NOAH
North Sea Observation and Assessment of Habitats

Total Organic Carbon (TOC) [%]

GENERAL OVERVIEW

Dataset name:
Total Organic Carbon (TOC) distribution in surface sediments of the southern North Sea

Project:
North Sea – Observation and Assessment of Habitats (NOAH)

Co-Principal Investigator:
Walter Puls ,Ulrike Kleeberg (Metadata and Web Services) , Dietmar Sauer (Model Tool)

Contact:
Helmholtz-Zentrum Geesthacht (HZG),
Max-Planck-Straße 1, 21502 Geesthacht, Ulrike.Kleeberg@hzg.de

DATASET SPECIFICATIONS

Dataset Parameter(s) and supplied Unit(s):
TOC [%]

Date(s) available:
Data collection (1980s – 2010s)

Validated:	**Version Date:**
See Notes and Limitations	*23.05.2014*

Current State:
final

Format:
Raster (tiff)

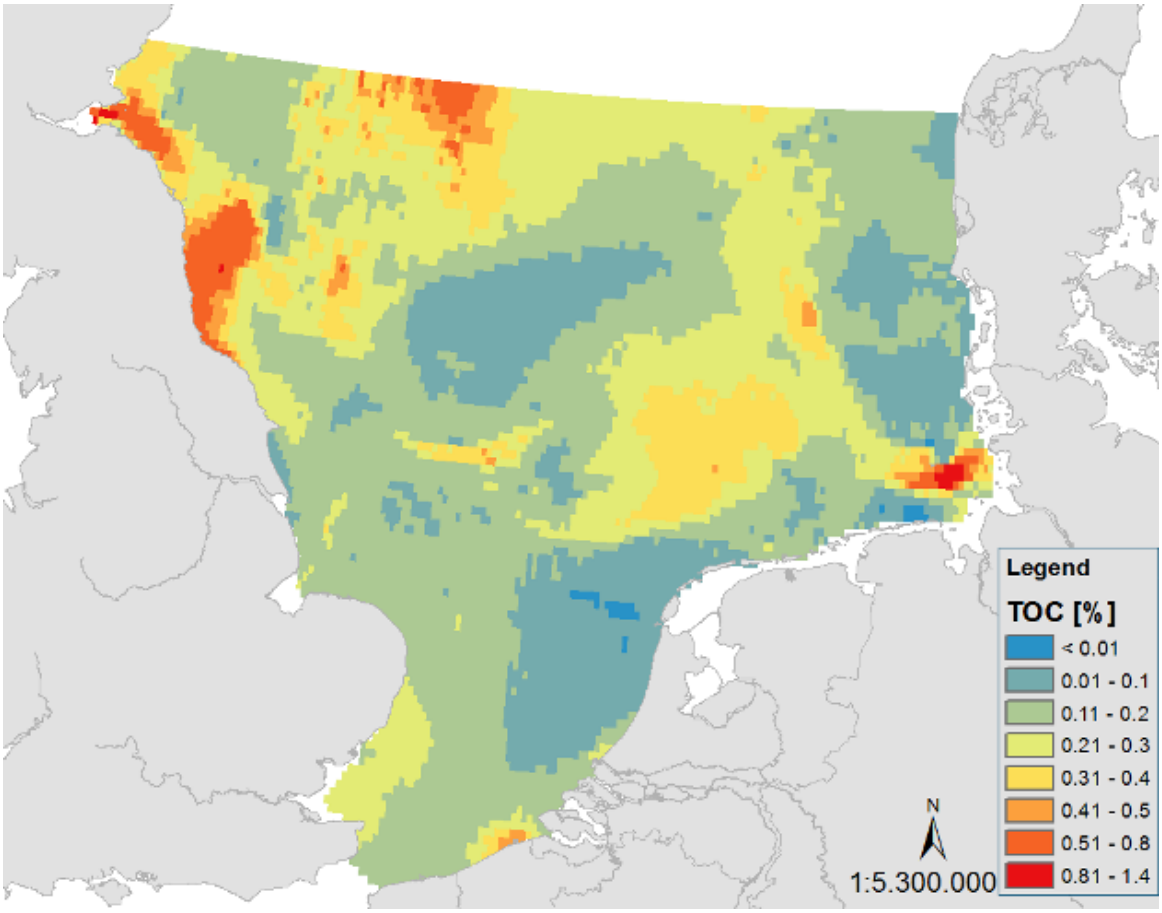
Citation:
Bockelmann, F., W. Puls, U. Kleeberg, D. Müller and K.-C. Emeis (2017). "Mapping mud content and median grain-size of North Sea sediments – a geostatistical approach." Marine Geology 397: 60-71.

