Mapping vertical and overhanging terrain in the deep sea

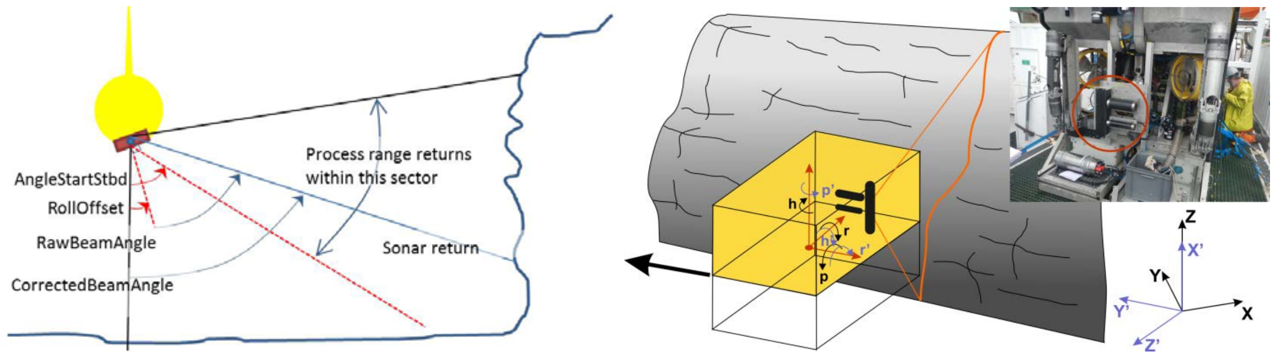
CODEMAP Protocol Factsheet 3

Aim Mapping the morphology of vertical and overhanging cliffs in the marine environment, in order to create a true 3D representation of the terrain.

Approach Depending on the resolution needed and the extent of the cliff to be mapped, different approaches have been developed by the CODEMAP team:

1. *Extensive, largely smooth cliffs, to be mapped at m-scale resolution*, making use of a survey-AUV (torpedo-shaped Autonomous Underwater Vehicle, specifically designed to travel long distances along smooth trajectories at a speed ~5km/h). The normal multibeam echosounder (MBES) receiver head is tilted to one side. Data processing follows normal procedures (e.g. using CARIS, CARAIBES or MB-System), incorporating the tilt angle as roll offset. Requires safe working distance from the cliff, re-balasting of the vehicle and the development of a collision avoidance solution.
2. *Focussed cliff sections in complex terrains, ~200x~1000m, to be mapped at 10cm-scale resolution*. A high-resolution MBES system is placed on the front of an ROV (Remotely Operated Vehicle), which allows visual control and real-time interaction during the operations. The ROV is then moved in sideways passes. A double coordinate transformation is required to project the data and attribute information into a temporary plane for processing, followed by a re-transformation into the actual 3D space afterwards[1,2].
3. *Specific details of marine cliffs, ~50x~100m, to be mapped at <mm scale resolution.* Sub-millimetre resolutions can be achieved with photogrammetry methods, either using stereo-cameras or using Structure-from-motion algorithms for moving cameras mounted on ROVs[4,5]. The advantage of photogrammetry is that not only the morphology, but also the terrain colour is recorded, which is useful for the identification of rock types or benthic species. Reconstructions can be made using commercially available softwares such as Agisoft Photoscan.

The processed data from all of the above techniques is then presented and analysed as point clouds, using software packages such as CloudCompare.



Schematic representation of the acoustic mapping methods for submarine cliffs: rotated Multibeam Echosounder receiver head enables the sideways mapping of cliffs from survey AUVs (left), while a high-resolution MBES mounted on the front of an ROV is the solution for detailed vertical mapping in complex terrains (right, after Huvenne et al., 2016)

