NOAH
North Sea Observation and Assessment of Habitats

Shear Stress by wave

GENERAL OVERVIEW

Dataset name:
North Sea Bed Shear Stress by Waves (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_w) , 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

Gaslikova, L., I. Grabemann, N. Groll (2013). „Changes in North Sea storm surge conditions for four transient future climate realizations". Nat. Hazards 66:1501–1518
https://doi.org/10.1007/s11069-012-0279-1

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

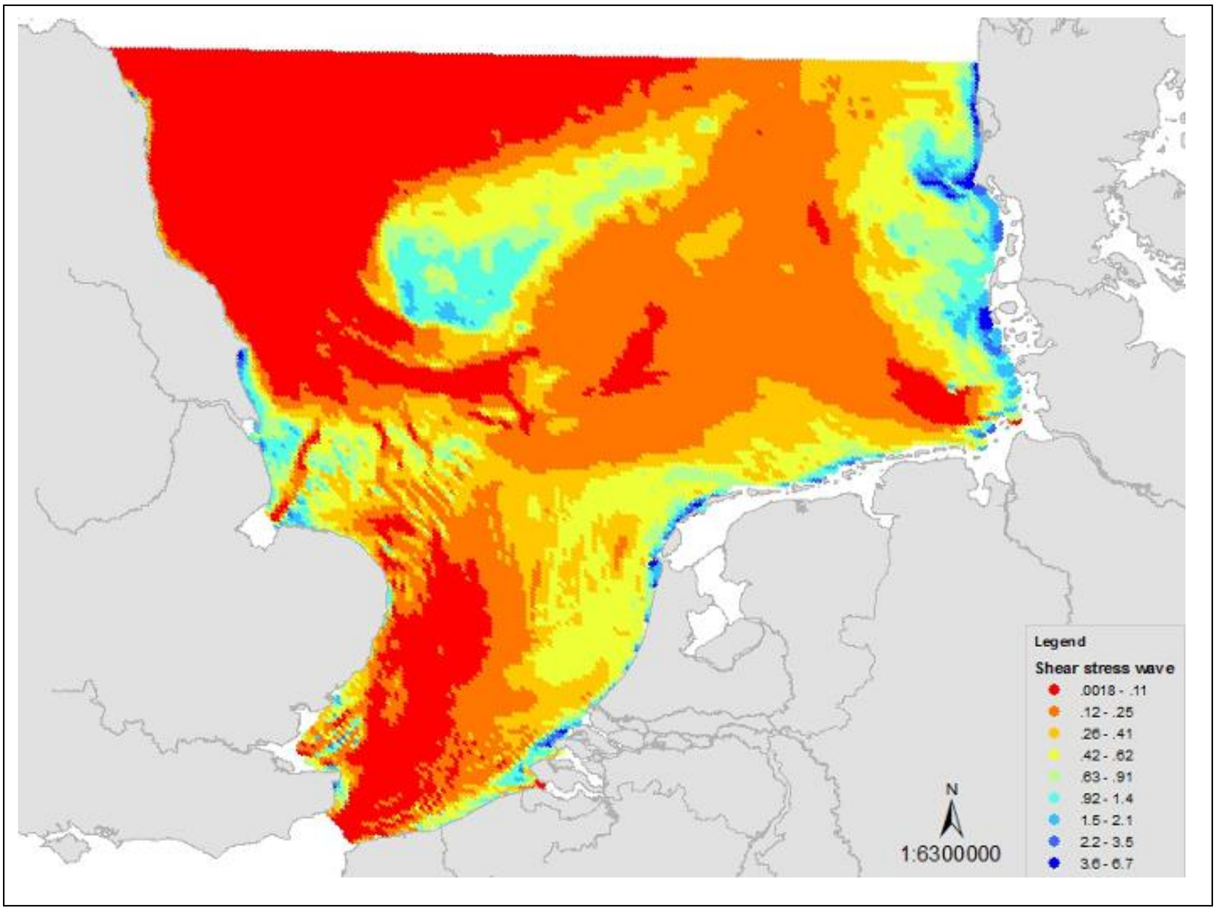
Spatial distribution of the bed shear stress in 2006 as induced by the dominating waves regime (τ_W) in the North Sea. Data represent annual average values calculated from hourly wave data produced with the WAM model. Bed shear-stress is an important quantity for sediment transport and has a potential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

The map shows the spatial distribution of time-averaged bed shear stress generated by waves in the southern North Sea. Wave data were calculated by the WAM model. 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 waves alone is τ_W.

The bed shear stress τ_W is high in shallow water and low in deep water. This is because the oscillatory water motion due to surface water waves decreases with depth.


Legend
Shear stress wave
.0018 - .11
.12 - .25
.26 - .41
.42 - .62
.63 - .91
.92 - 1.4
1.5 - 2.1
2.2 - 3.5
3.6 - 6.7
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NOAH
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Acquisition and Processing Description:

Acquisition:

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.

Processing Description:

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 c 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.

Notes and Limitations:

Data Quality:

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

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 (Gaslikova 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 τW 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.

Error Estimation:

The uncertainty of one individual value of τ_W depends on the uncertainties of the input data and of the formulas used to calculate τ_W. These uncertainties (given as standard deviations) are:

(1) The uncertainty of the median grain-size D_{50}. The uncertainty in ϕ-scale is about ±0.68. This uncertainty is the Kriging standard deviation shown here.

(2) The uncertainty of the two wave parameters used for the calculation of the near-bed amplitude U_W of the wave orbital velocity: the wave height and the wave period. Weisse and Günther (2007) report on a comparison between observed and hindcast wave data in the North Sea. The relative errors of the significant wave height and the mean wave period T_{m2} were found to be ± 30 % and 18 %, respectively.

(3) The uncertainty of the calculated wave (skin-) friction factor f_W. The uncertainty of the wave friction factor is estimated from the data points plotted in Fig. 15 (Soulsby 1997). The plot shows the deviations of a fitted f_W-equation from measured f_W data. The standard deviation of the difference between fitted $\log(f_W)$ and measured $\log(f_W)$ is ±0.11.

It may be taken into account that the uncertainties derived from the results of Weisse and Günther (2007) are based on data from the atmospheric model REMO (Feser et al. 2001). The wave data used here, however, were calculated not with REMO, but with the follow-up model CCLM (Groll et al. 2013) which should be more precise than REMO. By using the (higher) uncertainties of the REMO results, the error estimation should be on the safe side.
The uncertainty of τ_W is composed of the uncertainties given above. The 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_W were calculated during a Monte Carlo simulation run for one error estimation.
The results show that the relative standard deviation of τ_W depends on the magnitude of τ_W: the relative error increases with decreasing τ_W. The relative standard deviation is roughly between 60 and 80 %. The frequency distribution of the Monte Carlo τ_W-realizations is positively skewed.
The τ_W-map shows the time-averaged bed shear stress τ_W 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_W between years. In each grid cell the standard deviation of five annual τ_W-averages is determined. To obtain a relative variability, a standard deviation is divided by the overall five-year average of τ_W. The map with the spatial distribution shows that the τ_W variability between years is between 10 % and 35 % in most parts of the southern North Sea

Instruments / Models:

The wave parameters wave height and wave period are the basis of the determination of wave generated skin-friction bed shear stress τ_W. Wave height and wave period were calculated by the WAM model. The formulas to obtain τ_W from the wave parameters are given in Soulsby (1997).

Related Datasets:

- τ_C, *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