NOAH
North Sea Observation and Assessment of Habitats

Maximum Shear Stress 2010 - 2014

GENERAL OVERVIEW

Dataset name:
Spatial distribution of time-averaged maximum bed shear stress

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):
Maximum Shear Stress [N/m²]

Date(s) available:
Map View and Yearly Statistics: 2010 – 2014, Model Tool (1984 – 2015, , resolution hourly)

Validated:	**Version Date:**
Yes (See Notes and Limitations)	*23.05.2014*

Current State:
Updates expected

Format:
netCDF, Vector (Esri FGDB), CSV

Citation:

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

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

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Soulsby, R., Whitehouse, R., Marten, K., 2012. "Prediction of time-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.

Weisse, R., and H. Günther (2007), Wave climate and long-term changes for the Southern North Sea obtained from a high-resolution hindcast 1958–2002, Ocean Dyn., 57, 161–172, https://doi.org/10.1007/s10236-006-0094-x.

DATASET DETAILS

Abstract

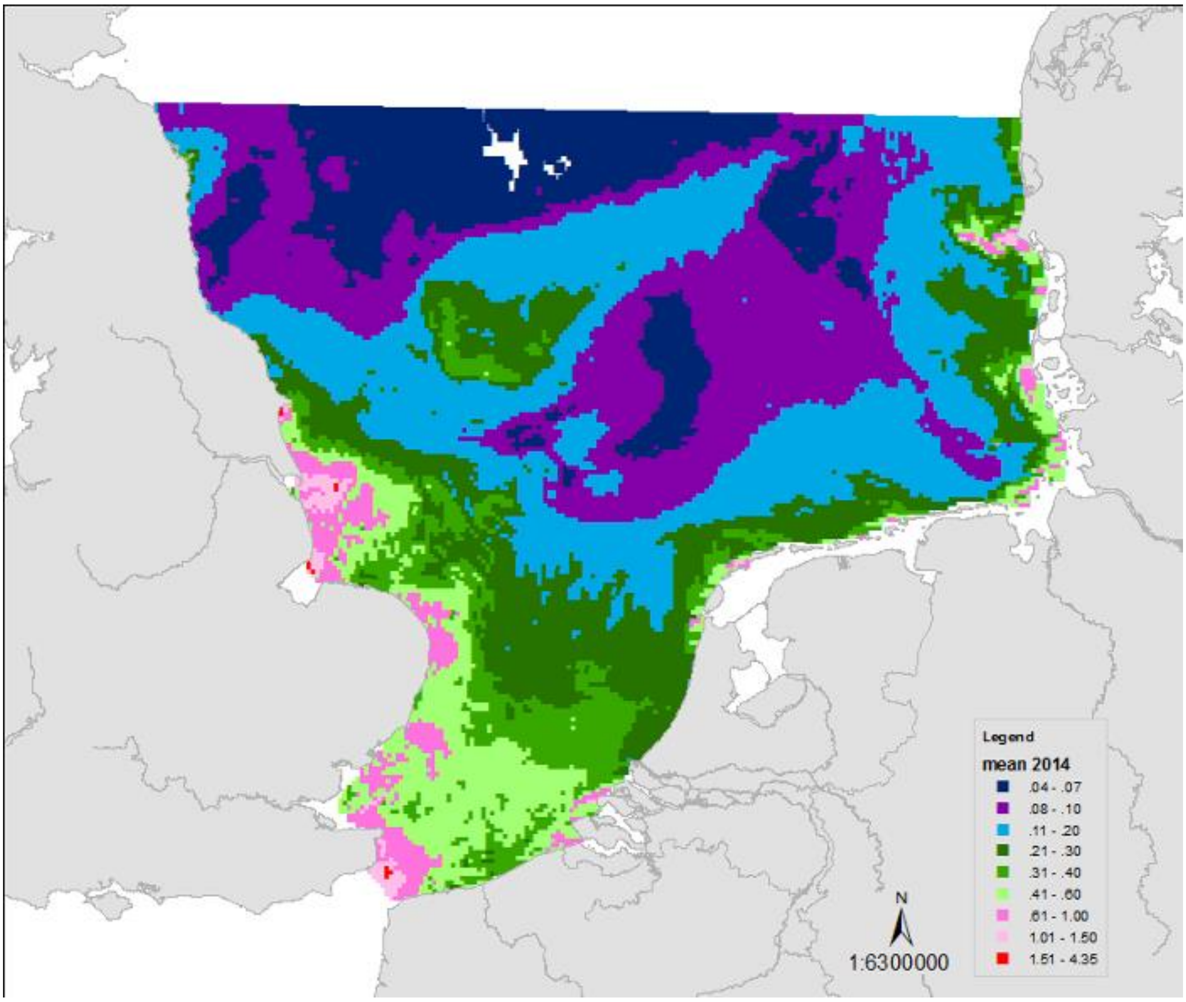
Spatial distribution of the bed shear stress maximum (2010 to 2014) as induced by the combined action of the dominating current and waves regime in the North Sea. Data represent annual average values calculated from hourly current and wave data produced with the TRIM and WAM model, respectively.
Bed shear-stress is an important quantity for sediment transport and has a potential effect on benthic faunal distributions.

The current data were calculated by the TRIM model. The wave data were calculated by the WAM model.

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 m2". 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.

