NOAH
North Sea Observation and Assessment of Habitats

Bedload Transport Frequency

GENERAL OVERVIEW

Dataset name:
Frequency of bedload transport events in the North Sea from 1984 to 2014

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

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DATASET SPECIFICATIONS

Dataset Parameter(s) and supplied Unit(s):
Bedload Transport Statistics [%]

Date(s) available:
2006 (Map View, yearly Statistic), 1984 – 2015 Model Tool (time resolution: hourly)

Validated:	**Version Date:**
See notes and limitations	*23.05.2014*

Current State:
Updates expected

Format:
netCDF, Vector (Esri FGDB), CSV

Citation:

Kapitza H. and D. Eppel (2000).“ Simulating morphodynamical processes on a parallel system”. In: Spaulding ML and Butler HL (eds) Estuarine and Coastal Modelling, Proceedings of the sixth International Conference. New Orleans, Louisiana, USA, November 3-5, 1999

Pätsch, J., Burchard, H., Dieterich, C., Gräwe, U., Gröger, M., Mathis, M., Kapitza, H., Bersch, M., Moll, A., Pohlmann, T., Su, J., Hagemann, H. T. M., Schulz, A., Elizalde, A., Eden, C., 2017. An evaluation of the NorthSea circulation in global and regional models relevant for ecosystem simulations. Ocean. 116, 70-95, ISSN 1463-5003. https://doi.org/10.1016/j.ocemod.2017.06.005.

Soulsby, R., Whitehouse, R., Marten, K., 2012. Prediction oftime-evolving sand ripples in shelf seas. Continental Shelf Research. 38, 47-62, ISSN 0278-4343. https://doi.org/10.1016/j.csr.2012.02.016.

Soulsby, R., 1997. Dynamics of Marine Sands: A Manual for Practical Applications. Thomas Telford Ltd, London.

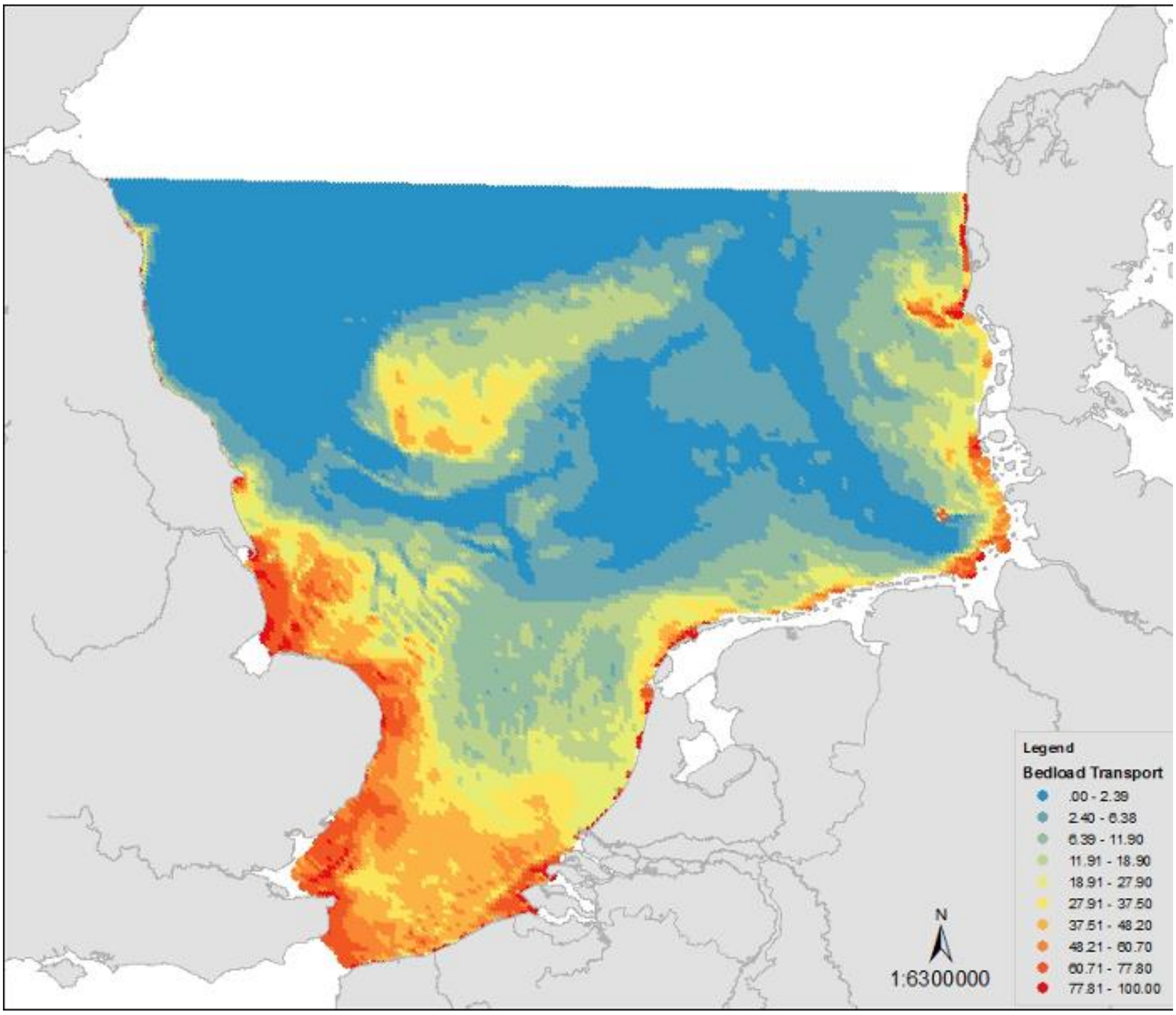
Staneva, J., Behrens, A., Groll, N., 2014. Recent Advances in WaveModelling for the North Sea and German Bright. Die Küste: Models of Coastal Waters in Germany – Performance and Application Examples. 81, 233-254, ISSN 0452-7739.

