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Interpretation of green laser and aerial photograph data for seabed sediment mapping in shallow areas, Søre Sunnmøre

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Interpretation of green laser and aerial photograph data for seabed sediment mapping in shallow areas, Søre Sunnmøre

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Summary:

This report provides a technical summary of the interpretation of green laser and aerial photograph data for seabed sediment mapping in shallow areas, Søre Sunnmøre. This work was conducted under Work Package 10 of the project "*Pilotprosjekt - Kartlegging av marin natur i Møre og Romsdal"* – a pilot project for mapping marine nature types in Møre og Romsdal. The work builds on two previous projects in the same area which provide the data used here – Marine basemaps Søre Sunnmøre, and the Green Laser Søre Sunnmøre (GLaSS) project.

Green laser (LiDAR) and aerial photography from the GLaSS project were made available by the Norwegian Mapping Authority (Kartverket) in late 2017 and provide seabed data in previously unmapped shallow areas of Søre Sunnmøre. The NGU seabed sediment map (1:20 000) for Søre Sunnmøre has been extended and updated based on these data. The mapping has provided invaluable extended coverage of the sediment map in nearshore areas.

The extended sediment map provides an important basis for further mapping and analysis of nature types according to Nature in Norway (NiN). This follow up work will be initiated through other work packages in the project and reported separately by project partners at the Norwegian Institute for Water Research (NIVA) and the Institute for Marine Research (IMR) who will also investigate the GLaSS data further for mapping specific nature types.

Keywords: Marine geology	Lidar	Green laser
Multibeam echosounder	Aerial photograph	Marine basemaps
Seabed sediments	GLaSS	Natur i Norge (NiN)

CONTENTS

1. NORSK SAMMENDRAG

Den foreliggende rapporten oppsummerer tolkning av grønn laser og flyfotodata for kartlegging av bunnsedimenter i grunne områder på Søre Sunnmøre. Arbeidet er utført i arbeidspakke 10 i prosjektet *Pilotprosjekt - Kartlegging av marin natur i Møre og Romsdal.* Prosjektet bygger på resultatene fra to tidligere prosjekter i samme område – Marine grunnkart Søre Sunnmøre, og Green Laser Søre Sunnmøre (GLaSS).

Grønn laser (LiDAR) og flyfotodata fra GLaSS-prosjektet ble gjort tilgjengelig av Kartverket i slutten av 2017. Dataene dekker grunne områder på Søre Sunnmøre som har ikke vært kartlagt tidligere. NGUs kart over «Bunnsedimenter kornstørrelse» i målestokk 1:20 000 er nå oppdatert og utvidet til å dekke de grunneste områdene helt inntil land basert på disse dataene.

Det utvidede bunnsedimentkartet danner et viktig grunnlag for videre kartlegging og analyse av naturtyper basert på Natur i Norge (NiN). Dette oppfølgingsarbeidet utføres i andre arbeidspakker i prosjektet, og rapporteres i samarbeid med prosjektpartnere fra Norsk Institutt for Vannforskning (NIVA) og Havforskningsinstituttet (HI). HI og NIVA skal også undersøke potensialet for bruk av GLaSS-data til kartlegging av utvalgte naturtyper.

2. INTRODUCTION

This report provides a summary of the work conducted under Work Package 10 of the project "*Pilotprosjekt - Kartlegging av marin natur i Møre og Romsdal"* – a pilot project for mapping marine nature types in Møre og Romsdal. Nature type mapping is according to Nature in Norway, the national standard for classifying and describing environmental and ecological variation at the nature system level (Halvorsen, 2016). This work builds on two previous projects in the same area which provide the data used here. A brief overview of these projects is provided in sections 1.1 and 1.2 below.

2.1 Marine basemaps Søre Sunnmøre (NGU)

In 2016, NGU published a suite of marine basemaps (*marine grunnkart*) from an area of approximately 570 km^2 in Søre Sunnmøre. Marine basemaps (Elvenes et al., in prep) are local-scale thematic maps of various seabed properties, including sediment grain size, anchoring conditions, sediment accumulation areas, diggability, slope and terrain. Maps in the study area are at a scale of 1:20 000, and are based on high-resolution multibeam echosounder (MBES) data previously acquired by the Norwegian Mapping Authority (Karverket) for navigational charting purposes. MBES acquisition took place over a period of seven years, using various vessels and echosounder systems.

The MBES data were processed in-house at NGU to make raster datasets of bathymetry and backscatter (seabed reflectivity) with grid sizes 1x1 or 2x2 m depending on data quality. Based on the information of seabed landforms and relative hardness contained in these datasets, we identified locations to be ground-truthed by video observation or physical sampling of seabed sediment. Fieldwork took place in August 2014 and August 2015, resulting in a total of 219 videos and 90 grab samples. Field observations and MBES data formed the basis of a full-coverage interpretation of seabed surface sediments. The other products in the set of marine base maps were derived directly from this interpretation, or from the MBES data.

Interpreting seabed sediment based on MBES data and field observation has been standard procedure in NGU's production of marine base maps over the last 15 years. This project was funded jointly by NGU, Fylkesmannen i Møre og Romsdal and the municipalities Hareid, Herøy, Sande, Ulstein and Vanylven.

2.2 Green Laser Søre Sunnmøre (GLaSS) project

GLaSS was a test project, conducted by Kartverket in 2017, which acquired green laser data and aerial photography data along coastal areas of Søre Sunnmøre. Green laser data can be an effective method of mapping coastal regions since it is suited to both topographic and bathymetric mapping. Nevertheless, the success of underwater mapping is limited to shallow depths (~5 m) due to attenuation of the laser signal in the water column. The success of bathymetric LiDAR mapping can also be affected by water column properties (turbidity etc.) seabed vegetation and seabed colour.

The data for the GLaSS project were acquired and processed by Terratec AS under contract to Kartverket. An Optech Titan laser sensor was used for the surveys, flown generally below 400 metres, with a field of view of ±15°. This system sends out laser light with 3 wavelengths of which only the 532 nanometres light penetrates the water surface (user data categories 3 and 4 in .laz files are relevant to this wavelength). See Terratec (2017) for further details and https://www.kartverket.no/prosjekter/glass/ for a general overview of the GLaSS project.

The GLaSS data have been evaluated by Kartverket in relation to bathymetric mapping (Kartverket, 2018). Here we evaluate the GLaSS dataset for geological mapping, specifically for the interpretation of surficial sediments.

2.3 Work package 10: Interpretation of data from green laser for extension of marine base maps in the shallowest areas

Work package 10 was led by NGU and feeds into work packages 11 and 12 - biological analysis of green laser data for mapping of marine hard bottom and soft bottom nature types, led by NIVA and IMR respectively.

2.3.1 Description of WP10

Green laser (LiDAR) and RGB-data (aerial photos) from the GLaSS project were made available by Kartverket in late 2017. The GlaSS dataset provides data in previously unmapped shallow areas of Søre Sunnmøre opening up the possibility of extending the existing marine base maps (bathymetry, seabed sediments) towards the coastline in the shallowest areas.

The work includes the following sub-tasks: technical preparation of LAS-data for geological interpretation in a GIS environment; assessment of data quality in different areas (e.g. flat or sloping areas); comparison of GLaSS LiDAR data with GLaSS aerial photograph data plus any existing data. The resulting geological interpretation (sediment grain size map) is based on all available data.

Note that no additional ground truth data were acquired to aid the interpretation. The updated map, however, was completed in June 2018 and served as a basis for field sampling in shallow areas by the Norwegian Institute for Water Research (NIVA) and the Institute of Marine Research (IMR) under other work packages in this project.

Deliveries WP10:

- Extended sediment map that includes the shallowest areas covered by GLaSS data, combined with previously developed maps (see Section 2 and Appendix)
- Short technical report with an evaluation of GLaSS-data (LiDAR/RGB) for geological mapping (this report)

Note that bathymetry data are available directly from Kartverket from https://hoydedata.no/ and do not form part of the delivery from this work package.

2.4 Data preparation

The following data were used to produce the sediment grain size map:

- GLaSS LiDAR data from Hoydedata.no. Data include height, intensity and classified returns (see 1.2.1). Heights are relative to NN2000 – the terrestrial standard for height above sea level https://www.kartverket.no/nn2000. Conversion is required to get these heights relative to chart datum (sjøkartnull) commonly used in marine applications (see section 3.3.1). Both the LAS dataset (points) and raster grids were downloaded from hoydedata.no for evaluation.
- Georeferenced aerial photographs from GLaSS were provided to NGU by Kartverket and
- Ortophotos from https://www.norgeibilder.no/
- Multibeam (bathymetry and backscatter) and grain size information (interpretation and samples) derived from the previous Marine basemaps Søre Sunnmøre project. Note that no ground truth samples are available within the GLaSS data coverage.

2.4.1 Summary of pre-processing applied to LiDAR (LAS) data from hoydedata.no

1. Unzip LAZ files downloaded from hoydedata.no to extract LAS files which can be imported in ArcGIS
2. Create a LAS dataset (ArcCatalog)
3. Import LAS files into the LAS dataset
4. Calculate LAS dataset statistics to get access to LiDAR classes (1: Unclassified, 2: Ground, 7: Low points, 17: Bridge, 25: Stones and rocks, 26: Seabed, 27: Water surface bathy, 29: Marine vegetation, 30: IHO objects, 31: No bottom). Stones represent cobbles and boulders.

These initial steps were performed in order to gain access to the full data provided by Terratec for further evaluation and use in interpretation. The LAS dataset can be easily viewed in ArcGIS and different symbolization settings used to display the elevation, class or return number directly on the point data. Using the LAS Dataset toolbar, it is easy to create an on-the-fly TIN showing the elevation, slope, aspect or contour, however this is generally of poor quality so for further use in our evaluation and geological interpretation it was most practical to convert the LAS data to raster grids at best possible, and lower, more practical resolutions. This was done in the following steps:

5. Create LAS Dataset Layer using class 26 (seabed) to get the seabed depth and not the sea surface.
6. Use ESRI LAS Dataset to Raster tool (Conversion toolbox) on the seabed LAS Dataset Layer to create a depth raster (0.25 m (detail) and 1 m (practical for use when panning and zooming)) from the LAS dataset.
7. Use ESRI LAS Dataset to Raster tool to create an intensity raster (0.25 m and 1 m) from the seabed LAS Dataset Layer.

Figure 1 compares the point data from the LAS dataset with the DTM downloaded from Kartverket via hoydedata.no.

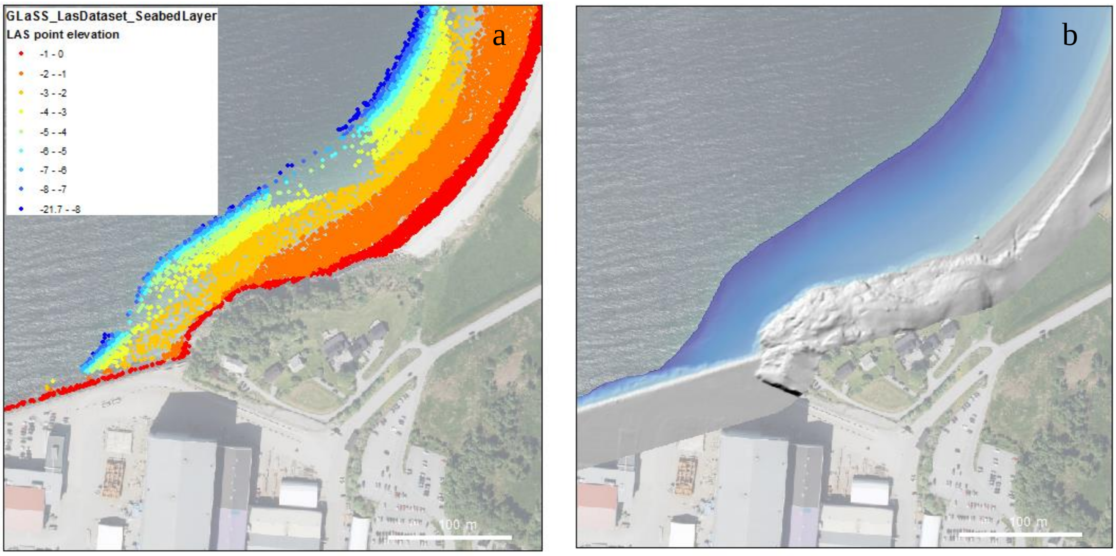

Figure 1. Example from Osnes, Hareidlandet illustrating the various formats of bathymetry data available from the GLaSS dataset (a) points displayed directly from the LAS dataset in ArcGIS – Seabed Layer showing the unequal distribution of points, (b) elevation data (shaded relief of bathymetry data) at 0.25 m raster resolution, as downloaded from hoydedata.no – the bathymetric part of the data are shown as colour shaded relief with the deepest data for this area (c. 6 m) shown in dark blue.

2.4.2 GLaSS raster data from hoydedata.no

The Kartverket raster data is tiled into 1128 individual *.tif* files, each at 25 cm resolution. The DTM was generated from the LiDAR point data (class 26, stones and class 27, seabed) by Kartverket using *Triangulate with Natural Neighbor Interpolation* or *Bin with Average Value* if the former was unsuccessful. The *.tif* files can be conveniently loaded in ArcGIS via the creation of a Mosaic Dataset which allows all the individual *.tif* files to be viewed seamlessly at high resolution and on-the-fly derived products like hillshade generated. Rasters of the entire area were also generated by NGU for the whole area but these large files are heavy to work with at <1 m resolution.

2.5 Evaluation of information content of each dataset for geological mapping

2.5.1 GLaSS depth raster

The GLaSS depth raster is a fine-scale resolution grid (whole dataset gridded at 25 cm) showing the morphology of the littoral zone, mostly to 1-2 m depth. Following comparison of the raster generated by NGU in ArcGIS from the LAS files and the raster produced by Kartverket (0.25 m resolution, available by direct download from hoydedata.no), it was decided to use the Kartverket raster as a basis for geological interpretation since it was of superior quality.

The coverage of the GLaSS bathymetry data is generally good, although considerable NoData areas have been noted by Kartverket (2018) which limit the utility of this technology alone for shallow water coastal mapping (see also section 3.3).

In many areas there is some overlap between the existing multibeam data and the LiDAR bathymetry data, making interpretation seamless between the existing sediment map and information from GLaSS data. Where multibeam data were available these were always prioritized over the LiDAR data since LiDAR data typically include some unreliable returns in deeper waters. Examples are shown in Figures 2 and 3.