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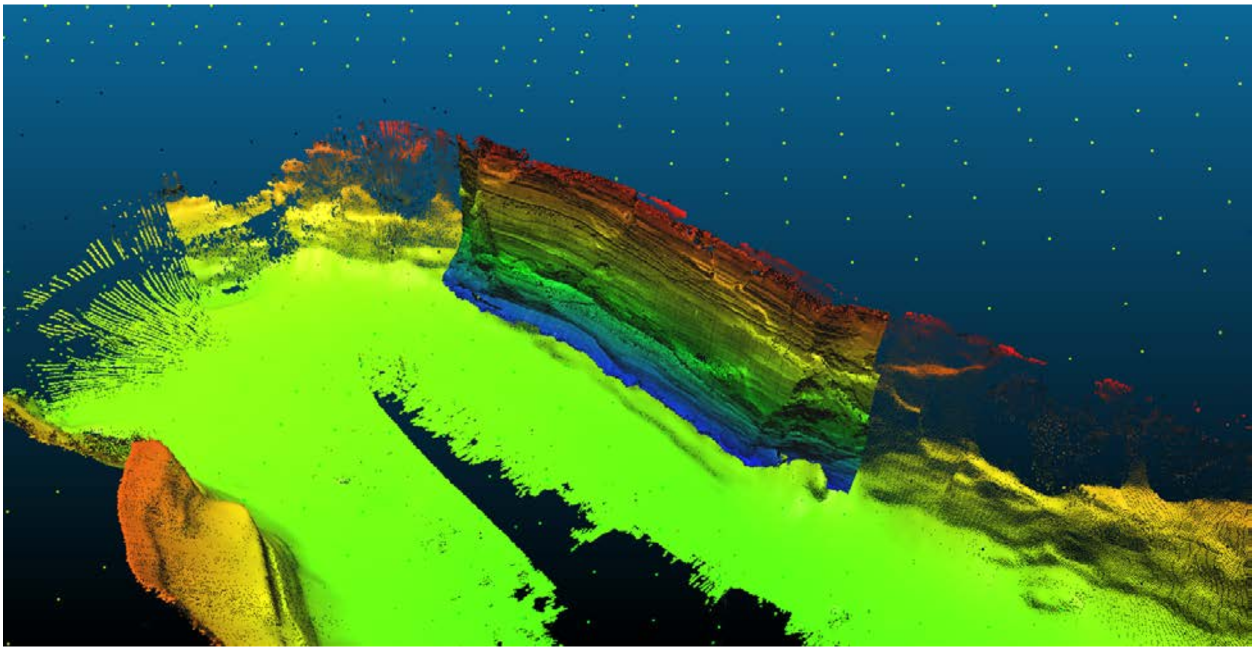

Point-cloud representation of shipboard multibeam bathymetry (50m pixel resolution: sparse dots in the background), AUV-based sideways mapped bathymetry (2m pixel resolution, dataset covering lower half of the image) and ROV-based high-resolution forward-mapped bathymetry (0.2m pixel resolution, dataset in centre) of a submarine canyon wall at 750m water depth in Whittard Canyon, Bay of Biscay.

Background Vertical and overhanging cliffs in the marine environment cannot be surveyed with conventional, downward-looking techniques, or using equipment deployed over the side of a ship. The increasing availability of robotic vehicles (AUVs, ROVs) now provides opportunities to solve this problem.

This is important, because vertical walls have been identified as key benthic habitats, especially for filter feeders, e.g. cold-water corals, deep-sea oysters and clams[2,3]. Besides providing a hard substrate for attachment, they can act as refuges from direct anthropogenic impact such as bottom trawling[2].

In addition, the techniques presented here allow quantitative geological information to be derived from the mapped outcrops, such as joint orientation, bedding structure, and tectonic fabric[4], which lead to a better understanding of the stability of these cliffs, and their geohazard potential (risk for submarine landslides)[1].

Further reading

[1]Huvenne et al. (2016) Novel method to map the morphology of submarine landslide headwall scarps using remotely operated vehicles. In: Lamarche G, et al. (eds) Submarine mass movements and their consequences, 7th International Symposium, vol 41. Springer, Heidelberg, pp 135-144

[2]Huvenne et al. (2011) A picture on the wall: innovative mapping reveals cold-water coral refuge in submarine canyon. PLoS One 6(12):e28755, doi: 10.1371/journal.pone.0028755

[3]Johnson et al. (2013) A vertical wall dominated by Acesta excavata and Neopycnodonte zibrowii, part of an undersampled group of deep-sea habitats. PLoS One 8(11):e79917, doi:10.1371/journal.pone.0079917

[4]Kwasnitschka et al. (2013) Doing fieldwork on the seafloor: photogrammetric techniques to yield 3D visual models from ROV video. Computers & Geosciences 52:218-226, doi:10.1016/j.cageo.2012.10.008

[5]Robert et al. (2016) Hanging gardens: vertical walls from images to fine-scale 3D reconstructions. In: Geohab 16th International Symposium, 2-6 May 2016, Winchester, UK, Abstracts Volume, p 140

CODEMAP The ERC project "COmplex Deep-sea Environments: Mapping habitat heterogeneity As Proxy for biodiversity" (Starting Grant no 258482) ran from April 2011 till January 2017, and was aimed at the development of robust, integrated and fully 3-D methods to map complex deep-sea environments (submarine canyons, cold-water coral reefs, seamounts,…), in order to quantify habitat heterogeneity and use this as proxy to estimate the spatial distribution of benthic biodiversity. The outcomes of the project are summarised in a series of protocol factsheets, and can be found on www.codemap.eu

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