WAMDI-Group, 1988. The WAM model − a third generation ocean wave prediction model. Journal of Physical Oceanography. 18, 1775−1810. https://doi.org/10.1175/1520-0485(1988)018<1775:TWMTGO>2.0.CO;2

DATASET DETAILS

Abstract

Values are a function of median grain size and model estimates of current and wave-induced bed shear stress. The data were calculated to provide information on sediment mobility, resuspension and transport for habitat mapping and biogeochemical modelling.
The map shows the frequency of bedload transport events during 2006, given in percent.
Strong tidal currents in the Southern Bight and along the English, Dutch and German coasts generate high frequencies of bedload transport. On Dogger Bank the frequency of bedload is also increased, but here bedload is produced by waves. This is also true for Horns Rev at the Danish coast. North of Dogger Bank bedload is infrequent because tidal currents are weak and because the water is so deep that surface water waves hardly reach the bottom.



Acquisition and Processing Description:

The bedload transport by waves plus currents was calculated according to the formulas of Soulsby (1997). The basic variables entering the Soulsby bedload formulas are the median grain-size of the sediment bed, the current bed shear stress (magnitude and direction) and the wave bed shear stress (amplitude and direction of wave travel). "For combined waves and currents, the waves provide a stirring mechanism which keeps the sediment grains mobile, while the current adds to the stirring and also provides a mechanism for net transport" (Soulsby 1997).

Acquisition and Processing ***median grain size**:*

The basis for the median grain-size distribution consists of more than 50,000 individual samples whose spatial distribution (in gridded form) is shown here. Only samples from the sediment surface (maximum sub-bottom depth 10 cm) were taken into account. The grain-size data were collected from more than 10 institutions and databases. The oldest data were measured in the fifties. All collected data are united into the same data set, disregarding the date of sampling.

The median grain-size (the 50 percentile) is the midpoint of a grain-size distribution. For a given set of grain-size fractions (e.g. obtained by sieving), the median grain-size is determined by a so-called Tauber Fit.
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 (median grain-sizes 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 (log-converted %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.

Acquisition and Processing ***wave bed shear stress**:*

The requirements for the calculation of the wave-generated bed shear stress τ_W are the availability of: (1) wave height and wave period and (2) the median grain-size of bottom sediments.