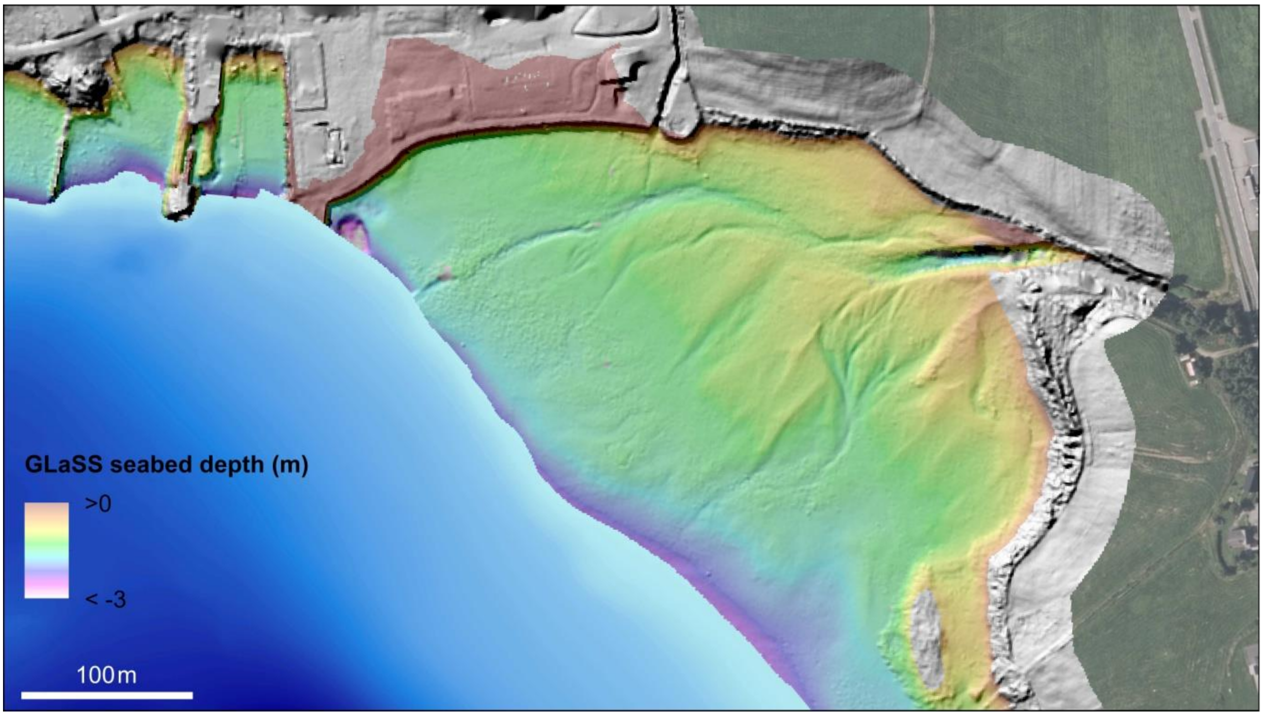

Figure 2. GLaSS LiDAR bathymetry (colour shaded relief) and multibeam bathymetry (blue-scale) showing 100% coverage and overlap between the 2 datasets. The multibeam data are shown on the top of the LiDAR data. Background data: orthophotos from www.norgeibilder.no

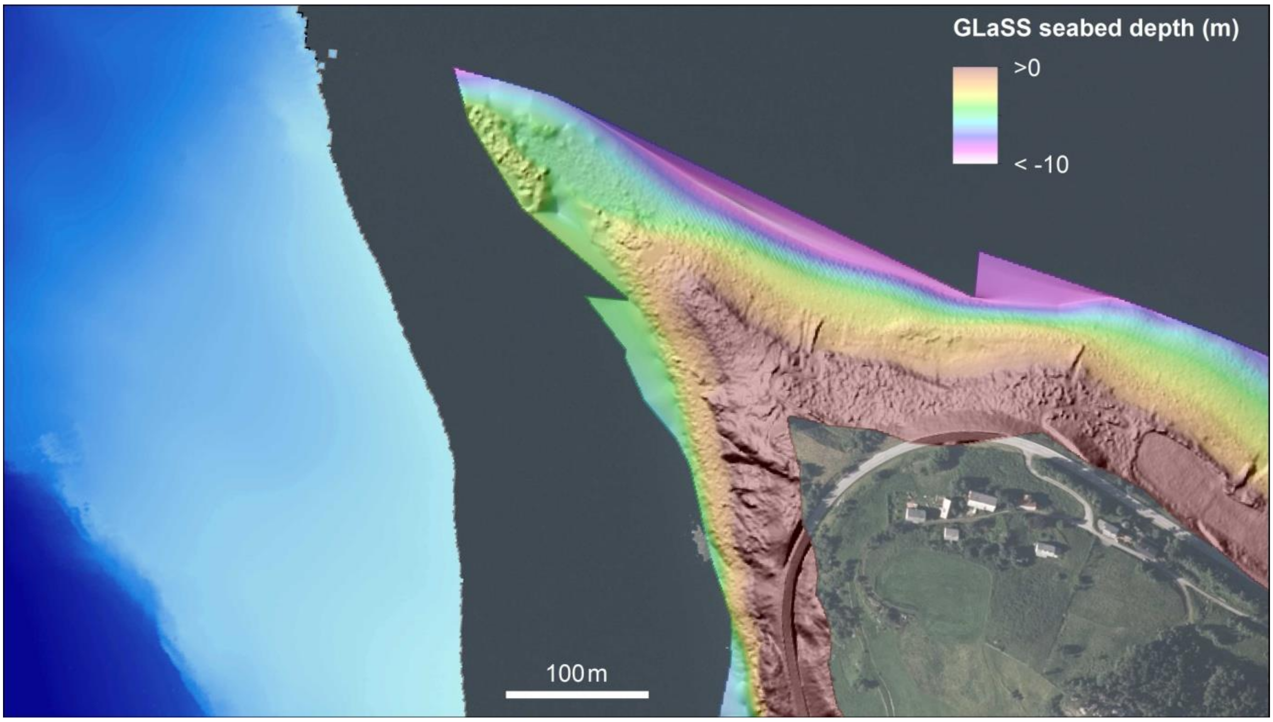

Figure 3. Example of a gap between the GLaSS dataset (colour shaded relief) and multibeam data (blue-scale). Background data: orthophotos from www.norgeibilder.no.

2.5.2 GLaSS intensity raster

The intensity of the LiDAR return signal can potentially give some indication of the ground or seafloor characteristics i.e. hard or soft bottom. Whilst the intensity dataset from the GLaSS LiDAR data may well be of value for terrestrial applications, unfortunately, no processing has been applied to the data to correct the underwater portion of the data for the effects of water depth, incidence angle or other factors that may influence the strength of the return signal. These corrections were, unfortunately, not part of the delivery specifications for the GLaSS project and were therefore not a required delivery from Terratec.

We note that feedback on the need for at least depth-corrected intensity data was included in a report to the Norwegian Environment Agency (Miljødirektoratet) by Moy et al. (2016) evaluating the usefulness of data from Kartverket's earlier LiDAR pilot project TopyBaty 2014 https://www.kartverket.no/Prosjekter/glass/tobobaty-2014/ for nature type mapping. Moy et al.'s (2016) report was circulated to Kartverket in January 2017, however by this time the GLaSS contract with Terratec was already in place. Unfortunately, this meant that the feedback on the need for correction of intensity data was not incorporated in the GLaSS work. Due to the above, neither the Terratec (2017) report or Kartverket (2018) reports contain details about the intensity data, although the intensity data values are included in the .las files according to project specifications.

Variations in LiDAR intensity are observed within the underwater study area and NGU examined these data in detail to ascertain whether the data contained information that may be helpful in determining sediment type. Unfortunately, based on the unprocessed data available there seems to be a weak link between sediment type and LiDAR intensity. The unprocessed intensity data, without corrections for the multitude of factors that can influence the signal (including incidence angle, surface roughness, surface humidity, echo number, distance, water volume, sensor optics or atmospheric influences) cannot be used in the same way as multibeam backscatter to provide a reliable proxy to sediment type.

Figure 4 shows an example of the intensity data together with bathymetry and aerial photograph data. Whilst we observe variations in the intensity raster these do not tally with observations of the seabed from aerial photos, and the intensity values seem to be driven mainly by depth.

In their review of LiDAR radiometric processing, Kashani et al. (2015) noted how most LiDAR systems also record "intensity", loosely defined as the strength of the backscattered echo for each measured point. The authors further state how intensity data have proven beneficial in a wide range of applications because they are related to surface parameters, such as reflectance. The examples cited are mostly terrestrial but include a handful of benthic habitat mapping studies and investigations of hydrodynamic and sedimentological properties. We note that the references cited for these applications are all from conference proceedings, suggesting that results were somewhat preliminary. No follow up articles appear to have been published by the cited authors.

Kashani et al. (2015) further note how intensity data need processing to be used (e.g. angle of incidence and attenuation coefficient). This need is also noted by Webster et al. (2015) who used topo-bathymetric LiDAR for seabed mapping including investigation of eelgrass distribution. Webster et al. (2015) developed an empirical normalization of their intensity data by taking samples of the reflectance over known bottom types across depth ranges. Zavalas et al. (2014) used Hue Saturation Intensity to separate encoding of surface scattering and topographic effects but do not comment on how useful these data were for habitat mapping relative to the rest of the LiDAR information. Both these approaches are beyond the scope of this work package and would require more accurate knowledge of the bottom types from detailed ground truthing than we are able to obtain from our 'pseudo ground truthing' from aerial photographs.

Neither NGU nor Terratec has experience in correction of underwater LiDAR intensity data for the effects of depth/incidence angle at the present time and Terratec has not been successful in obtaining sufficiently detailed information from Optech as to how, or indeed whether, corrections can be made in post-processing based on the data from this sensor. Further confirmation from Terratec indicates that even in 2018, several years on from the aforementioned studies, these types of corrections are still an emerging science. Intensity signals are specific to each sensor system. It is possible that empirical corrections can be made, based on a comparison of data within the overlap zone with data from different lines. Depending on the success of empirical methods, additional field sensors and/or ground truthing may be required to calibrate the corrections. Under a project for Kartverket, Terratec has recently evaluated incorporating range corrected, calibrated reflectance values for intensity within the point cloud dataset for the National Elevation Model (NDH) (Aarstad, 2018) instead of the standard amplitude values delivered today. Although the report focusses on terrestrial data, it is interesting to note the conclusion that there are many benefits to this alternative approach and adoption is recommended. It is likely that different sensors which directly report reflectance should be favoured since the process of converting amplitude data from the Titan sensor used for GLaSS to reflectance is a complex process involving calibration of the light intensity at the sensor, distance as well as computation of absorption in both air and water and spreading of the laser pulse in water. Although some tests have been reported (e.g. Liu et al., 2011) Terratec is not currently aware of any commercial solutions which offer ready to go solutions for delivering reflectance from the seabed.

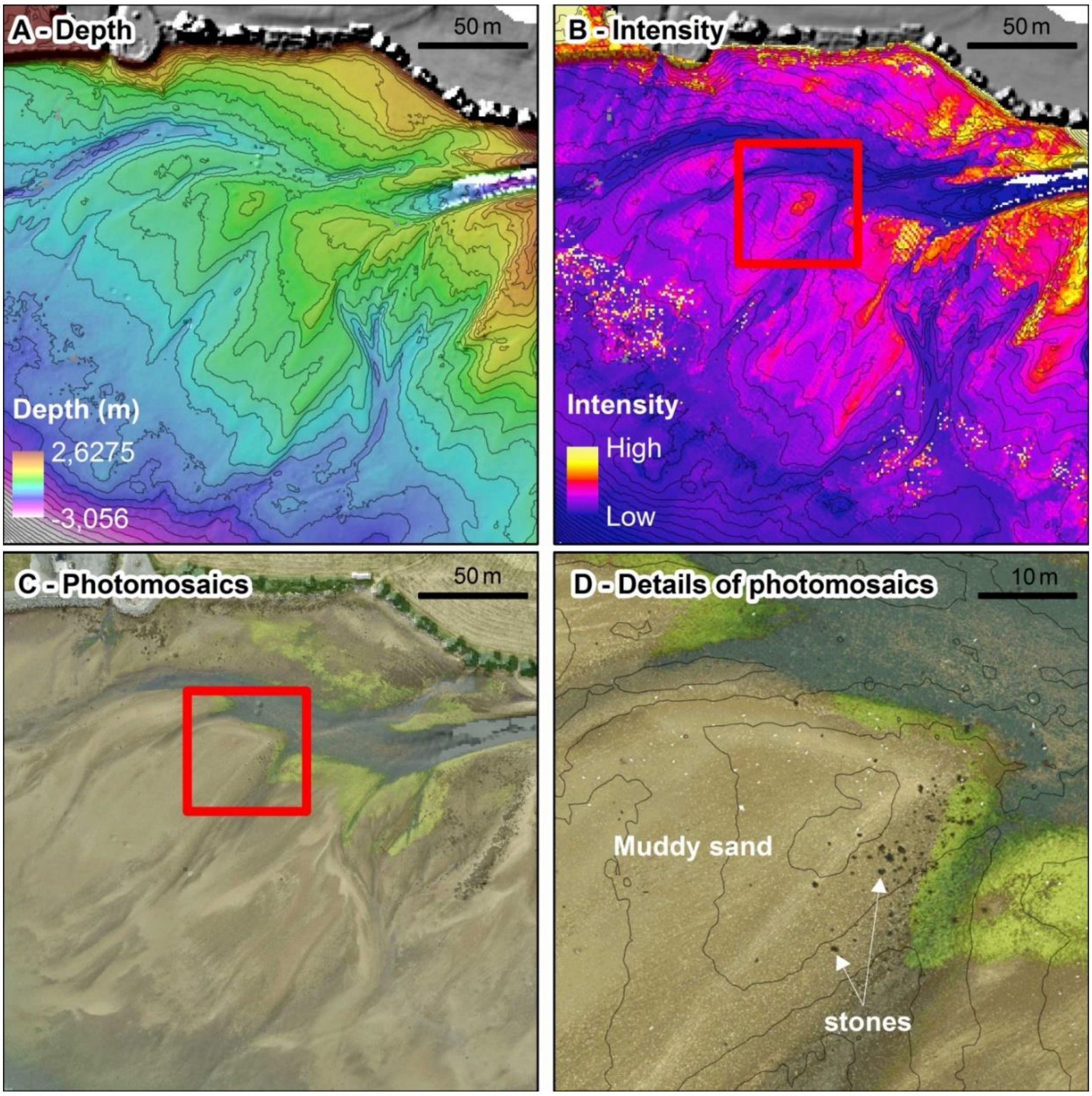

Figure 4. Example showing how the intensity values appear to be mostly driven by depth and follow the contours with higher values occurring in shallower areas, not linked to sediment type. (a) GLaSS LiDAR bathymetry, (b) GLaSS LiDAR (unprocessed) intensity data and (c, d) GLaSS aerial photos. Ten-centimetre depth contours are shown to aid interpretation. The red square indicates the area covered by the zoomed aerial photograph image in (d). Note how high intensity values in the red square correspond to a shallower area and do not show harder sediments (e.g. stones) in the photomosaic detail (d). In fact, stones are observed in aerial photograph data (d) on the east side of the shallow area but do not correspond to higher values in intensity data.

