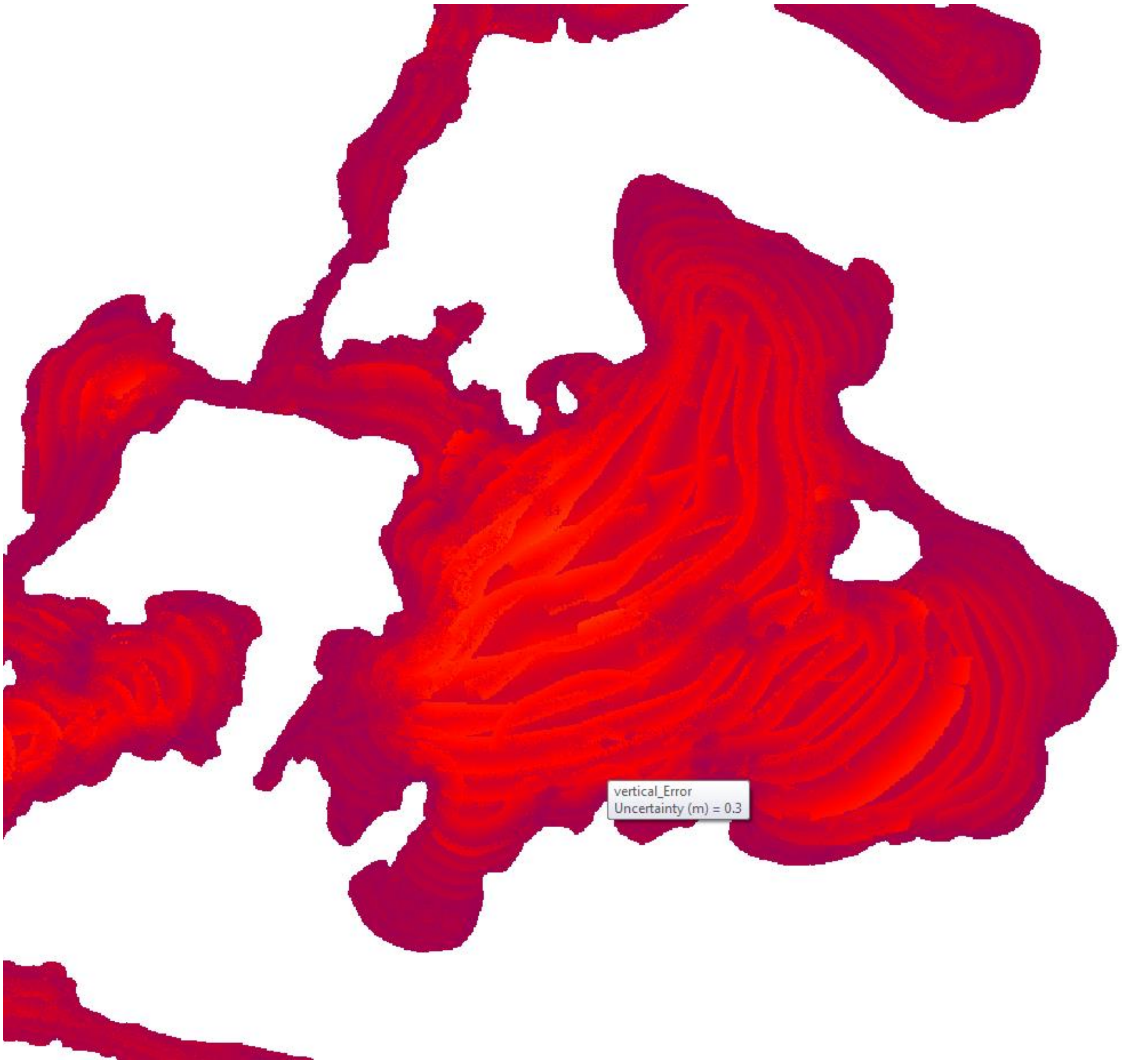

Fig. 8: Shows the uncertainty surface for hydrographic chart-0208 by using TPU information, in this example of Vertical Error.

Fig. 9. Shows the area of uncertainty for hydrographic chart-0208 by using standard deviation. Each cell has an uncertainty value that tells about the spread in the data. Some cells have been observed where Std_Dev = 0. This is quite simply where only one sounding is included, or two soundings with the same depth value.

4. Summary

In previous discussions, the necessity of showing the shoalest depth value within each grid cell has been repeatedly highlighted.