Wirth, H. and G. Wiesner(1988).“ Sedimentary facies in the North Sea”. Mittlg. Geol.-Paläoantol. Inst. Univ. Hamburg, 65:269-287

DATASET DETAILS

Abstract
The map shows the spatial distribution of %TOC (total organic carbon as a percentage of dry sediment mass) in the surface sediments of the southern North Sea. Organic matter is preferentially attached to clay and silt sized particles (grain-size < 63 µm). The map of %TOC therefore reflects the spatial distribution of %mud in the North Sea.
Organic pollutants preferably adhere to organic matter. This is why the content of organic pollutants is often given as a percentage of the amount of organic material in the sediment. Organic loading of surface sediments is frequently used as an abiotic factor to explain the community structure of benthic fauna.
%TOC in the map represents the amount of organic matter in the surface sediments, not its nutritional quality (i. e. the food value for benthic animals). In depositional environments the sediment organic matter is mostly refractory and has a low nutritional quality.

The complete area coverage in the map is predicted by Co-Kriging, using %mud as the external variable.
Mapping of TOC provides important background information for spatial analyses of organism assemblages, contaminant loadings and benthic remineralization processes.



Acquisition and Processing Description:

<u>Acquisition:</u>
The basis for the map of %TOC consists of about 2000 individual samples whose spatial distribution is available in gridded form. Only samples from the sediment surface (maximum sub-bottom depth 10 cm) were taken into account.

The TOC data were collected from more than 10 institutions, projects and databases. The oldest data were measured during the eighties. All collected data are united into the same data set, disregarding the date of sampling.
%TOC data are non-uniformly distributed in the southern North Sea. This is due to differing efforts or differing interests in the countries around the North Sea. It is, however, also due to the different ways how organic carbon in sea floor sediment is determined. CEFAS Lowestoft, as one example, measures organic carbon content on the sediment grain-size fraction < 63 µm. BSH Hamburg, as another example, measures %TOC on bulk sediment for using it as a reference value for organic

pollutants, but the majority of BSH organic carbon data is about organic carbon content on the grain-size fraction < 20 µm.

Data Processing:
%TOC data is measured directly from bulk sediment samples. The sample data need not be processed.

Before applying Co-Kriging, the %TOC fraction of each individual sample is converted to base-10 log:

$$log\_TOC = log \frac{0.01\% + \%TOC}{1\ \%}$$

The value "0.01 %" has been included in order to cope with "%TOC = 0". The value "0.01 %" has been selected because the value can be taken as a lower limit of "realistic" %TOC values. The results of the log-conversions of %TOC = 0, 0.001 % and 0.01 % are log_TOC values of -2.00,-1.96 and -1.70, respectively. So the three log_TOC values do not differ appreciably which expresses that differences among values of %TOC < 0.01 % are not regarded as being significant.

The generation of a map covering the North Sea area of interest is done by Co-Kriging using the R-routine "krige" (R-library "gstat"). The values of the primary variable (%TOC of individual samples) are provided at the original sample locations. The values of the secondary variable are provided at the target grid nodes. The secondary variable (%mud) is known at all the target grid nodes.

The result of Co-Kriging is a full-coverage estimation of the primary variable at the target grid nodes. Co-Kriging tends to produce a smoothed image. Along with the estimate of the primary variable ("kriging mean"), kriging gives an estimate of the estimation error ("kriging variance") at every target grid node.

Notes and Limitations:

Data Quality:

The measurement of %TOC involves many steps of sample preparation and different methods of organic carbon determination. There is no way to align the different data sets to one another. Therefore all data were treated equally, regardless of sample preparation and analytical method.

The %TOC values of a newly added data set were inspected for compatibility with already existing %TOC data from the same site. In some cases the new data set was discarded because it did not match the already existing data.

Outliers were removed. Outliers do not always result from improper handling of samples or analysis mistakes, but can also result from the (intentional) selection of sample positions. As an example: Off Sylt island (German Bight) the sediment is invariably sandy or even gravelly. However, there are also small-scale pits due to sand excavation works where the sediment is muddy. It is clear that samples from those pits are completely atypical for the coastal zone off Sylt island. The data obtained from those samples must be treated as outliers.

Data were inspected for incompatibilities across the borders of EEZs within the North Sea. As the %TOC samples are sparse, such incompatibilities were not detectable.

Along the English coast original %TOC data are especially sparse. However CEFAS Lowestoft measured organic carbon content on the grain-size fraction < 63 µm at 44 sites between Dover Strait and 56° N. In order to fill the %TOC data gap along the English coast the CEFAS organic carbon data were converted to %TOC values. It is quite natural that the quality of these converted data is reduced.