According to Soulsby (1997), "the bed shear stresses beneath combined waves and currents are enhanced beyond the values which would result from a simple linear addition of the wave-alone and current-alone stresses. This occurs because of a non-linear interaction between the wave and current boundary layers." The bed shear stresses generated by the combined action of waves and currents are commonly represented (a) by the mean and (b) by the maximum bed shear stress during a wave cycle. The map shows the maximum bed shear stress τCW.MAX. The most important task of τCW.MAX in a sediment transport model is the erosion of bottom sediment.

The spatial distribution of τCW.MAX in the southern North Sea shows the characteristics of both the current bed shear stress τC and the wave bed shear stress τW. The high values of τCW.MAX in the Southern Bight and along the English coast are due to high τC values (resulting from strong tidal currents), while the high values of τCW.MAX in shallow areas (e.g. Dogger Bank) are due to high τW values.



Acquisition and Processing Description

Acquisition:

The requirements for the calculation of the wave-current-generated maximum bed shear stress τCW.MAX are the availability of: (1) wave height and wave period, (2) near bed current velocity and (3) 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) Current velocities were calculated by the TRIM model. Just as the WAM model, the TRIM model is also 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. The current data are provided every one hour.

(3) 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 maximum bed shear stress generated by the combined action of currents and waves, τCW.MAX, uses the formulas in Soulsby (1997). In the case of waves, the bed shear stress is oscillatory, having an amplitude τW.

The data processing to obtain the current-alone bed shear stress τC and the wave-alone bed shear stress τW are described in the text of the respective map. Both τC and τW are available at time intervals of 1 hour. The information about τC and τW also implies their directions.

The determination of τCW.MAX from τC and τW is done by using the approach DATA2 in Soulsby (1997).

Based on the maps of τC and τW, an area-covering map of τCW.MAX (positioned in the center of horizontal grid cells) was produced. For the year 2006 such maps of τCW.MAX were produced at every full hour. The final step was to generate the map of τCW.MAX for the whole year 2006 by calculating the time averages of each grid cell.

Used Models:

The wave parameters significant wave height H_S , mean wave period T_{m2} and wave direction were calculated by the WAM model. The near-bed current velocity (both magnitude and direction) was calculated by the TRIM model. The formulas to obtain $\tau_{CW.MAX}$ from wave and current data are given in Soulsby (1997).

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 the 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.

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 formula used for calculating $\tau CW.MAX$ from the near-bed current and wave velocities were derived by Soulsby (1997). Soulsby tested several relevant theories and models against a data set of 131bed shear stresses which were measured both in the laboratory and in the field. He finally derived a formula "DATA2" which can be regarded as the "model of choice" as the "DATA2" formula is reliable and robust.

<u>Error Estimation:</u>
The uncertainty of one individual value of $\tau CW.MAX$ depends on the uncertainties of the input data and of the formulas used to calculate $\tau CW.MAX$. These uncertainties (given as standard deviations) are:
(1) The uncertainty of the median grain-size D50. 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 UW 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 error of the significant wave height and the mean wave period Tm2 was found to be ± 30 % and 18 %, respectively.
(3) The uncertainty of the near-bed current velocity which is estimated to be ± 14 %.
(4) The uncertainty of the wave direction is equated to the uncertainty of the wind direction. The uncertainty of the wind direction was roughly estimated from a scatterplot in Weisse and Günther (2007): the uncertainty of the wave direction is ± 30°.
(5) The uncertainty of the calculated wave (skin-) friction factor fW. 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 fW-equation from measured fW data. The standard deviation of the difference between fitted log(fW) and measured log(fW) is ±0.11.
(6) The uncertainty of the formula which calculates $\tau CW.MAX$. The uncertainty of the $\tau CW.MAX$-formula itself (the uncertainty if all input data are precisely known) was deduced from Fig. 17 in Soulsby (1997) which shows the results of eight relevant models to calculate $\tau CW.MAX$. Discarding two models as outliers, the standard deviation of the remaining six models was $\pm 0.064\cdot(\tau C + \tau W)$.
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 $\tau CW.MAX$ 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 $\tau CW.MAX$ were calculated during a Monte Carlo simulation run for one error estimation.
The results show that the relative standard deviation of $\tau CW.MAX$ depends on the magnitude of $\tau CW.MAX$: the relative error increases with decreasing $\tau CW.MAX$. As an example, for a wave with a significant wave height of 3.4 m and a wave period of 6.5 s, travelling at angle 45° to a steady current of near-bed velocity 0.3 m s-1 over a bed with median grain-size 250 µm, τW is 3.78 ±1.93 N m-2 (relative error ±50%) in water depth of 20 m, but 0.13 ±0.16 N m-2 (relative error ±120 %) in water depth 60 m. The parameter which is mainly responsible for this error behaviour of τW is the wave period T. In 20 m water depth an increase of T by 1 % induces an increase of τW by XX %, but in 60 m water depth τW increases much more by YY %.
The frequency distribution of the Monte Carlo τW-realizations is positively skewed. The skewness is particularly strong at places where τW is small.
The τW-map shows the time-averaged bed shear stress τW 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 τW between years. In each grid cell the standard deviation of five annual τW-averages is determined. To obtain a relative variability, a standard deviation is divided by the overall five-year average of τW. The map with the

spatial distribution shows that the τW variability between years is between 10 % and 35 % in most parts of the southern North Sea.

Instruments / Models:
The wave parameters significant wave height HS, mean wave period Tm2 and wave direction were calculated by the WAM model. The near-bed current velocity (both magnitude and direction) was calculated by the TRIM model. The formulas to obtain τCW.MAX from wave and current data are given in Soulsby (1997).

Related Datasets:
- τC, the skin-friction bed shear stress generated by currents
- τW, the skin-friction bed shear stress generated by wave

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