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Spatial analysis of marine categorical information using indicator kriging applied to georeferenced video mosaics of the deep-sea Håkon Mosby Mud Volcano

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ABSTRACT

The exact area calculation of irregularly distributed data is in the focus of all territorial geochemical balancing methods or definition of protection zones. Especially in the deep-sea environment the interpolation of measurements into surfaces represents an important gain of information, because of cost- and time-intensive data acquisition. The geostatistical interpolation method indicator kriging therefore is applied for an accurate mapping of the spatial distribution of benthic communities following a categorical classification scheme at the deep-sea submarine Håkon Mosby Mud Volcano. Georeferenced video mosaics were obtained during several dives by the Remotely Operated Vehicle *Victor6000* in a water depth of 1260 m. Mud volcanoes are considered as significant source locations for methane indicated by unique chemoautotrophic communities as *Beggiatoa* mats and pogonophoran tube worms. For the detection and quantification of their spatial distribution 2840 georeferenced video mosaics were analysed by visual inspection. Polygons, digitised on the georeferenced images within a GIS, build the data basis for geostatistically interpolated mono-parametric surface maps. Indicator kriging is applied to the centroids of the polygons calculating surface maps. The quality assessment of the surface maps is conducted by leave-one-out cross-validation evaluating the fit of the indicator kriging variograms by using statistical mean values. Furthermore, the estimate was evaluated by a validation dataset of the visual inspection of 530 video mosaics not included within the interpolation, thus, proving the interpolated surfaces independently. With regard to both validating mechanisms, we attained satisfying results and we provided each category applied for the identification of biogeochemical habitats with a percentage probability value of occurrence.

1. Introduction

In limnology and marine research, environmental and ecological studies are mainly based on datasets obtained at distinct sites (points) or along track lines gathered during cruises by research vessels. Examples for data collection at distinct sites are water samples acquired for chemical analysis of nutrients or pollutants, plankton samples, or geochemical analysis of sediment cores (Fig. 1). From a geoinformatical perspective these data are of the type point (x_1, y_1, z_1) or multipoint (x_1, y_1, $z_1 \ldots z_n$). Sampling by bottom trawls or dredges for fishery or petrography are examples for line features ($x_1 \ldots x_n$, $y_1, \ldots y_n$, $z_1 \ldots z_n$). Only, investigations by multi-beam systems (e.g., applied for bathymetric mapping), by side scan sonar, or video surveys are able to cover strips (polygons) of the seafloor with a width of a few meters to a few hundred meters. Even