Terratec also have a number of related projects ongoing which may allow them to investigate the potential for intensity correction in more detail for application to future projects including underwater applications. From work to date it appears that combining intensity data with hyperspectral imagery may offer the best alternative and this can offer benefits both for retrieval of bathymetry (Ma et al., 2014) and geologically relevant information. The use of hyperspectral imagery for geological characterisation of seabed types is still an emerging science (Aarestad, 2014; Dolan et al., 2016) but the use of such systems for underwater (e.g.

Dumke et al., 2018) and coastal applications (e.g. Manzo et al., 2015; Pan et al., 2015) is increasing. Terratec has recently gained some experience with these systems which were reported at a GLaSS follow up workshop at Kartverket in January 2018. A new deep-water Laser from Optech offers a function for reflectance through combination with hyperspectral data which may be a promising option. Terratec has scheduled trials of this system in October 2018.

Following this initial review of the intensity data we concluded that we were not able to extract any reliable and useful information from this dataset to aid in geological interpretation. Had the data been corrected for depth and incidence angle it seems likely there is potentially useful information in this dataset. For the purposes of sediment map production, the GLaSS LiDAR intensity data were therefore disregarded, and the GLaSS LiDAR bathymetry and aerial photograph data were used further for sediment interpretation.

2.5.3 GLaSS aerial photos (photomosaics)

Aerial photography data from GLaSS, also referred to as RGB data, were supplied as a georeferenced photomosaic by Kartverket. This dataset was GIS-ready and provided visual imagery of the seabed in clear, shallow waters and was very useful for estimation of the bottom type, either directly or by serving as ground-truthing of the bathymetry data. The high resolution (10 cm resolution) allowed us to see the presence/absence of cobbles and boulders. It may be possible to resolve coarse gravel using the original aerial photograph (2.5 - 4.5 cm) data rather than the photomosaics (10 cm) but these data were not used in the present study (see section 4.2). Sandy and muddy areas were also observed, although the relative proportion of mud and sand (i.e. the difference between areas that should be classified as muddy sand or sandy mud etc.) are difficult to determine visually.

2.5.4 Orthophoto

Orthophotos from norgeibilder.no were used as a backup information when the GLaSS aerial photographs and/or the GLaSS depth raster were missing or uninterpretable. As with the aerial photographs, this visual dataset gives a good estimation of the bottom type, (Figure 5) although the imagery is typically of poorer quality than the GLaSS data.

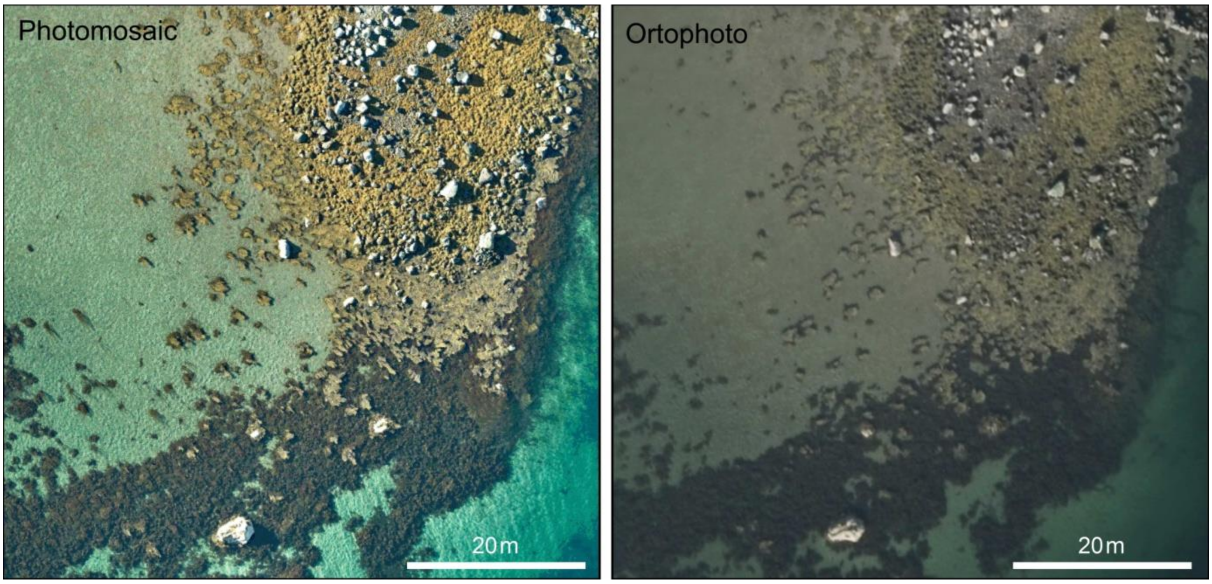

Figure 5. Comparison between GLaSS aerial photo and orthophotos from https://www.norgeibilder.no/. In this example, sand and stones are clearly observed in both datasets although the lighting is better in the GLaSS image.

Combination of bathymetric and visual datasets also seem to provide a very useful view of the seabed, through the use of semi-transparent overlay in GIS. Some examples are shown in Figure 6, illustrating how the bathymetry gives morphological context to the aerial photos.

2.5.5 Existing multibeam and ground-truth data

The multibeam data that was used in the production of the existing sediment map was consulted in all areas but were particularly useful where the data overlapped or came within a short distance of the GLaSS dataset. The video data and sample data that served as ground-truth data for the original sediment map were also available for consultation. However, since most samples/videos were generally far away from the GLaSS data coverage the interpreted sediment map, which is based on both multibeam data and samples/video, was the most useful reference.

Figure 6. Examples of transparency applied to GLaSS aerial photographs overlain on GLaSS LiDAR and multibeam shaded relief allowing bottom types visible in the photographs to be related to topographic variations. This makes it easier to delimit areas with similar properties.

3. SEDIMENT MAP PRODUCTION

3.1 Geological Interpretation

Once all the data were integrated into GIS the geological interpretation generally followed the following workflow. The interpretation of the GLaSS data was done by NGU geologist Valérie Bellec in conjunction with NGU geologist Sigrid Elvenes. Elvenes conducted fieldwork and was responsible for interpretation and production of the existing sediment map for Søre Sunnmøre (multibeam area).

Table 1. Summary of the workflow for geological interpretation

Step	Geologist responsible	Task
1	Bellec	Zoom to an area at approximately 1:1000. Note that it was necessary to zoom in further than would normally be done when digitizing to map at this scale (approx. 1:20 000). This was because of the need to check the sediment types on the aerial photos. Digitizing rules were employed to ensure that interpretation was not overly detailed in the resulting map (see below).
2	Bellec	Examine existing sediment interpretation in nearby areas (multibeam area).
3	Bellec	Determine the sediment type based on GLaSS aerial photograph data (and/or the orthophotos as applicable).
4	Bellec	Check this interpretation against the GLaSS elevation data (depth). Transparency was applied to the aerial photograph data which was overlain on GLaSS and/or multibeam datasets as shown in Figure 6.
5	Bellec	Polygons of different sediment types digitized following digitizing rules outlined below.
6	Bellec	Move to the next area and repeat 1-5. Repeat until entire mapping area is complete.
7	Elvenes, Bellec	Joint review and quality control of the interpretation for the whole GLaSS area.

Digitizing ruleset

- Map scale – approximately 1:20 000 – as for the published map for the multibeam area. A distance of 50 m between polygon nodes was used to maintain consistency with the previous interpretation. However, a few more complicated areas may have a shorter node spacing where it was not applicable to generalize. The digitizing scale was influenced by the resolution of the aerial photos used as ground-truthing, and often was higher than 1:1000. Nevertheless, only objects larger than 50 m were digitized in order to maintain consistency with the published map and avoid overly detailed interpretation.

- A maximum gap between MBES and GLaSS data of 50 m was interpreted. Where a gap in MBES/GLaSS data coverage exceeded 50 m no interpretation was made, resulting in a gap in the sediment map between the GLaSS and multibeam datasets. This approach avoids interpretation in areas with no data, and makes clear which areas lack data.
- Landward limit. Zero metre contour from the GLaSS dataset (i.e. 0 m NN2000 = 1.25 m above sjøkartnull). Note that this boundary was used as a guide – the digitizing rules mean that the contour will be crossed in some places. Most of the lines are between 0 and +1 m contours.

In addition to the sediment map, we added attributes to the Terratec coverage polygon to include an assessment of which dataset was the most useful in each area. This information provides a convenient overview of to what extent the various components of the GLaSS dataset were important in geological interpretation across the study area.

3.2 Database integration

Digitizing of geological interpretation was carried on in the versioned SDE-database at NGU using ESRI ArcGIS software v10.5.

Figure 7. (a) Newly interpreted areas (green boundaries) adjacent to polygons from earlier mapping. (b) Old polygons (with no boundaries) reinterpreted. (c) Old interpretations adjusted after new coastline.

There were three main results from the process of interpreting GlaSS data (Figure 7):

1. New seabed sediment maps based on GlaSS LiDAR and GLaSS aerial photographs in shallow water inshore from the previously published maps from the Marine basemaps Søre Sunnmøre project and to the zero contour (NN2000).
2. Reinterpretation of seabed sediment map from Marine basemaps project, in the areas where GlaSS LiDAR data overlapped with multibeam data and together with GLaSS aerial photographs facilitated more detailed and accurate interpretations.

3. Corrections of interpretation boundaries toward land in places where man-made constructions and landfills (e.g. harbours) had changed the coastline since 2015.

The final interpretations are located in the NGU marine geology database in the dataset for detailed data (M >1:50 000) together with other geological interpretations in similar scale. The resulting grain size map looks visually seamless, but in order to preserve the provenance of data (GLaSS/multibeam) the new and re-interpreted polygons were not merged with the previous interpretations. Based on specific date these can easily be queried and found in the database. The decision to keeping GLaSS data separate from earlier data was made in cooperation with project partners at NIVA and IMR, on the basis that merging would result in loss of important origin and quality information, whilst keeping the polygons separate would not cause any problems for modelling (which commonly uses a raster version of the data). Separated polygons will keep open the possibility for special products and deliveries should these be required at some point in the future.

The boundaries (a separate line feature class accompanying the polygons), which carry the quality information and other metadata about the interpretation, were given a set of specific values in the attribute table, that distinguish GlaSS data from other sediment interpretations.

3.3 Delivery and dissemination

Detailed grain size data, including the new interpretations from the GlaSS project, can be accessed and used in various ways, depending on the purpose of the end user.

- Visit web-sites with interactive maps that publish grain size data from NGU.
  ngu.no (GEOLOGY IN MY MUNICIPALITY/GEOLOGIEN I MIN KOMMUNE)
  mareano.no (Maps/Miscellaneous/Marine base maps)
- Integrate one of the Web Map Services (WMS) that publishes grain size data into your GIS- project.
  MarinBunnsedimenterWMS
  http://geo.ngu.no/mapserver/MarinBunnsedimenterWMS?LANGUAGE=ENG&
    - (Layer: Grain size, Detailed)

  MarineGrunnkartWMS
  http://geo.ngu.no/mapserver/MarineGrunnkartWMS?LANGUAGE=ENG&
    - (Layer: Grain size, Detailed)
- Download grain size data through NGUs download application, where you can choose the dataset, data format and coordinate system.
  http://www.ngu.no/en/topic/datasets (SEABED SEDIMENTS (GRAIN SIZE), N25 DETAILED)

For more detailed information, guidance and recommendations for use of different options, see the user manual for marine basemaps (Appendix 1). The product specification for detailed grain size maps (including but not limited to Søre Sunnmøre) is available at

http://www.ngu.no/upload/Kartkatalog/Produktspesifikasjon_Marin_SedimentKornstorrelse.pdf
and the accompanying product sheet is available at
http://www.ngu.no/upload/Kartkatalog/Produktark_Marin_SedimentKornstorrelse_Det.pdf

4. SEDIMENT MAPPING RESULTS SUMMARY

This section provides an overview of the updated sediment map for Søre Sunnmøre with some examples. Figure 8 shows the areas covered by the updated map indicating where the GLaSS data have been used to extend the original coverage.

4.1 Data coverage and relative usefulness of the GLaSS sub-datasets

The total area of the newly interpreted GLaSS data (red polygons shown in Figure 8) is 21 km^2. Whilst this is not a huge increase in the overall area mapped, new information is provided along the entire coast of Søre Sunnmøre within the GLaSS project area, providing valuable new geological data in nearshore areas.

The relative usefulness of the various GLaSS sub-datasets (bathymetry, aerial photos or orthophoto (not GLaSS) for geological mapping is shown in Figures 9 and 10 which show the ranking of each sub-dataset by Terratec data coverage polygon. Note also that the previously available interpretation from multibeam was crucially important, especially to determine which kind of soft sediments (from mud to sand) the photomosaics/orthophotos show. Interpretation of GLaSS data without this background information and knowledge of the area would have been far more difficult, most likely resulting in fewer, more generalized seabed sediment types being mapped.

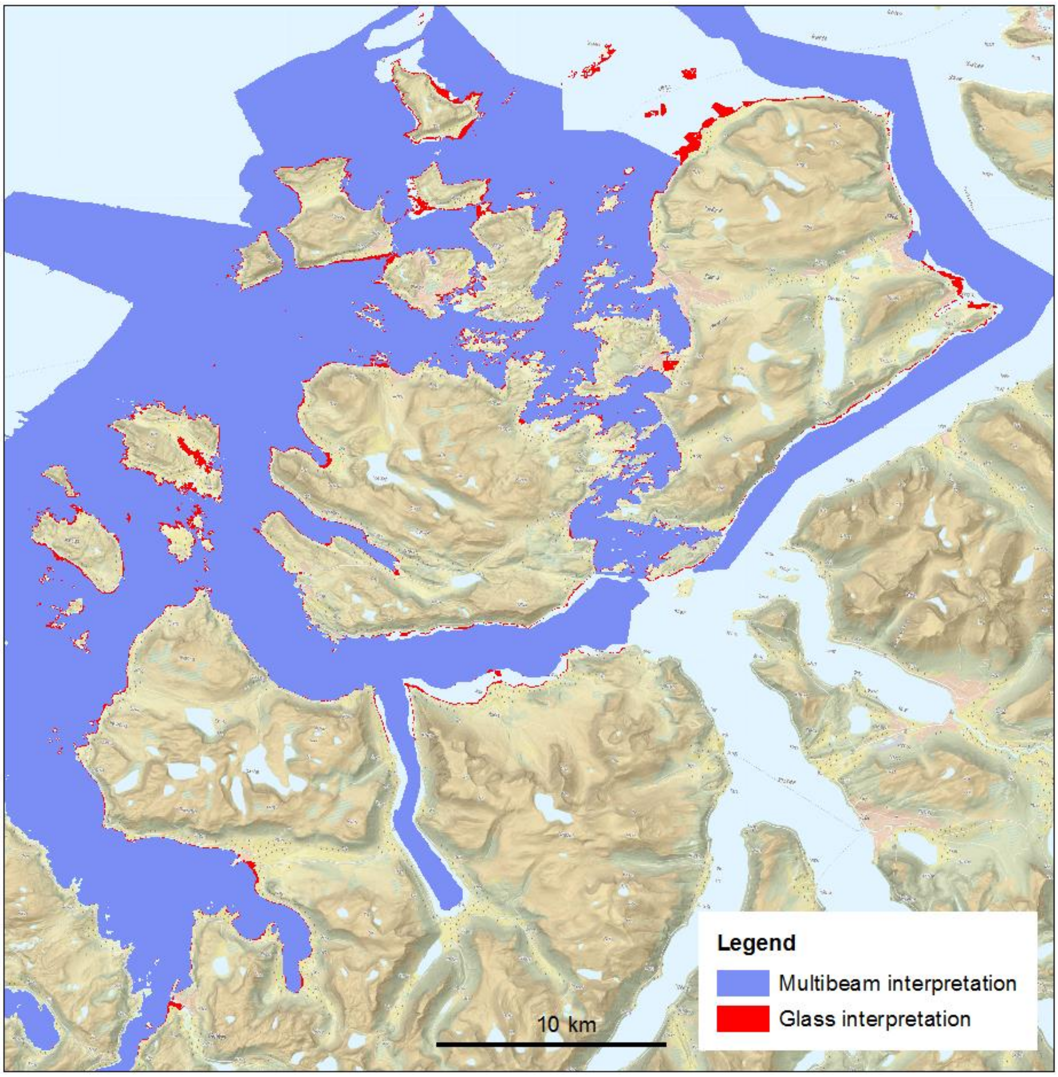

Figure 8. Multibeam (in blue) and GlaSS (in red) interpretations of the studied area. Background data from Kartverket (WTMS).