(1) Wave parameters were calculated by the WAM model. The WAM model is used for long-term computation runs at the Institute of Coastal Research, HZG Geesthacht. The calculated wave parameters are provided as gridded, area-covering data. The wave data are provided every one hour.
(2) The basis for the median grain-size distribution consists of more than 50,000 individual samples whose spatial distribution (in gridded form) is shown here. Only samples from the sediment surface (maximum sub-bottom depth 10 cm) were taken into account. The grain-size data were collected from more than 10 institutions and databases. A full-coverage, gridded estimation of the median grain-size is obtained by Co-Kriging.

The calculation of bed shear stress generated by waves in the North Sea uses the formulas in Soulsby (1997). The wave-generated bed shear stress is oscillatory, having an amplitude τ_W. Significant wave height H_S and mean wave period T_{m2} were provided by the WAM model at time intervals of 1 hour. From these parameters and the water depth, the amplitude U_W of the wave orbital velocity at the sea bed was calculated.
H_S and T_{m2} represent random waves with a natural spectrum. The near-bed velocity amplitude U_W of a monochromatic (single frequency) wave having the same velocity variance as the full spectrum was calculated using the JONSWAP curve in Fig. 14 of Soulsby (1997). The procedure is described on page 79 in Soulsby (1997). The zero up-crossing wave period T_Z used in Soulsby (1997) is approximately equal to T_{m2} (remark: Soulsby (1997) uses the term "T_m" instead of "T_{m2}").
The amplitude of the wave skin-friction shear-stress τ_W was calculated by the standard formula

$$\tau_W = \frac{1}{2} \cdot \varrho_W \cdot f_W \cdot U_W^2$$

where f_W is the wave (skin) friction factor and ρ_W is the density of sea water. The wave friction factor f_W was calculated using Soulsby's own formulas in Soulsby (1997).
To produce an area-covering map of τ_W the first step was the generation of area-covering maps (a) of sediment median grain-size D_{50} and (b) of the wave parameters H_S and T_{m2}. A bathymetry map provided the water depths. A D_{50} map was produced by spatial interpolation of individual sample data. This interpolation was done by Co-Kriging using the R-routine "krige" (R-library "gstat"). The external variable used by Co-Kriging was log-converted %mud. Maps of H_S and T_{m2} were produced from the wave data provided by the WAM model.
Based on the maps of D_{50}, H_S and T_{m2}, an area-covering map of τ_W (τ_W values positioned in the center of horizontal grid cells) was produced. For the year 2006 such maps of τ_W were produced at every full hour. The final step was to generate the map of τ_W for the whole year 2006 by calculating the time averages of each grid cell.

Acquisition and Processing current parameter: **current bed shear stress**:

The requirements for the calculation of the current bed shear stress τ_C are the availability of: (1) current velocities (including their directions) and (2) the median grain-size of bottom sediments.

(1) Currents were calculated by the TRIM model. The TRIM model is used for long-term computation runs at the Institute of Coastal Research, HZG Geesthacht. The calculated current velocities are provided as gridded, area-covering data, with a vertical resolution of 1 m in the upper 20 m of the water column. The current data are provided every one hour.
(2) The basis for the median grain-size distribution consists of more than 50,000 individual samples whose spatial distribution (in gridded form) is shown here. Only samples from the sediment surface (maximum sub-bottom depth 10 cm) were taken into account. The grain-size data were collected from more than 10 institutions and databases. A full-coverage, gridded estimation of the median grain-size is obtained by Co-Kriging.

The calculation of τ_C in the North Sea uses the formulas in Soulsby (1997).
Vertical profiles of current velocities are provided by the TRIM model with a time interval of 1 hour. The calculation of τ_C in a model grid cell is done in three steps:

- *A near-bottom vertical mean u_{MEAN} is calculated based on the current velocities in the four grid layers which are nearest to the bottom. The water column which is covered by the four layers is H_4.*
- *The current velocity u_1 at 1 m above bottom is calculated from H_4 and the "near-bottom vertical mean velocity" by assuming a logarithmic velocity profile. The applied bed roughness length z_{0TRIM} is the same z_0 as the one used in the TRIM model:*

$$u_1 = u_{MEAN} \cdot \frac{ln \frac{1m}{z_{0TRIM}}}{ln\left(\frac{H_4}{z_{0TRIM}}\right) - 1}$$