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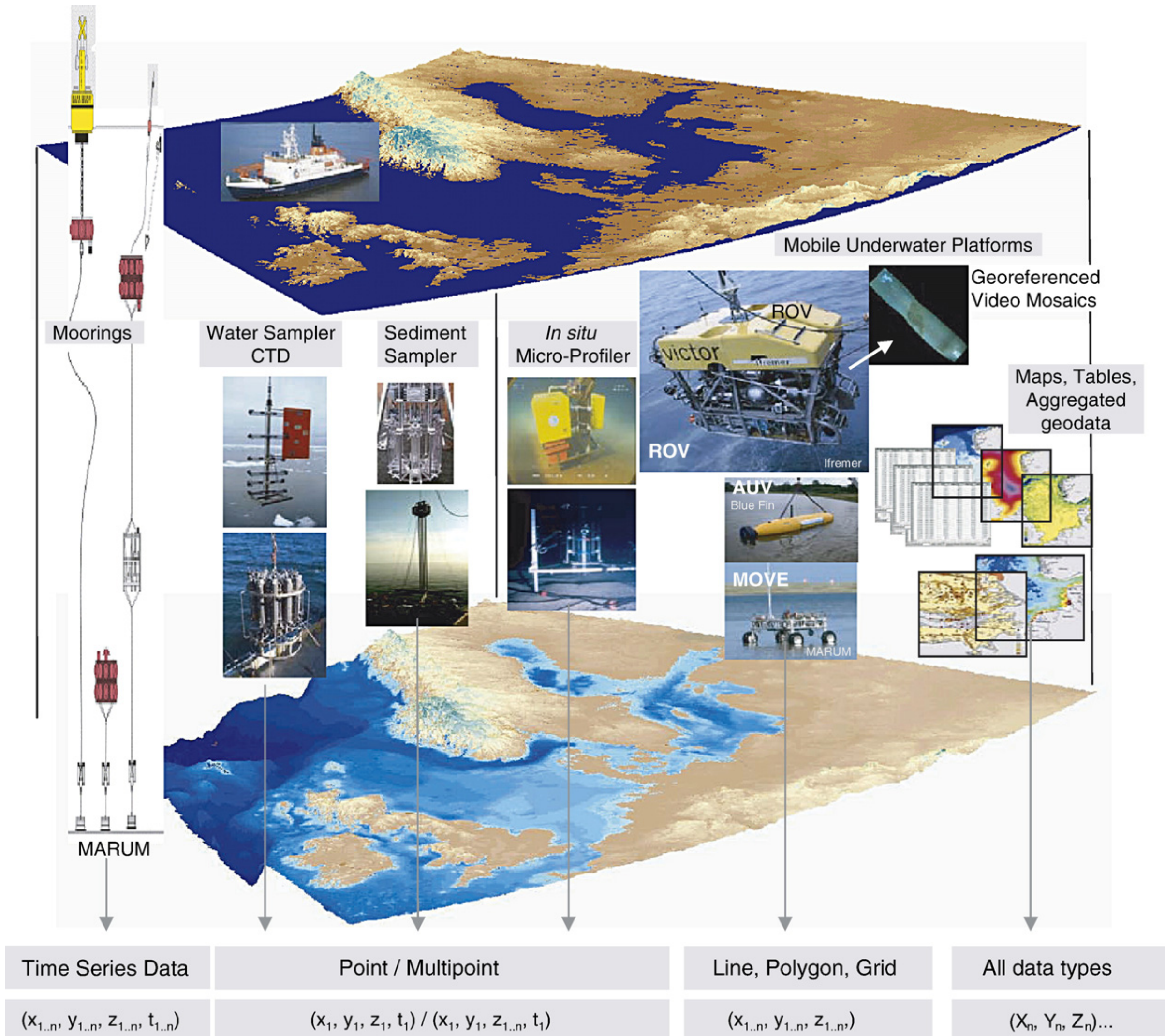

Fig. 1 – Examples for sampling methods and data types used in marine research. New techniques as AUVs, ROVs, Crawlers. or moorings (the two latter from MARUM, Univ. Bremen) provide underwater platforms for in situ analysers, acoustic sensors or video systems and for mapping of the seafloor. AUVs are unmanned, self-propelled vehicles designed to carry out measurements along pre-programmed courses and water depths, generally launched and recovered by a surface vessel. ROVs are connected by a cable to a surface vessel and are usually equipped with manipulators (robot arms) for sampling and experiments at the seafloor.

such surveys are unable to provide a dense coverage of larger areas of the coastal zone or the ocean due to time and financial restrictions.

New underwater technologies, as “Autonomous Underwater Vehicles” (AUVs), “Remotely Operated Vehicles” (ROVs) or Crawlers (Fig. 1), operated by offshore industry and a few research institutes, provides a step towards a refined spatial coverage of sampling sites and multi-parameter mapping of the seafloor. These underwater vehicles serve as platforms for in situ analysers (chemical and biological), for acoustic sensors, and underwater imagery by e.g., high resolution video cameras. A major advantage for multi-parameter mapping by ROVs and AUVs is the very accurate navigation by Ultra Short Base Line (USBL) or inertial navigation during the dives.

Due to the large amount of geodata compiled during cruises and dives by ROVs and AUVs marine environmental and ecological studies require concepts for data management of large volumes of heterogeneous datasets. Spatial analysis has to consider and to combine different types of geodata (point, line, and polygon features or time series) and scales. This includes metric scales as measurements of temperature or chemical concentrations, relative scales derived by acoustic mapping techniques, or categorical data associated to the occurrence/absence of benthic organisms or geological features. Geostatistical techniques for neighbourhood analysis as well as for computation of spatial distributions and maps are applied.

Especially for mapping of geological or biological data, as occurrence of different rocks or sediment types or of benthic organisms and habitats, visual observations by underwater still photography or video imagery are very promising techniques. For example, video surveys by an ROV provides, in contrast to most towed systems, accurately georeferenced