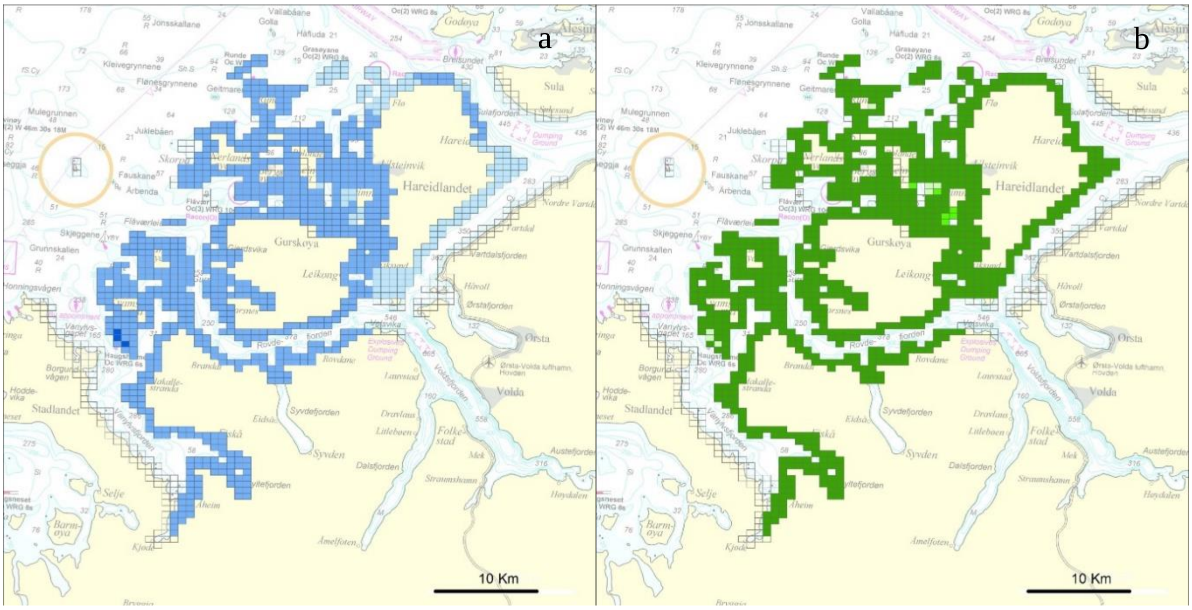

Figure 9. Ranking of (a) GLaSS bathymetry data – 1 = dark blue (most useful), 2 = mid-blue (useful supporting information), 3 = light blue (not useful) (b) GLaSS aerial photograph data 1= dark green (most useful), 2=bright green (useful supporting information), 3 = light green (not useful).

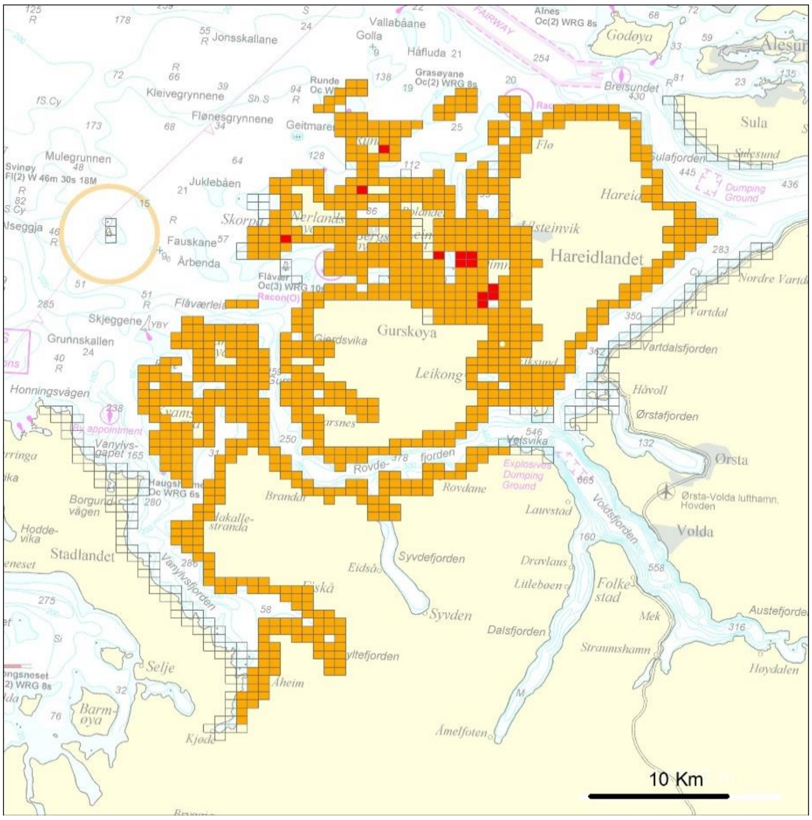

Figure 10. Overall relative usefulness of GLaSS data (bathy and photo). Orange areas show where GLaSS bathy or aerial photo were ranked 1 (most useful) or 2 (useful). Red areas indicate where the GLaSS data were only used as secondary information – orthophoto gave the best information (ranked 1).

4.2 Evaluation of GLaSS aerial photographs for sediment mapping

Aerial photographs are available for the entire GLaSS project area. The quality of these is generally good although in some areas the images are too dark, hence the need to use orthophotos. The resolution of the aerial imagery far exceeds that of the bathymetry data. Where the seabed is visible through the water, and/or in the littoral zone these detailed imagery from these data are very useful for interpreting sediment type. An example is shown in Figure 11 highlighting the different sediment types visible in the imagery. We can also see from Figure 11 that the light level varies between images, so the colour is not consistent across the entire dataset (see also section 3.2.1). So long as the images are not too dark, this does not greatly impact manual interpretation of the images but would likely prove challenging for more automated interpretation of the data. As might be expected, aerial imagery is most valuable in areas where the seabed slopes more gradually from the shore. In areas where there is a sharp drop off in depth, there is less useful information available as the seabed is obscured by water.

Note that the aerial photography data in the GLaSS project formed part of the required delivery but was not fully specified in the tender documents. It was later agreed between Kartverket and Terratec that the data be combined to a 10 cm image mosaic, without significant colour balancing, which would be suitable for use as a background dataset. The original georeferenced images have higher resolution (2.5 - 4.5 cm) and with sufficient effort in suitable GIS/images processing software these images could potentially be better balanced in terms of colour and brightness. This additional processing was beyond the scope of this work package and our analysis was limited to use of the 10 cm image mosaic which is generally sufficient for sediment interpretation at the relevant map scales.

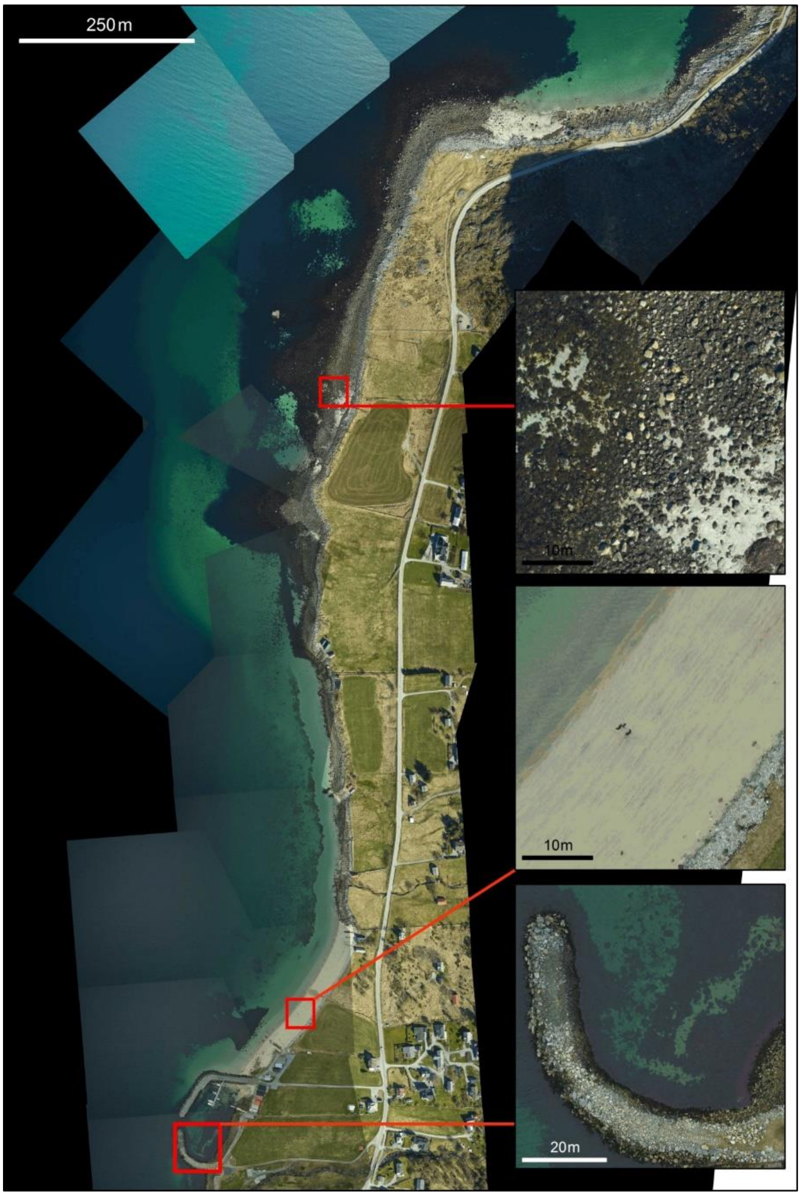

Figure 11. Example of several aerial photographs showing contrasting sediments types. Details can be seen in the zoomed in images on the right: Top: mixed sediments (sand, gravel and stones) – it is often possible to see the extension of the same bottom type underwater; middle: sand; bottom: gravelly sand (lighter areas) and mixed sediments (sand, gravel and stones) around a man-made construction.

4.2.1 Challenges related to the use of GLaSS aerial photo mosaic

Whilst the GLaSS aerial photograph data were of tremendous value for geological interpretation, in some areas the quality of these images was insufficient or inconsistent, making interpretation more challenging. Figure 12 shows an example of images taken along several flight lines where there is a strong variation in image brightness. This is most likely a result of different flying height and/or weather conditions at the time of acquisition. In some areas, aerial photograph data are totally absent. Note that our comments refer to the image mosaic and that further enhancement of the image data may be possible through use of the original images.

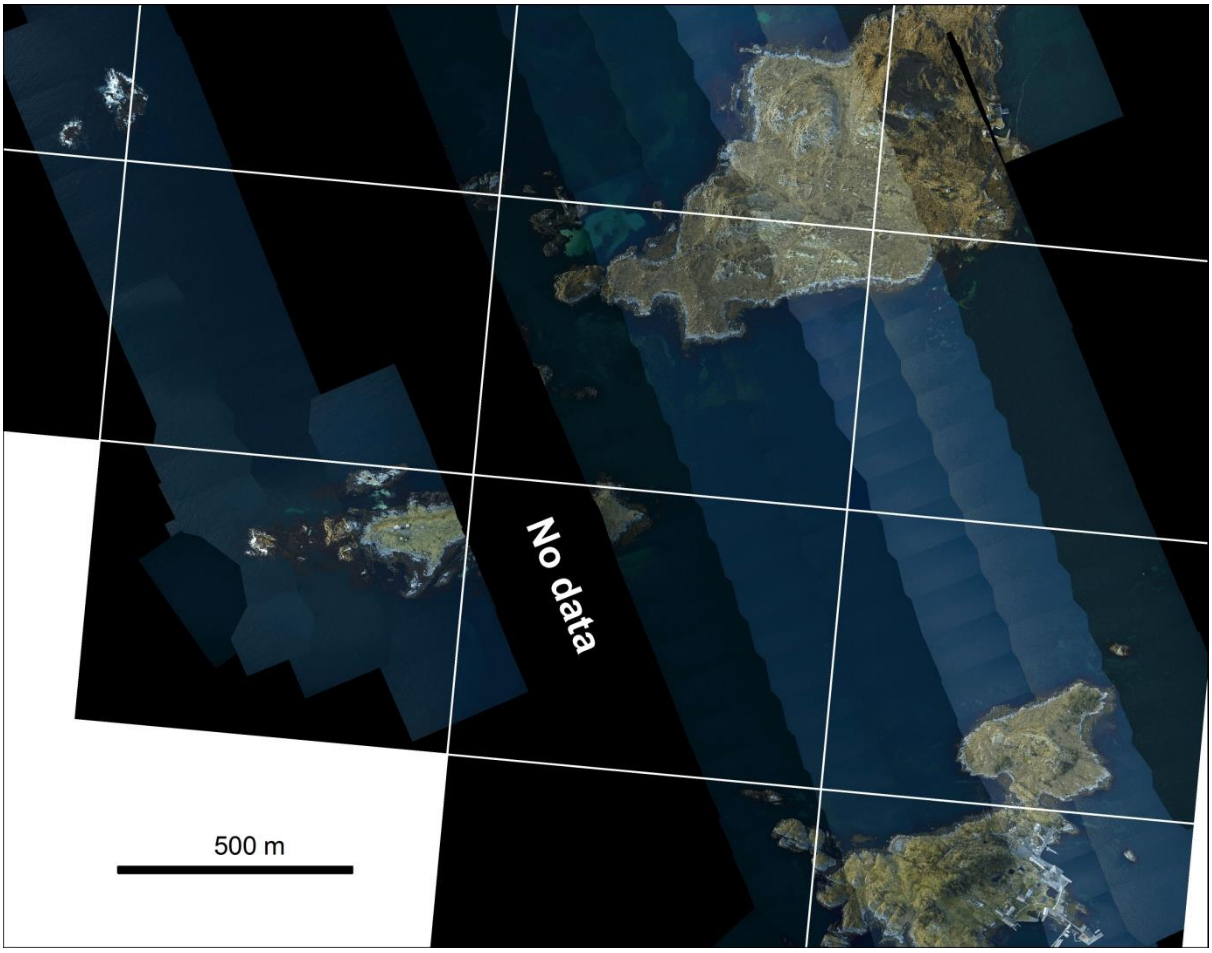

Figure 12. Example of GLaSS aerial photos (individual images delimited by the white lines), assembled as a photomosaic, showing different brightness intensity, and in the extreme case a totally black background (no data area).