- *τ_C is calculated from u_1, now applying $z_0 = D_{50}/12$ in the logarithmic velocity profile. D_{50} is the local median grain-size, ρ_W is the water density. :*

$$u_* = \frac{0.4 \cdot u_1}{ln \frac{1m}{z_0}}$$

$$\tau_C = \varrho_W \cdot u_*^2$$

To produce an area-covering map of τ_C the first step was the generation of an area-covering map of median grain-size D_{50}. A D_{50} map was produced by spatial interpolation of individual sample data. This interpolation was done by Co-Kriging using the R-routine "krige" (R-library "gstat"). The external variable used by Co-Kriging was log-converted %mud.
Based on the D_{50} data and the velocity data calculated by the TRIM model, an area-covering map of τ_C (τ_C values positioned in the center of horizontal grid cells) was produced. For the year 2006 such maps of τ_C were produced at every full hour. The final step was to generate the map of τ_C for the whole year 2006 by calculating the time averages of each grid cell.

Notes and Limitations:

WAM Model
The WAM model is a state-of-the-art spectral wave model. The quality of its results depends primarily on the quality of wind forcing and on the correctness of the bathymetry. Wind forcing is simulated with the regional climate model COSMO-CLM (Groll et al. 2013), the first non-hydrostatic atmosphere model of the German Weather Service (DWD). This atmosphere model is at the leading edge of research and development.
The formulas used for calculating τ_W from the near-bed wave velocities were derived by Soulsby (1997). Soulsby is one of the leading experts for hydraulics and sediment transport in the world. The formulas and procedures suggested by him are state-of-the-art.

TRIM Model
TRIM is a 3-dimensional fully baroclinic model. It calculates sea surface elevation, three velocity components, temperature and salinity. In addition it calculates the vertical eddy diffusivity by using the public domain turbulence model GOTM. TRIM is a state-of-the-art model - the quality of its results depends primarily on a correct bathymetry and correct boundary conditions (e.g. wind velocity above the water surface, water elevation at the seaward boundaries). TRIM uses the results of the REgional atmosphere MOdel REMO (Feser et al. 2001) to drive current velocities and water temperatures at the water surface.
The formulas used for calculating τ_C from the near-bed current velocity are the standard formulas found in each textbook on hydraulics.

Interpolated grain size data:
Raw data consists of the grain-size fractions of individual sediment samples. The main difference between data sets is that the grain-size fractions were gained by different methods: wet or dry sieving, laser diffraction analyzer (from different manufacturers), settling test. In addition, sample preparation influences the results quite substantially. There is no way to align the different data sets to one another. Therefore all data were treated equally, regardless of the analytical method.
Processed median grain-sizes of a newly added data set were inspected for compatibility with already existing median grain-sizes 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.
Data were inspected for incompatibilities across the borders of EEZs within the North Sea.
Two special aspects which reduce the quality of the median grain-sizes:
(1) A Tauber fit was not applied if a substantial part (e.g. 55 %) of a sample's sediment mass was not analyzed adequately for grain-size fractions. This was the case if either the coarsest or the finest fraction represents more than 55 % of the sediment mass. The grain-size parameters of that sample are not included in the results list. The consequence is that areas with particularly coarse or fine sediment are not adequately represented in the maps. This means a substantial reduction of data quality.
Along the English North Sea coast, the situation described above is mostly distinct. The percentage of gravel (grain-size > 2 mm) can be above 90 % while the standard grain-size analysis procedure

used a coarsest sieve of 2 mm. However, in the case of the English coast sediment samples, a Tauber fit was nevertheless carried out. This could be done because the sediment fraction > 2 mm was artificially split into several sub-fractions. The rule for that artificial splitting was obtained from more adequate grain-size analyses (using sieves of up to 45 mm mesh size) of coarse samples from the same study area.
(2) In the German Bight the dominating grain-size data set is that of Figge (1981). Unfortunately the grain-size fraction > 4 mm was separated from the sediment sample before starting the grain-size analysis. The existence of grains > 4 mm was recorded in the sample protocol, but the percentage mass of grains > 4 mm was not recorded. In German Bight areas with much gravel, the median grain-sizes given in the maps are thus too small. This bias reduces the quality of the Figge data for coarse-grained sediments.

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