By using the "Shoalest"Depth" / "Shoalest Depth True Position" we will ensure this information. At the same time, it is important to point out that it is limited where we have data sets with this data.

To illustrate the difference between the Basic Weighted Mean and Shoalest Depth algorithms, a difference surface was generated with the models from the hydrographic chart-4108 data set (8 × 8 metres). The deviations are -33.8 meters and + 63.6 metres respectively. Some is due to the steep bathymetry which is further amplified by the horizontal uncertainty from the Shoalest Depth model (Fig. 10)

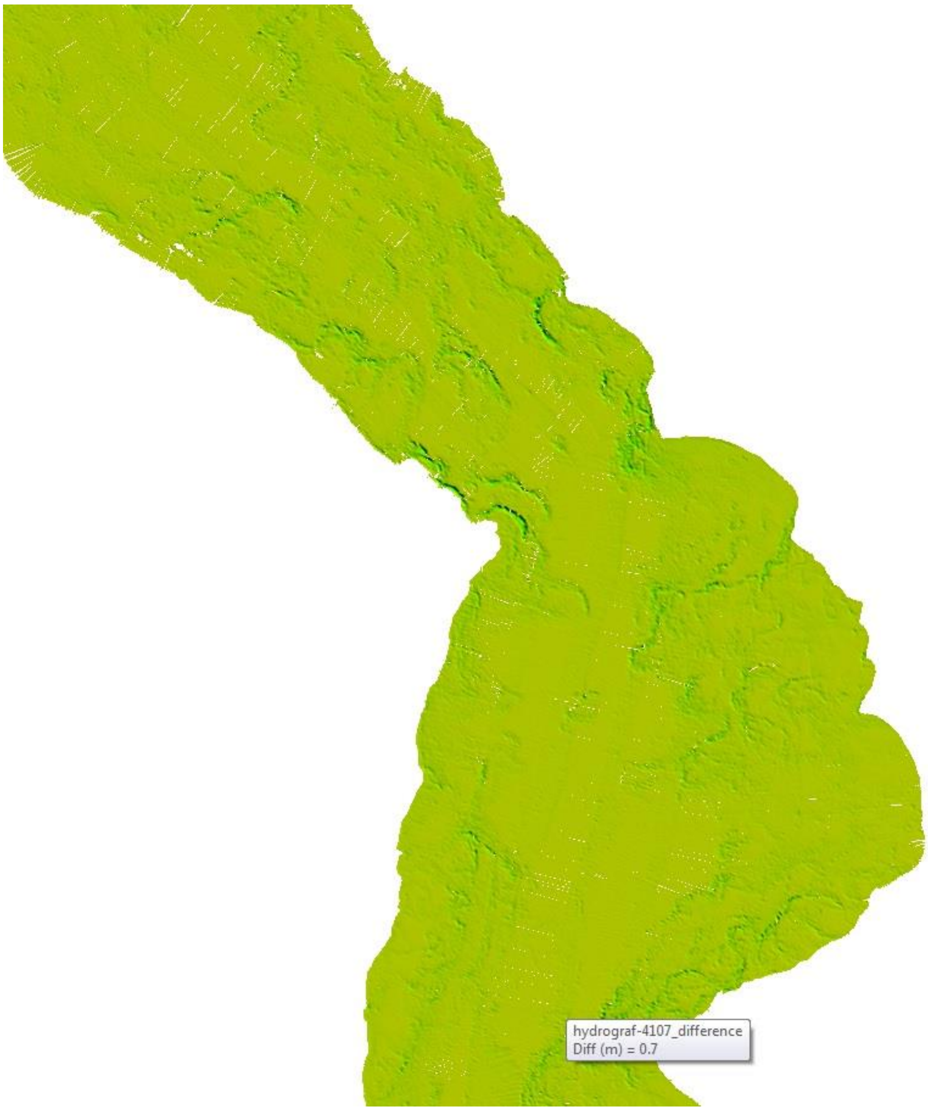

Fig. 10. Differential model that shows the differences between Basic Weighted Mean and Shoalest Depth.

It is also important to highlight how data is processed after completion by the Norwegian Hydrographic Service If data is "re-sampled" and changed from the original coordinate system, a source of errors is introduced, both horizontally and vertically.

What is described above are the main opportunities in our current production software tool with the current functionality.

5. Other Sources:

http://www.kartverket.no/sehavniva/Tidevann-og-vannstand/Viktige-vannstandsniva/