Other images that were challenging to use included those with particularly dark photos. Some examples are shown in Figure 13, highlighting how it is harder to see the details in the dark images than in the normal-brightness images.

Figure 13. Examples of dark aerial images with poorer resolution of details (top portion of photomosaic), compared to the normal brightness images (lower portion of photomosaic).

A further major challenge is shadows caused by mountains, buildings, trees etc. Some examples are shown in Figure 14. As with the dark images in Figure 13, the shadow obscures the details of the seabed.

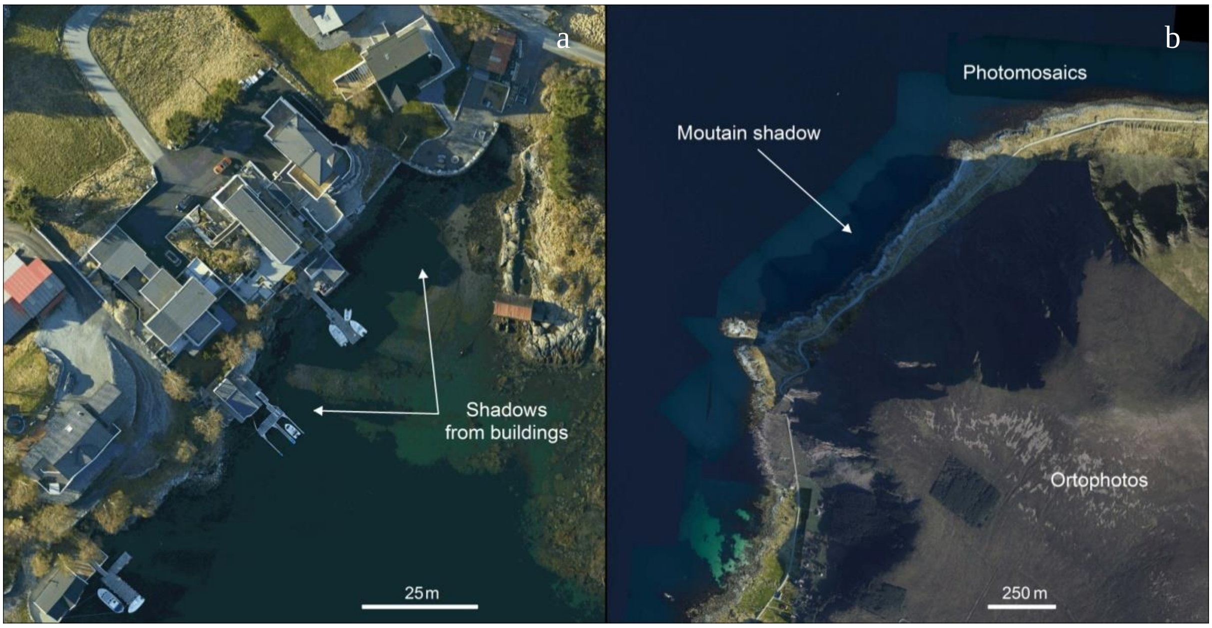

Figure 14. Examples of shadows obscuring the seafloor in aerial photographs. (a)shadows projected by buildings, (b)shadow from a mountain.

Where GLaSS aerial photographs were of poor quality, the Norge i Bilder orthophotos were used as a backup. Similar issues as with the GLaSS data are, however, also applicable to the orthophotos. In a few places, the orthophotos and photomosaics were of little use (due to black backgrounds and/or large shadows), and the GLaSS depth data were the only data available. Such an example is shown in Figure 15.

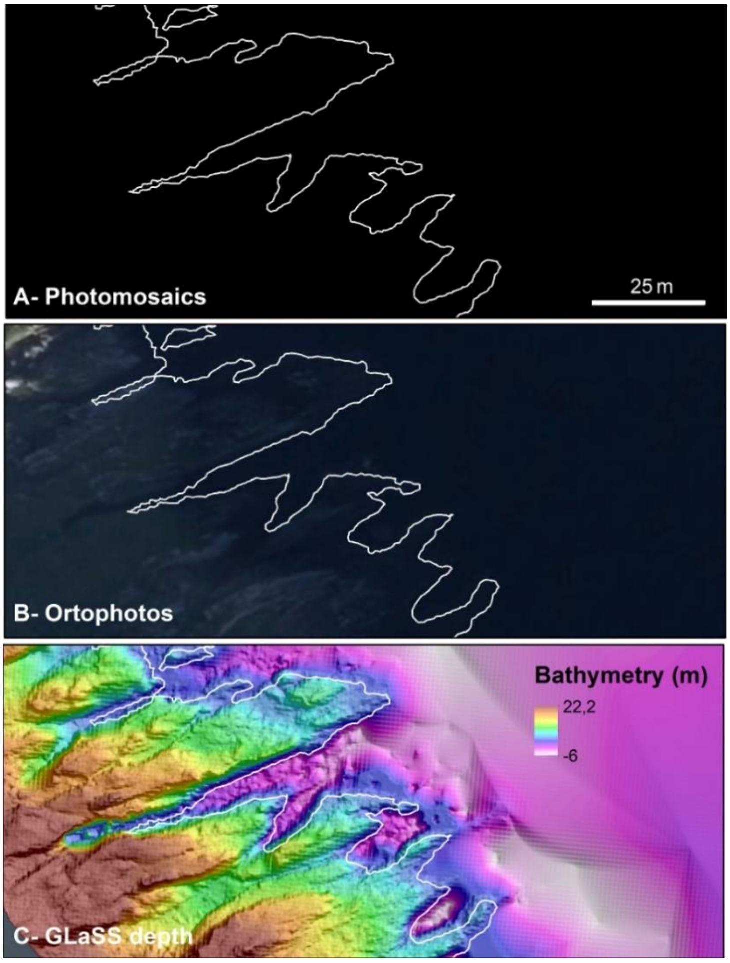

Figure 15. Example showing (a) photomosaics with a totally black background and (b) very dark orthophotos due to mountain shadow. Fortunately here and in some other locations, the GLaSS bathymetry data (c) is of good quality even though the detailed data do not extend very deep. The white line corresponds to the zero contour from the GLaSS depth dataset (NN2000).

4.3 Evaluation of GLaSS bathymetry data for sediment mapping

Generation of shaded relief images from the fine-scale (25cm) bathymetry data allows an excellent representation of the seabed morphology to be obtained. We found it useful to generate shaded relief with illumination from different angles to adequately capture the morphological variations in some areas since a single illumination angle can sometimes obscure features.

Detailed examination of the seabed morphology allows a rough interpretation of seabed sediments into three main classes which have characteristic relief.

i. soft sediments usually characterized by flat seafloors
ii. stony areas with moderate rugosity - fine-scale variations in relief
iii. bedrock areas with high rugosity - broader scale variations in relief.

Combination of these bathymetry data with the aerial imagery further aids interpretation. For example, light colour patches on photomosaics/orthophotos are observed where sandy seabed occurs as in Figure 16. Gravelly areas and bedrock may also be visible in the imagery when zoomed in fully (e.g. Figure 10).

In more steeply sloping areas where there is little information to be gained from aerial photographs, the GLaSS data coverage is more commonly closer to the multibeam coverage i.e. where deeper water is near to the coast. Here the information from previous mapping is invaluable in interpreting the morphology with respect to sediment type as the geological setting is already known.

Figure 16. Example of GLaSS bathymetry data, overlain by photomosaics with 60% transparency. Note the different properties of the three main classes (i) sandy areas (here likely gravelly sand, clearly visible in the photomosaics with light color patches) occurring as flat seabed (ii) stony areas (here sand, gravel, cobbles and boulders) show moderate rugosity with variations in relief representing boulders (iii) bedrock areas have a high rugosity. Background data: Orthophotos from www.norgeibilder.no.

4.3.1 Challenges related to the use of GLaSS bathymetry data

Although much of the GLaSS bathymetry are of good quality NGU have noted several issues which occur in certain areas and which make the use of these data somewhat challenging for geological interpretation.

Artefacts

In several areas, we observe artefacts in the data i.e. acquisition related inconsistencies in the bathymetry data. An example of this is shown in Figure 17 where we observe a sharp break in the recorded depths. It appears this artefact may be related to changes in the vegetation cover visible in the aerial photographs.

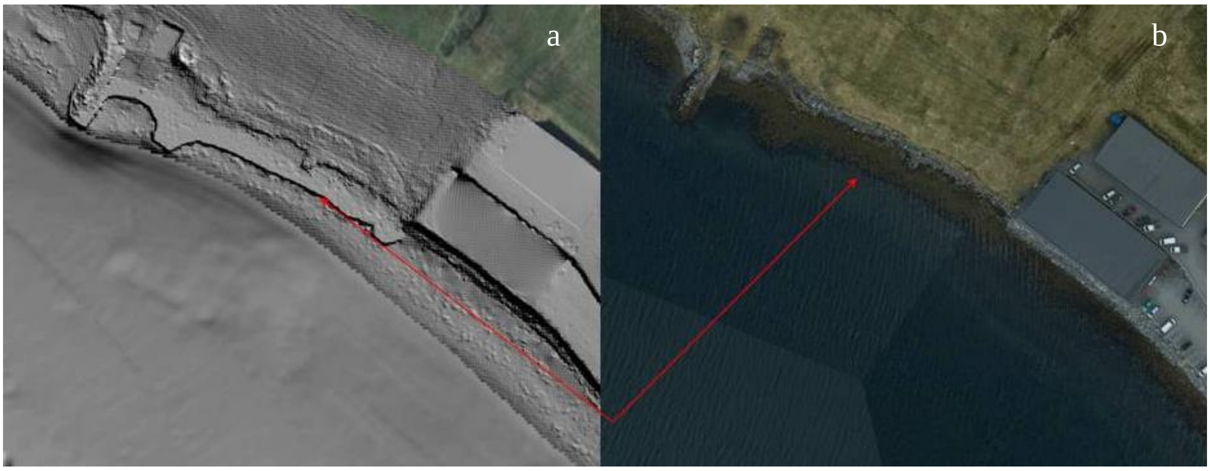

Figure 17. Depth (a) and photomosaics (b) details showing an artefact on the depth data which appears to be linked to a shift of colour observed in the photomosaics (seaweeds in this example).

DTM quality

The DTM quality is variable, due to the underlying LiDAR point density. In Figure 18 we see an area of bedrock with is clearly visible in the aerial photographs, but which is difficult to resolve in the bathymetry shaded relief. This contrasts with the bedrock observed in Figure 16 which was clearly resolved in the shaded relief.

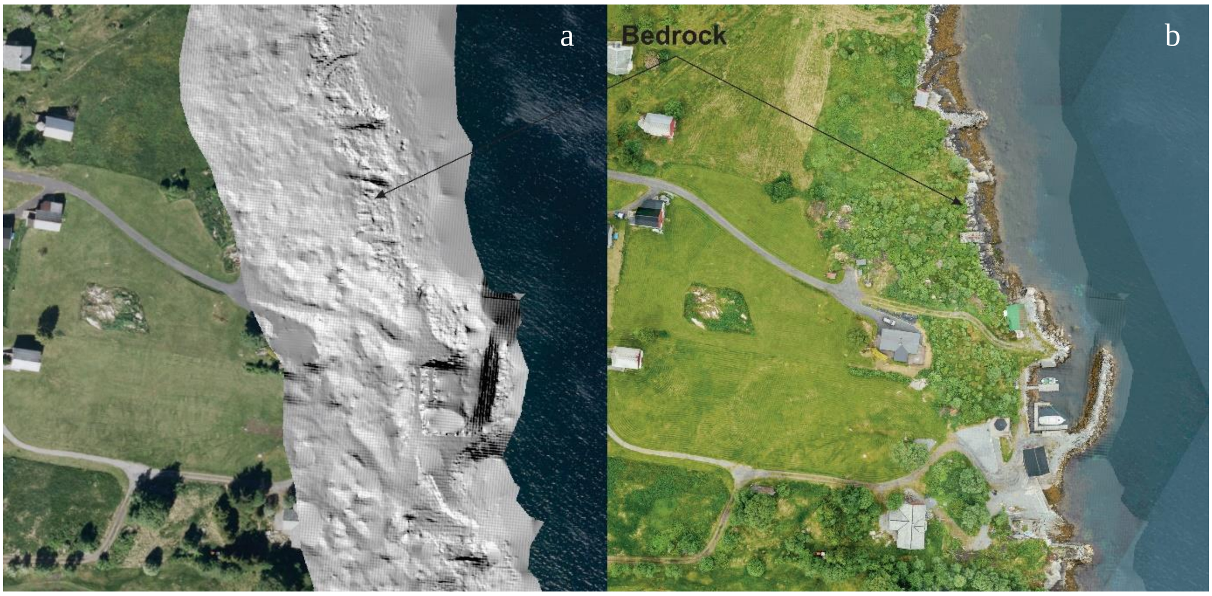

Figure 18. An example of a location where the bedrock interpretation is not as obvious as in Figure 16. (a): depth from GLaSS dataset, (b) photomosaic clearly showing bedrock.

Also linked to the underlying LiDAR point density is the seemingly 'flat' areas mapped in deeper waters (Figure 19). There are often not enough data points available to resolve the morphology of features in deeper waters (> ~2 m below NN2000) and considerable interpolation has been used here to generate the 25 cm DTM. As a consequence, not all morphological features that would be relevant to the geological interpretation are resolved. Where existing multibeam data are available and overlap the deeper part of the GLaSS coverage this is not an issue, since the necessary details are resolved by the multibeam data, however in areas where there is no multibeam coverage the interpretation of morphology in deeper parts of the GLaSS dataset becomes quite uncertain. This is an important reminder of how data quality and DTM uncertainty influences the utility data. DTM resolution alone is an insufficient descriptor of these influences.

