NOAH
North Sea Observation and Assessment of Habitats

Shear Stress by current

GENERAL OVERVIEW

Dataset name:
The bed shear stress in the North Sea as induced by currents for the year 2006

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

Co-Principal Investigator:
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DATASET SPECIFICATIONS

Dataset Parameter(s) and supplied Unit(s):
Shear Stress by current (τ_C) , Statistics Year 2006 [N/m²]

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:

Feser, F., R. Weisse, and H. von Storch, 2001: Multi-decadal atmospheric modeling for Europe yields multi-purpose data. Eos Transactions, 82, 305,310

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., H. Burchard, C. Dieterich, U. Gräwe, M. Gröger, M. Mathis, H. Kapitza, M. Bersch, A. Moll, T. Pohlmann, J. Su, H. T. M. Ho-Hagemann, A. Schulz, A. Elizalde and C. Eden (2017). "An evaluation of the North Sea circulation in global and regional models relevant for ecosystem simulations." Ocean Modelling 116: 70-95.

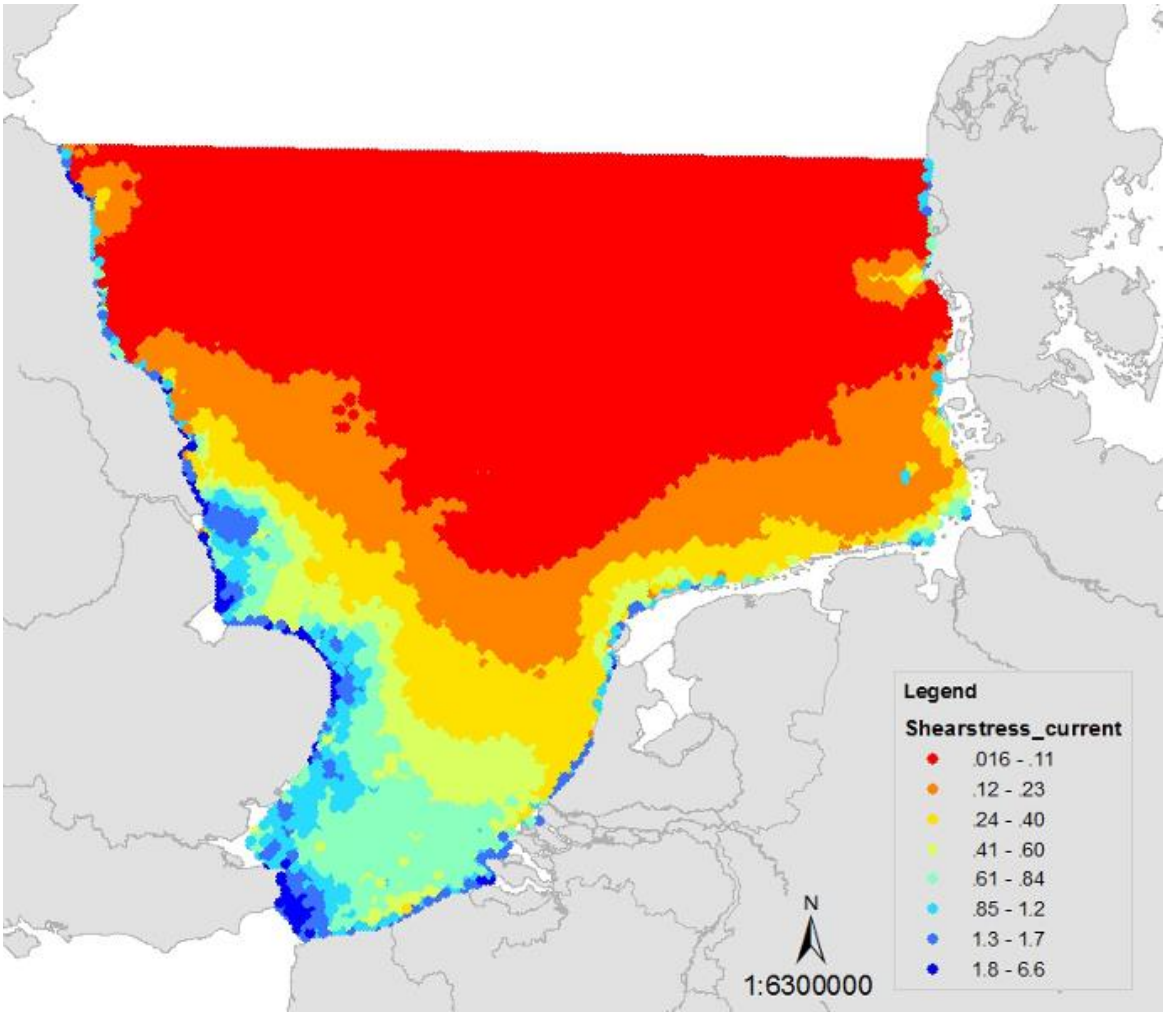
Soulsby, R., Whitehouse, R., Marten, K., 2012. Prediction oftime-evolving sand ripples in shelf seas. Continental Shelf Research. 38, 47-62, ISSN 0278-4343. https://doi.org/10.1016/j.csr.2012.02.016.