Within the North Sea Benthos Project 2000, Hillewaert measured organic matter content (loss on ignition 450 °C) instead of %TOC. Those data were converted to %TOC by a formula which was deduced from North Sea sediment data of the TOSCH project (Wirth and Wiesner 1988).

Error Estimation:

Individual samples:

For individual samples an estimate of the %mud error can be obtained from data of CEFAS Lowestoft (2012). The samples were taken at sites where "it is expected there will not be changes in sediment type at these sites over time".

At a muddy site (Farnes Deep) 12 sediment surface samples were taken between 1999 and 2010 at the same position. For error estimation the %mud values were converted to log scale:

$$log10\_\%mud=log\ (0.01\%+\%mud)/(1\ \%)$$

On this log scale, mean and standard deviation of "log10_%mud" are 1.64 ± 0.03. Re-conversion from log scale to linear scale gives a geometric mean for %mud of 44.1 %. According to the Gaussian law of error propagation the standard deviation of an individual sample's mud content is:

$$stddev\ \%mud=0.03\cdot\ (0.01\%+\%mud)\ \cdot ln(10)$$

This means that the standard deviation is not constant but depends on %mud. For the geometric mean value (%mud = 44.1 %) the standard deviation is ±3.05 %.

At a sandy site (off East Anglia) the geometric mean of %mud (11 sediment surface samples between 2000 and 2010) is 0.115 % with a standard deviation of ±0.11 %

Map southern North Sea:

The standard deviation of "log10_%mud" as predicted by Co-Kriging is in the order of stddev(log10_%mud) = 0.63. This value is rather uniform in space. According to the Gaussian law of error propagation the standard deviation of the kriging mean "%mud" is

$$stddev\ \%mud=\ stddev(log10\_\%mud)\cdot\ (0.01\%+\%mud)\ \cdot ln(10)$$

The spatial distribution of the Kriging standard deviation is thus not uniform in space but is to some extent linearly correlated with the kriging mean %mud.

Instruments / Models:

Instruments:

Surface sediment samples were taken by various types of grab and box core samplers. %TOC was measured by CHN analyzers .

Models:

The generation of area-covering maps (on the basis of individual sample data) is done by Co-Kriging using the R-routine "krige" (R-library "gstat").

Related Datasets:

- *Median grain-size of the surface sediment grain-size distribution*
- *Mud content (grain-size fraction < 63 µm) of surface sediment*

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Data Sources

The data for the generation of sediment maps were obtained from the following institutions:

NAVAL OFFICES and RESEARCH INSTITUTES:
Forschungs- und Technologiezentrum Büsum, Germany
Bundesamt für Seeschifffahrt und Hydrographie (BSH), Hamburg, Germany
Senckenberg Institut Wilhelmshaven, Germany
Helmholtz Zentrum Geesthacht, Germany
Bioconsult Schuchardt & Scholle GbR, Bremen, Germany
Deltares, Utrecht, The Netherlands
British Geological Survey, Marine Information Project, Edinburgh, UK
Marine Scotland, Marine Laboratory, Aberdeen, UK
Universität Hamburg, Institut für Geologie und Paläontologie, Hamburg, Germany
Royal Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands
Geological Survey of the Netherlands (TNO), Utrecht, The Netherlands
School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, UK
CEFAS, Lowestoft, UK
Geological Survey of Norway (NGU), Trondheim, Norway
Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
Bureau de Recherches Géologiques et Minières (brgm), Orléans, France

PROJECTS:
Management, Research and Budgeting of Aggregates in Shelf Seas related to End-users (MAREBASSE, 2002-2006), Ghent University, Belgium
North Sea Benthos Survey 1987
North Sea Benthos Project 2000
Zirkulation und Schadstoffumsatz in der Nordsee (ZISCH, 1984-1989), Universität Hamburg
Biogeochemistry and Distribution of Suspended Matter in the North Sea and Implications to Fisheries Biology (TOSCH, 1984-1988), Universität Hamburg
Geopotenzial Deutsche Nordsee (GPDN, 2009-2013), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) Hannover, Landesamt für Bergbau, Energie und Geologie (LBEG) Hannover, Bundesamt für Seeschifffahrt und Hydrographie (BSH) Hamburg, Germany

DATABASES:
Flanders Marine Institute (VLIZ) Data Centre, Ostend, Belgium
Management Unit of the North Sea Mathematical Models (MUMM), Brussels, Belgium
International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark
Publishing Network for Geoscientific & Environmental Data (PANGAEA), Alfred-Wegener-Intitut (AWI), Bremerhaven, Germany