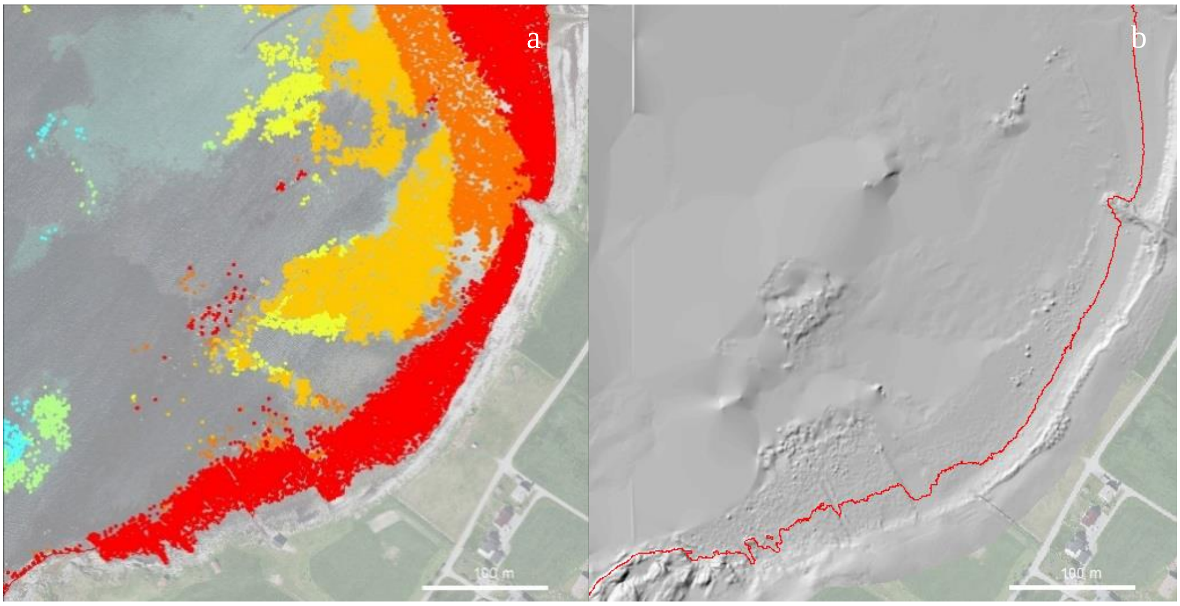

Figure 19. (a) Example of differing density of LiDAR seabed data points from Flø, Hareidlandet (b) Shaded relief image of bathymetry data (0.25 m resolution) showing misleadingly 'flat' morphology due to interpolation where there are few data points.

Kartverket have also indicated that the choices made when processing the LiDAR data have an effect on the terrain forms visible in the resulting DTM. On land, stones are generally filtered out of the DTM (classified separately), whereas stones are retained as an important terrain feature in underwater areas. Within the littoral zone, this can lead to inconsistencies in the terrain forms captured since LiDAR surveys are generally conducted at low-water. In the GLaSS dataset, those areas which were dry during the survey have had stones filtered out, whilst those which are wet at the time of survey are treated like the rest of the seabed and stones retained. Ideally special processing would be applied to the littoral zone to ensure consistent processing. This experience will be taken on board for future surveys.

No Data areas

In addition to fewer LiDAR data points in deeper waters, there are also other reasons why there are few LiDAR data points in some areas. Where the seabed is dark or covered by vegetation, the laser pulse is absorbed giving no return signal (Terratec, 2017). The percentage of the GLaSS project area affected by NoData is summarized by Kartverket (2017). They report that nearly half of the GLaSS area is affected by the dark bottom, leading to no return signal from the laser. Furthermore, they estimate about 65% of the seabed does not get a good enough signal and are classified as NoData areas. The additional causes of No Data include turbidity (Secchi depth), turbulent water, vegetation and objects. Figure 20 shows an example of the NoData layers provided by Terratec indicating how extensive these NoData areas are around Runde, with the western coast being particularly affected by turbulent water. Note that in most cases the DTM extends across the NoData areas meaning that there are fewer data points available for DTM generation (i.e. more interpolation used).

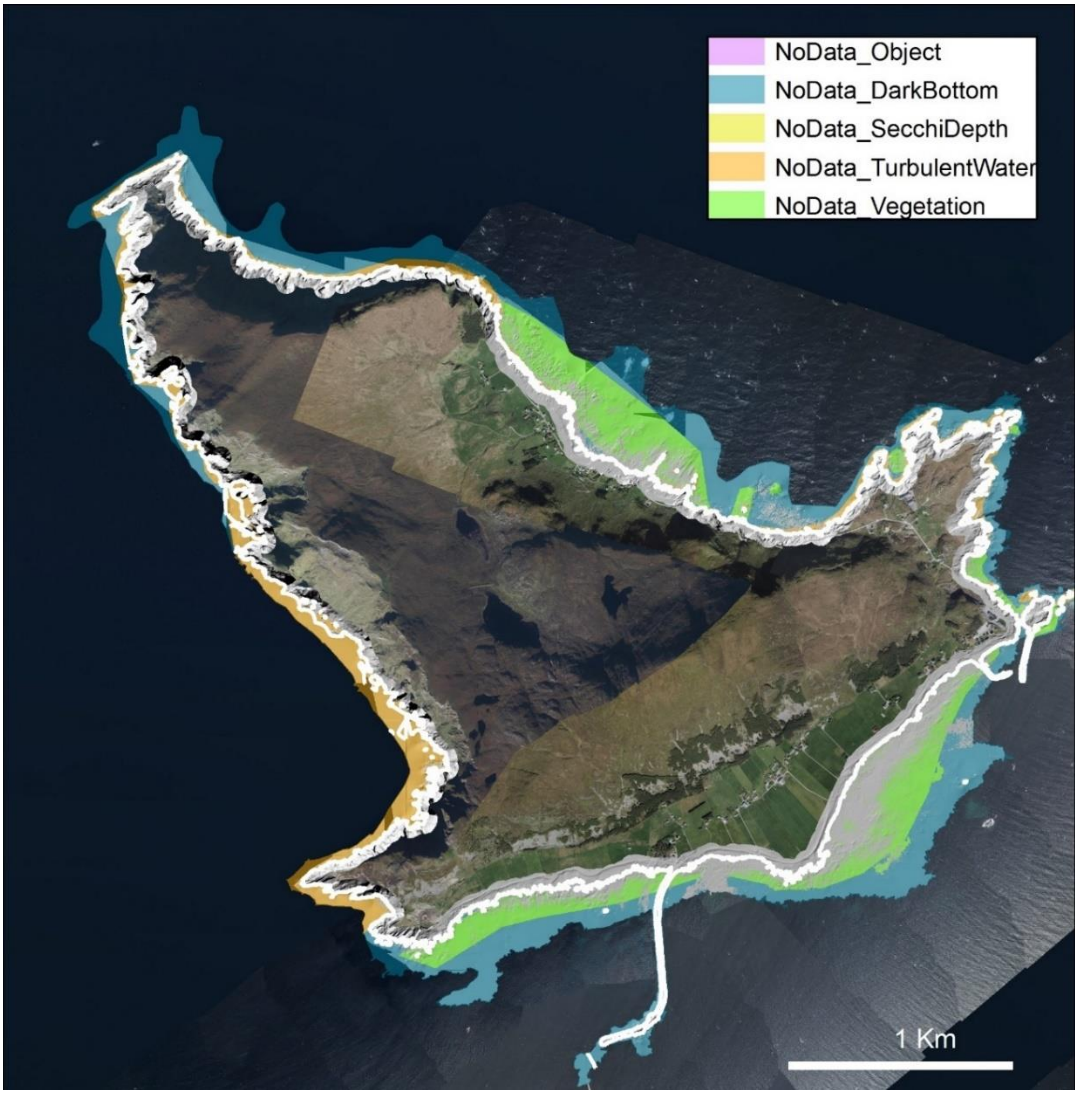

Figure 20. Example of NoData polygons (LiDAR data) supplied by Terratec for the area around Runde. The zero-metre contour (NN2000) is shown in white to mark the limit of the underwater data.

The No_Data polygons have not been explored in detail as part of this work, however as part of other work packages in the current project NGU intends to investigate the potential value of the No_Data Objects shapefile for mapping anthropogenically altered seabed - NiN main types M14 and M15 (Halvorsen et al., 2016).

Datum and data formats from hoydedata.no

As mentioned in Section 1.2 all the elevation (bathymetry) data downloadable from hoydedata.no is relative to vertical datum NN2000. No height mismatch between the multibeam and LiDAR datasets are observed provided both datasets are downloaded from hoydedata.no. Nevertheless, the datasets are separate and have not been merged into a single DTM by Kartverket to date.

This means that the data user must mosaic the two datasets together if they wish to work with all available bathymetry data for the Søre Sunnmøre area. Further, if the data are to be used for marine-based work the data must be converted to chart datum (sjøkartnull). The conversion offset varies by area and according to Kartverket NN2000 is approximately 1.25 m below chart datum in Søre Sunnmøre but should ideally be computed via a conversion model, the reverse of the model which was used by Kartverket to convert all the multibeam data (originally referenced to chart datum) for use on hoydedata.no.

Both mosaicing of the GLaSS and multibeam datasets, plus the datum conversion requires bathymetry data users to have a decent level of GIS expertise, plus access to GIS tools that can perform the computations. Leaving these operations in the hands of data users can lead to inappropriate DTMs being generated by novice GIS users. For example, good multibeam data are ‘lost’ below heavily interpolated GLaSS data if mosaicing is performed without ensuring that settings reflect the relative data quality.

Although we recognize that NN2000 is in widespread use by county councils and other coastal planners, we recommend the downloading functionality from hoydedata.no be extended to allow users to select the desired datum. Downloading data directly in with chart datum would have allowed data to go directly into existing databases at NGU, IMR and NIVA. In addition, functionality that mosaics bathymetry data from a given study area with appropriate consideration given to relative data quality should be considered.

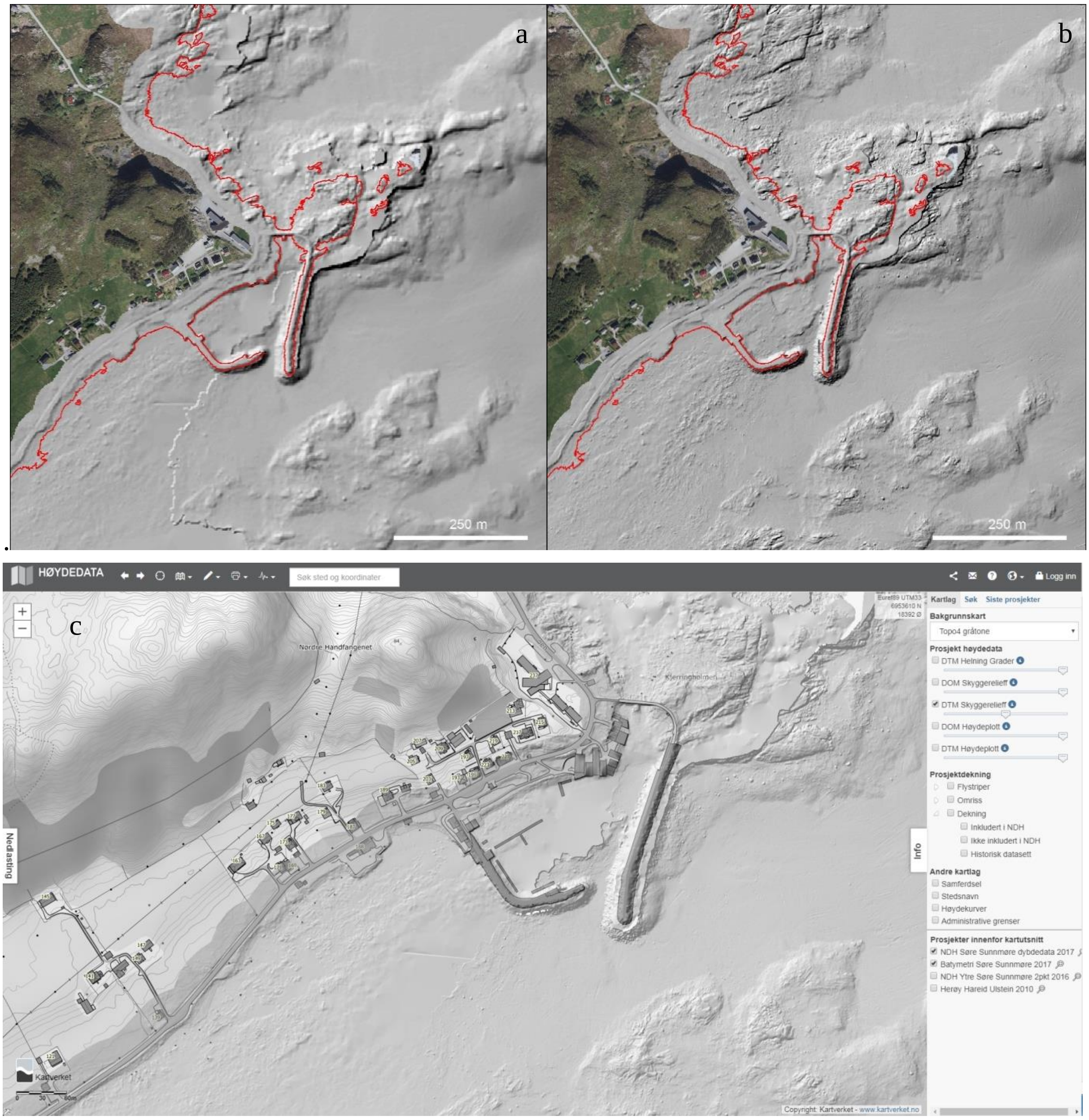

Figure 21. Example of datum and resolution issues from the coast offshore Runde Miljøsenter, Runde. (a) Shaded relief image of GLaSS bathymetry data (25 cm resolution, NN2000) mosaiced directly with bathymetry data from Marine basemaps Søre Sunnmøre project (2 m resolution, chart datum). Note artefacts from depth difference resulting from datum difference and the level of detail visible in the 2 m resolution mosaic. (b) Shaded relief image of GLaSS bathymetry (25 cm resolution, NN2000) data mosaiced with multibeam bathymetry (25 cm resolution, NN2000), both downloaded directly from hoydedata.no. Multibeam data is used in the mosaic in favour of GLaSS data where an overlap exists. A depth shift of +1.25 m has been applied to the entire mosaic to bring all depths to chart datum prior to generation of the shaded relief image. (c) The GLaSS and multibeam bathymetry data shown as shaded relief. Note that in this image the GLaSS data is above the multibeam data and we see mismatches in depth between the interpolated GLaSS data in deeper waters vs. the multibeam data which should really be prioritized here as in (b).

Disregarding the datum issues, the newly available multibeam DTM from hoydedata.no with 25 cm is an improvement in terms of resolution compared with the previously available 2 m grid that was generated for the Marine basemaps Søre Sunnmøre project. This provides greater detail in shallow areas, benefiting from the dense soundings here (Figure 21). However, it is important to remember that the underlying data density is far from constant across Søre Sunnmøre, varying between 100 points/m^2 to 0.2 points/m^2. This means that in deeper areas, a considerable degree of interpolation has been applied to the data, as mentioned earlier in relation to the GLaSS bathymetry data.