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

DATASET DETAILS

Abstract

Spatial distribution of the bed shear stress (τ_C) in the North Sea as induced by currents for the year 2006. Data represent annual average values calculated from hourly current data produced with the TRIM model. Bed shear-stress is an important quantity for sediment transport and has a potential effect on benthic faunal distributions.



The map shows the spatial distribution of time-averaged bed shear stress generated by currents in the southern North Sea. The time-averaging period is the year 2006.
The skin-friction bed shear-stress (or bottom friction) is the frictional force exerted on unit area of sea bed generated by currents and/or waves. It is usually given in "Newton per m^2". The skin-friction bed shear-stress τ is an important quantity for sediment transport purposes (Soulsby 1997). So it may be assumed that τ also represents a relevant impact on benthic fauna.
The bed shear stress generated by currents only is τ_C.
The bed shear stess τ_C is highest in the Southern Bight and along the English coast south of Flamborough Head. In these areas tidal currents are particularly strong. Near-bed current velocities

and thus τ_C generally decrease towards the north. Moreover near-bed currents in shallow water are stronger than in adjacent deeper water.

Acquisition and Processing Description:

Acquisition:

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

Processing Description:

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

- 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:

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Data Quality:
Concerning the quality of the median grain-size data see the appropriate section of the median grain-size map.

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 τC from the near-bed current velocity are the standard formulas found in each textbook on hydraulics.

Error Estimation:
The uncertainty of one individual value of τ_C depends on the uncertainties of the median grain-size and of the near-bed current velocity. The formulas for the calculation of τ_C are assumed to be exact.
The uncertainty of the median grain-size in ϕ-scale is about 0.68. This uncertainty is the Kriging standard deviation shown here.
The uncertainty of current velocities as calculated by the TRIM model was estimated from comparing the model results with ADCP measurements in the German Bight. At the ADCP site maximum tidal currents were about 50 cm/s. The measurements were carried out by the Federal Maritime and Hydrographic Agency Hamburg in October 2000. Only the peak values U of (vertically averaged) ebb and flood tidal currents were compared. The result of 87 peak values U was: The relative differences

$$\frac{U_{ADCP} - U_{TRIM}}{U_{TRIM}} \cdot 100$$

have a mean and a standard deviation of -8.7 % ± 14 %. The bias of -8.7 % may be due to the special characteristics of the site (near Helgoland island), it is not considered any further. The standard deviation of ± 14 % is taken as typical uncertainty of the simulated current velocities as compared to the true current velocities. The result is valid for depth-mean currents. It is assumed that the result is also valid for near-bed currents.
The uncertainty of τ_C is composed of the ϕ50 uncertainty and of the uncertainty of the near-bed current velocity. These two uncertainties are joined by a Monte Carlo procedure. The random numbers for the Monte Carlo procedure were taken from a normal (Gaussian) distribution. Typically N = 10000 realizations of τ_C were calculated during a Monte Carlo simulation run for one error estimation. The result was a standard deviation for τ_C of about ±29 %. According to the Gaussian law of error propagation, the uncertainty of the current velocity alone induces an uncertainty of 2·14 = 28 %. This shows that the additional uncertainty induced by median grain-size (via the bed skin roughness z_0) is comparatively small.
The τ_C-map shows the time-averaged bed shear stress τ_C for the year 2006. The uncertainty of this annual average is estimated by comparing the 2006 map with maps of other years. The results of the five years 2003 to 2007 were available for calculating the variability of τ_C between years. In each grid cell the standard deviation of five annual τ_C-averages is determined. To obtain a relative variability, a standard deviation is divided by the overall five-year average of τ_C. The map with the spatial distribution shows that the τ_C variability between years is below 2 % in most parts of the southern North Sea. This is due to the dominance of tidal currents which do not change between years.

Instruments / Models:
Current velocities are the basis of the determination of current generated skin-friction bed shear stress τ_C. These currents were calculated by the TRIM model. The formulas to obtain τ_C from the current velocities are given here.

Related Datasets:

- τ_W*, the skin-friction bed shear stress generated by waves*
- $\tau_{CW.MAX}$*, the skin-friction bed shear stress generated by the combined action of waves and currents.*

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