4.4 Examples from the new sediment map based on GLaSS data

In this section, we present a few examples from the newly interpreted sediment grain size map based on GLaSS data. These data are difficult to distinguish from the previously published sediment map when zoomed out to the entire study area so we instead present a series of examples of the newly interpreted portion of the map based on GLaSS data. Readers are referred to the GIS shapefile where the newly interpreted area is combined with the existing sediment map for Søre Sunnmøre. For further investigation of the entire area – see Appendix. Following the completion of this project, NGU web map services will be also updated with the newly extended map.

Figures 22-24 illustrate the coverage and interpretation of sediments from the GLaSS data in 3 areas. Figure 22 shows a typical example of an area where the multibeam and GLaSS data coverage is overlapping or nearly overlapping. In this area, the newly extended map is seamless between the 2 datasets.

Figure 23 shows a further example of where the multibeam and GLaSS data coverage is close, but also highlights how it has been possible to use the GLaSS data to extend the interpretation inland.

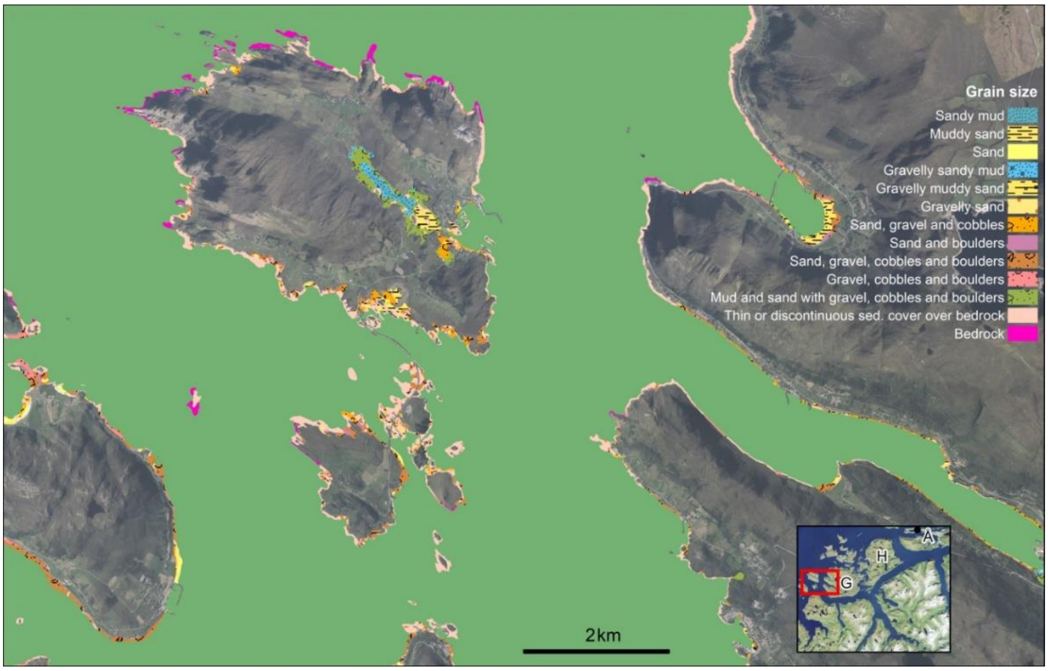

Figure 22. Example showing the relative coverage of interpreted sediment grain size map from GLaSS (coloured polygons) and multibeam (green polygon). Background data: orthophotos from www.norgeibilder.no. G: Gurskøy, H: Hareidlandet, Å: Ålesund.

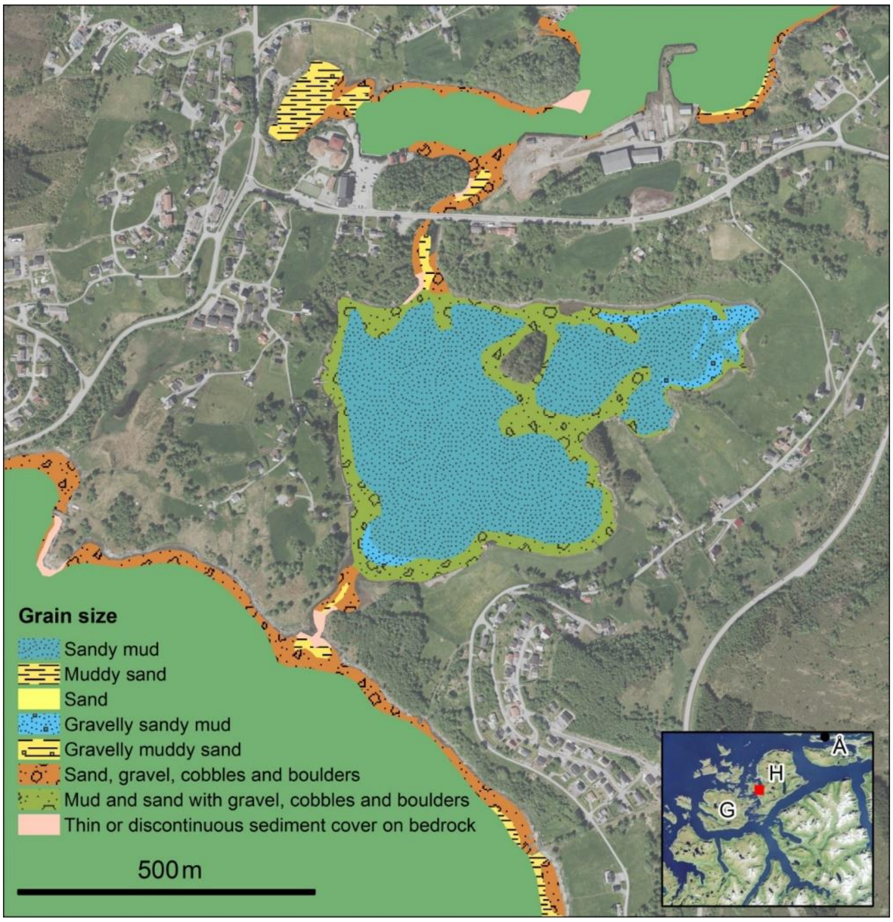

Figure 23. Example of GLaSS grain size interpretation. Full coverage. The green polygon corresponds to the multibeam coverage. Background data: orthophotos from www.norgeibilder.no. G: Gurskøy, H: Hareid-Landet, Å: Ålesund.

Figure 24 shows a contrasting example where the seabed is shallow further from the coast and slopes less steeply. Here the GLaSS data coverage allows for sediment interpretation further from the coast, yet the data coverage does not meet the multibeam data coverage. In such cases, the sediment map cannot be joined up with the previously published map as there are no data available in the zone between the two datasets upon which to base an interpretation (See Digitizing Ruleset, Section 2.1).

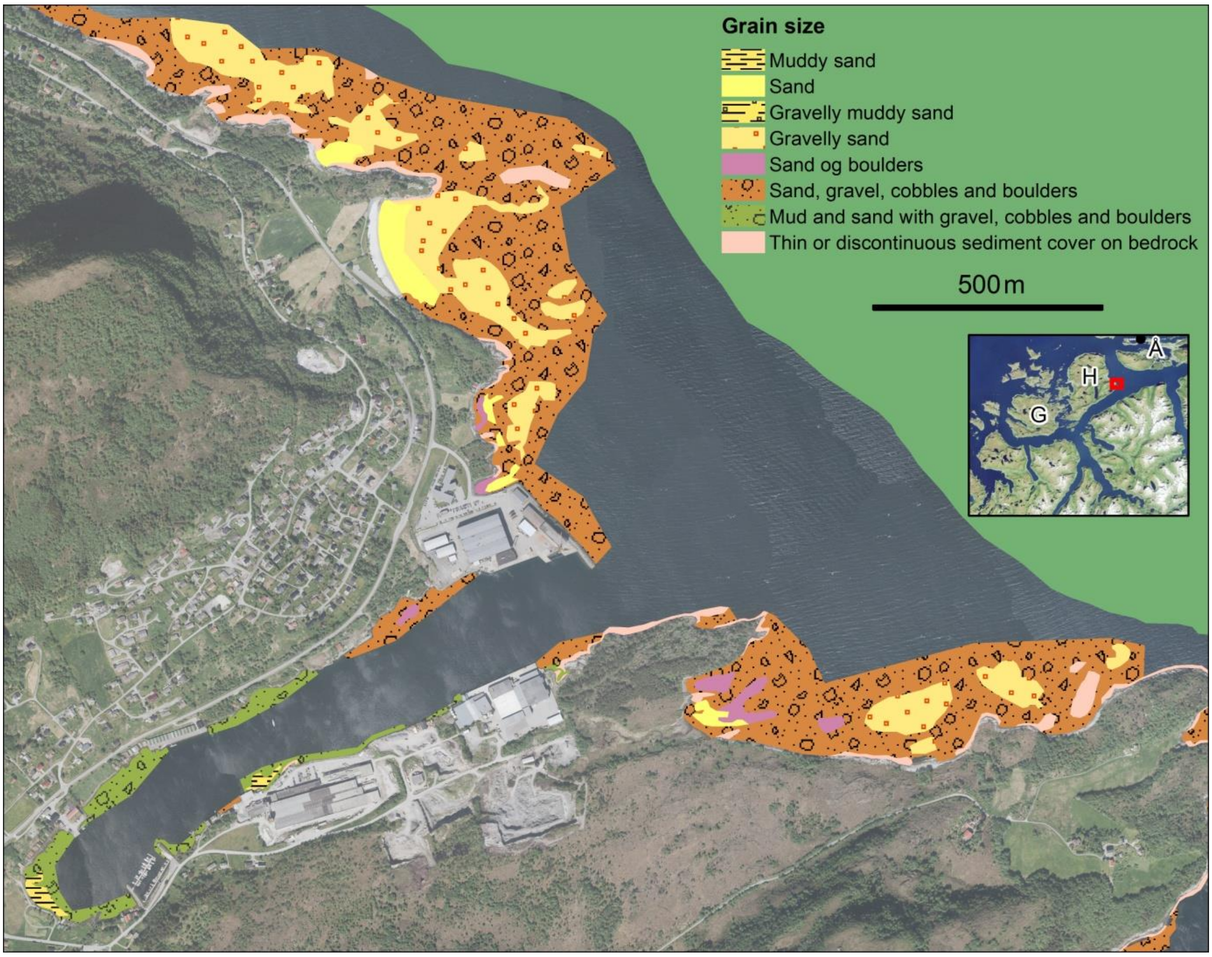

Figure 24. Example of sediment grain size interpretation from GLaSS data. Note the gap between the grain size interpretation and the previous interpretation from multibeam (green polygon). Background data: orthophotos from norgeibilder.no. G: Gurskøy, H: Hareidlandet, Å: Ålesund.

5. SUMMARY AND CONCLUSIONS

Here we provide a summary of the work completed together with a recap of the main feedback on GLaSS data quality/usability that should be taken into consideration for future LiDAR surveys.

- The NGU sediment map (1:20 000) for Søre Sunnmøre has been updated based on LiDAR and aerial photo data from the GLaSS project. The new data provide extended coverage in nearshore areas.
- Existing geological knowledge of the data from the Marine basemaps Søre Sunnmøre project was an essential prerequisite for interpreting the GLaSS data. Without previous knowledge of the surficial geology of the seabed, interpretation of GLaSS data would have been limited to mapping of four broad classes. Only broad classes of bedrock, hard bottom (gravel, cobbles and boulders), mixed sediments (mud and/or sand with gravel, cobbles and boulders), and soft sediments (mud to sand) interpreted from the bathymetry and aerial photograph data could have been recognised, unless substantial ground truthing was conducted within the GLaSS area.
- GLaSS LiDAR bathymetry and aerial photo data were the most useful data for geological interpretation and the sediment map in shallow areas is primarily based on these data. The aerial photography data served as pseudo ground truthing of the LiDAR data. Limitations of these data were encountered in deeper waters (>1-2 m) and/or where images were of poor quality. It can be difficult to distinguish different soft sediments types from the aerial photograph data. Coarser sediments can be more reliably determined. Additional information from multi/hyperspectral sensors and/or direct ground truthing would be helpful. A revised workflow for editing the DTM within the littoral zone is recommended to ensure that stones both above and below the water line during LiDAR surveys at low tide are processed in a consistent manner for DTM production (section 3.3.1).
- GLaSS LiDAR intensity data provided no useful information for sediment mapping since the intensity values were not corrected for depth, incidence angle, sensor or atmospheric effects (Section 1.3.2). It will be important to include these corrections in any future topo-bathy LiDAR surveys in order to maximise the utility of the LiDAR data for geological and habitat mapping and potentially to report range-corrected, calibrated reflectance values rather than standard intensity values (Section 1.5.2). If LiDAR intensity data can provide a reliable proxy to sediment type, akin to multibeam backscatter data, then ground-truthing can effectively be planned to maximise the efficiency of this validation dataset. Reliable, corrected intensity data do not remove the need for ground-truthing for geological mapping.
- During this work an image mosaic version of the aerial photographs was used (10 cm resolution).We recognise potential for improving the imagery dataset by applying image processing (colour/brightness balancing) to the original individual georeferenced images (2.5 - 4.5 cm resolution).

- The information content of the aerial photos was useful, however, we recommend using multispectral or hyperspectral imaging for future surveys. These data can provide a more robust characterisation of ground-types since a characteristic optical signature can be obtained which can help distinguish between areas which are visually similar.
- As concluded by Kartverket (2018) and several other authors in the scientific and popular scientific literature, a multi-sensor approach seems best suited to coastal mapping via remote sensing, since no one method is optimal in all situations. We consider this conclusion to be equally applicable to geological mapping as it is to bathymetric mapping and recommend that a multi-sensor approach is taken to any future topo-bathymetric mapping projects in the Norwegian coastal zone.
- In order to ensure error-free onwards use of the bathymetry data for marine applications it is recommended that the data be merged by Kartverket and made available as a seamless dataset via hoydata.no or similar. There are many pitfalls that unexperienced users unfamiliar with multibeam and Lidar technology and/or merging of DTMs can make. By providing the data as separate datasets referenced to a land-based datum (NN2000) there is an unnecessarily large risk that errors will be introduced by the data users, or that all data will not be used due to lack of knowledge on how to merge and vertically correct the data.

6. ACKNOWLEDGEMENTS

The authors wish to thank the GLaSS teams at Kartverket and Terratec and to our project partners at NIVA and IMR for useful discussions and clarifications related to this work. All GLaSS and multibeam data shown in this report were provided by Kartverket. Technical evaluation of the Lidar data, DTMs and aerial photograph data was conducted by Dolan and Bellec. Geological interpretation was undertaken by Bellec and Elvenes while Lepland was responsible for database integration and dissemination of the sediment map.

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APPENDIX 1. USER MANUAL FOR MARINE BASEMAPS SØRE SUNNMØRE

The following document (in Norwegian) is a user manual offering guidance and recommendations for use of the marine basemaps, including the sediment map. This is a generic document which covers all marine basemaps in Søre Sunnmøre.

SLIK FINNER DU MARINE GRUNNKART FRA SØRE SUNNMØRE

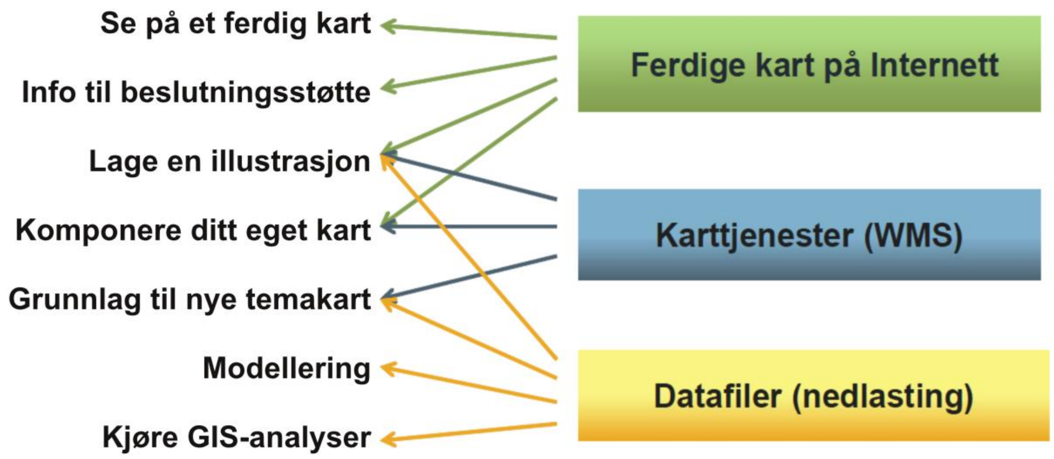
Aave Lepland og Sigrid Elvenes

Norges geologiske undersøkelse (NGU) har kartlagt havbunnen på store deler av Søre Sunnmøre i svært høg oppløsning. NGUs serie med **marine grunnkart** i målestokk 1:20 000 omfatter blant annet kart over bunntyper, helning, ankringsforhold, gravbarhet, bunnfellingsområder og havbunnsterreng, og kartene er fritt tilgjengelige for alle. NGU har tilrettelagt dataene for ulike brukergrupper, og marine grunnkart kan både studeres på internett, brukes i egne karttjenester og lastes ned for videre analyser. Dette er en veiledning for den som ønsker tilgang til NGUs marine grunnkart. Før du begynner bør du tenke gjennom hvordan du vil bruke dataene:

Vil du først og fremst se på kartene? Gå til NGUs karttjenester på nett: www.mareano.no/kart, www.ngu.no (detaljert fremgangsmåte er forklart under)

Vil du vise kartene i egne GIS-verktøy? Koble til NGUs WMS-tjenester: http://www.ngu.no/emne/karttjenester

Trenger du data til videre bearbeiding, analyser, modellering eller lignende? NGUs nedlastningstjeneste finnes her: http://www.ngu.no/emne/datasett-og-nedlasting

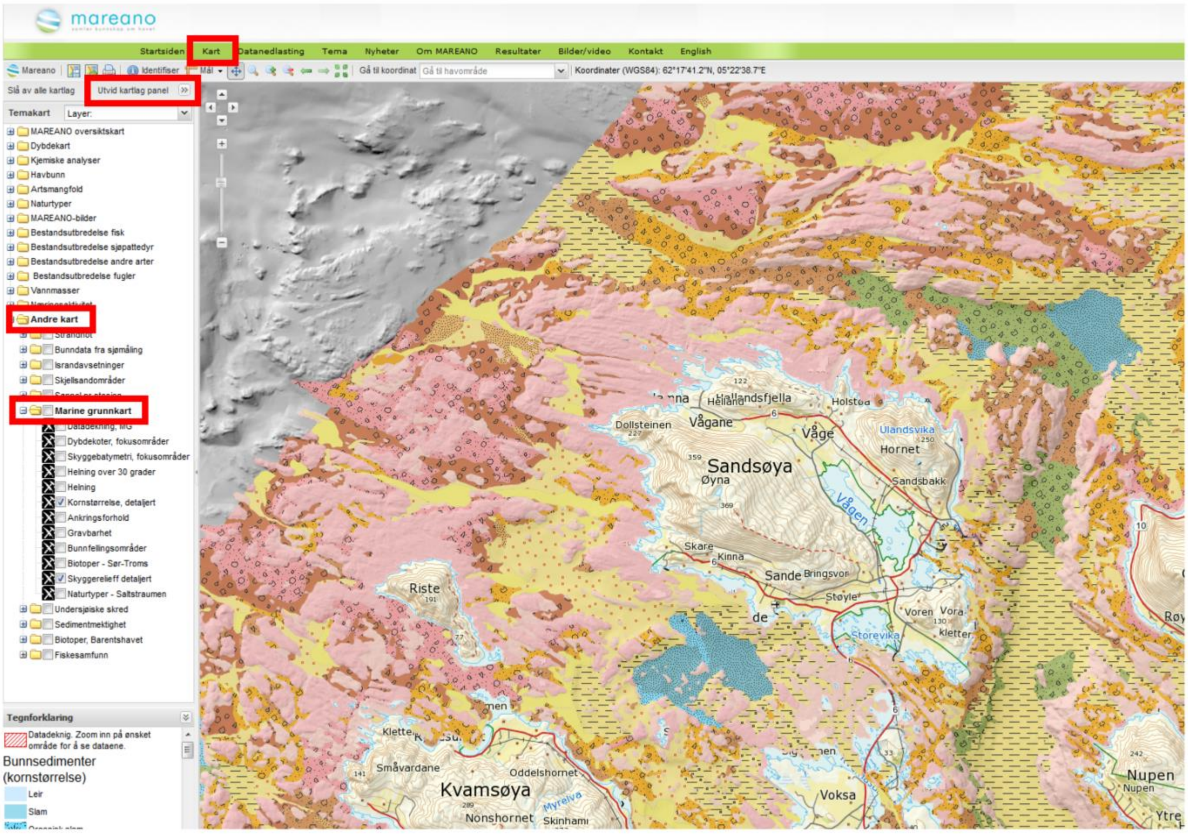


WEBSIDER SOM VISER MARINE GRUNNKART

For å se på de nye dataene fra Søre Sunnmøre er det enklest å åpne en webside med ferdiglagede kart. Der kan du også få mer informasjon om kartene. Det er flere ulike karttjenester som viser marine grunnkart, enten hele serien eller utvalg av den. På sikt ønsker NGU å få lagt ut alle temakart i alle tjenester.

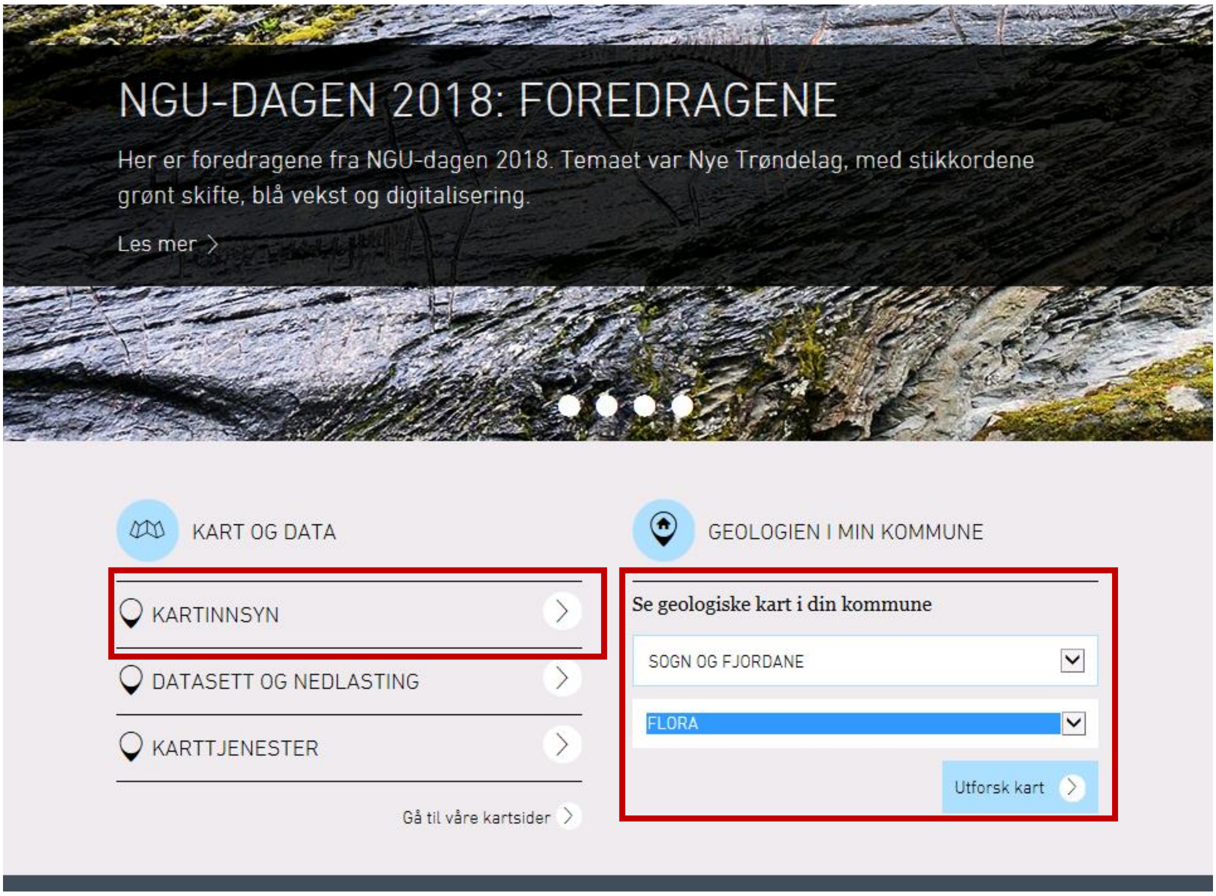
www.mareano.no/kart

På denne karttjenesten finnes det mest komplette utvalget av marine grunnkart. Kartene åpnes fra venstremenyen, under mappene ”Andre kart” og ”Marine grunnkart”. Zoom inn på området du er interessert i, så kommer de detaljerte kartene til syne. Du kan slå av og på alle kartlag ett og ett eller samtidig, og i tillegg kombinere med kartlag fra andre tematiske mapper. Utvider du kartlagpanelet kan du i tillegg endre bakgrunnskart og rekkefølgen til kartlagene, og du kan finne informasjon om kartlagene. Verktøylinja øverst gir muligheter for lagring, utskriving og eksport av kart.



www.ngu.no

På NGUs nettsider vises et utvalg av marine grunnkart i karttjenesten **Geologien i min kommune**.



Tjenesten lar deg velge fylke og kommune og utforske ulike geologiske temakart. I venstremenyen finnes tre havbunnskart under overskriften ”Landskap”: Bunnsedimenter, ankringsforhold og gravbarhet. Du kan slå på ett og ett kart og samtidig få opp lenker til produktark og tegnforklaring. NGU jobber med å legge ut flere temakart fra marine grunnkart-serien i denne karttjenesten.

Via lenken til **Kartinnsyn** får du også tilgang til alle NGUs innsynsløsninger, deriblant maringeologiske kart. NGU jobber med å få lagt ut alle marine grunnkart fra Søre Sunnmøre også her, men foreløpig (juni 2016) er det bare detaljert havbunnsterreng fra området som kan sees på denne karttjenesten.

En ny karttjeneste for marine kart er under utvikling i 2018.

WMS-TJENESTER

Er det behov for å ta inn marine grunnkart i egne web-tjenester eller GIS-prosjekter, for eksempel for å se/vise dem sammen med andre data, er det enklest å bruke WMS-tjenester fra NGU. I WMS-tjenester hentes data direkte fra NGUs databaser og symboliseres etter utarbeidede retningslinjer. Vi anbefaler å bruke WMS-tjenester så lenge det går an, fremfor å laste ned selve dataene og lage egne kart og tjenester. Med WMS-data slipper du å bekymre deg for riktig symbolisering og navngiving, og dataene vil alltid være oppdatert. Alt du trenger å gjøre er å kopiere og lime inn URL-en til tjenesten i "Add WMS-server" i ditt GIS-verktøy, eller peke mot denne URL i tjenesten du utvikler. For mer info om tilgjengelige lag klikk på lenken GetCapabilities. Det er tre WMS-tjenester fra NGU som publiserer data fra Søre Sunnmøre-prosjektet (sammen med kystnære data fra andre prosjekter):

MarinBunnsedimenterWMS

MarinBunnsedimentWMS viser kartlaget Bunnsedimenter (kornstørrelse), detaljert. Dette laget er grunnleggende i marine grunnkart-serien, siden de fleste temakartene bygger direkte på dette, og det inneholder mye informasjon som ikke er representert i temakartene.

URL: http://geo.ngu.no/mapserver/MarinBunnsedimenterWMS?
GetCapabilities

MarineGrunnkartWMS

Her finnes temakartene i marine grunnkart-serien. NGU vil sterkt anbefale å bruke denne WMS-tjenesten sammen med MarinBunnsedimenterWMS (se over), for ikke å gå glipp av detaljert havbunnsinformasjon.

URL: http://geo.ngu.no/mapserver/MarineGrunnkartWMS?
GetCapabilities

MarinTerrengWMS2

MarinTerrengformerWMS2 viser grått skyggerelieff i gridstørrelse 10 til 100 m.

URL: http://geo.ngu.no/mapserver/MarinTerrengWMS2?
GetCapabilities

Mer info om alle WMS-tjenester fra NGU finner du på **www.ngu.no** under KARTTJENESTER.

NEDLASTING AV KARTDATA

Trenger du å laste ned selve datasettet, for eksempel for å utvikle nye kartprodukter, kjøre GIS-analyser eller ta med dataene der kartene ikke kan nås på internett, kan dette gjøres via NGUS nedlastingstjeneste. Denne finner du på www.ngu.no under DATASETT OG NEDLASTING. For enklest tilgang klikk her.

Gjennom nedlastningstjenesten får du tilgang til datasettet **Bunnsedimenter (kornstørrelse), N25 detaljert.** Dette er NGUs viktigste produkt i marine grunnkart-serien, og det er dette datasettet de fleste andre marine grunnkartene bygger på.

For å få tak i andre datasett i marine grunnkart-serien, ta kontakt med NGU på e-post: *marindata@ngu.no*.

Dybdedata tilhører Kartverket og kan ikke lastes ned gjennom NGUs tjenester. Ønsker du tilgang til dybdedata, henvend deg til Kartverkets sjødivisjon: *sjo@kartverket.no*.

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