Surface Wave Dynamics in the Coastal Zone

Gerbrant Ph. van Vledder
Department of Civil engineering and Geosciences, Delft University of Technology
P.O. Box 2048, 2600 GA Delft, The Netherlands
t: +31 15 2783255, f: +31-15 2784842, e: g.p.vanvledder@tudelft.nl

Sander Hulst
BMT ARGOSS bv, PO. Box 61, 8325 ZH, Vollenhove, The Netherlands
t :+31-527-242299, f:+31-527-242016; e: sander.hulst@bmtargoss.com

Kevin. C. Ewans
Shell International Exploration and Production B.V.
Regional Discipline Lead – Metocean, Sarawak Shell Bhd,
50450 KUL-DWO, Malaysia.
e: Kevin.ewans@shell.com

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LONG-TERM GOALS

The proposed work will contribute to the improvement of existing third-generation (3G) wave models as well as to the development of the next generation of numerical wave modeling capability. The results will be applicable in the coastal zone from deep water up to and including the surf zone. Our efforts will focus on analyzing high quality datasets to support further development of the source terms for triad interactions (Snl3), depth induced wave breaking (Sbrk) and bottom friction (Sbot) in the near-shore zone. Another point of interest is the generation of bounded long waves in the surf zone.

OBJECTIVES

The scientific or technological objectives of this project are to understand the physical processes of the evolution of wind waves in the coastal zone and develop accurate parameterisations of these processes for application in numerical wave prediction models.

APPROACH

The proposed work is subdivided in five main work packages (WP).

1) Assembly of high quality data set;
2) Analysis of spectral evolution;
3) Development of a source term for wave breaking in shallow water;
4) Development of a source term for triad interactions.
5) Improvement of source terms for bottom friction.
6) Numerical simulation of infra-gravity waves in the coastal zone.

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WORK COMPLETED

Collection of data sets

In the previous years TU Delft and BMT Argoss have collected an extensive set of shallow water wave data suitable for the calibration and verification of newly developed source terms for wave breaking, bottom friction and triad interactions. An overview of the most relevant data set collected is given in previous annual reports for this award. Full details are provided in the manuscripts prepared by Salmon and Holthuijsen (2013, and Salmon et al. (2014a, 2014b)).

The last year we extended our dataset with measurements in the Southern North Sea collected by Shell at the platforms Leman, L09 and AWG. The locations of these measurement locations are shown in Figure 1.

Figure 1: Locations in the Southern North Sea of the measurement locations.

Five storm periods were selected for validation of the newly developed source terms for deep and shallow water:

- 31st Oct 2006 – 04th of Nov 2006
- 08th Nov 2006 – 16th Nov 2006
- 05th Nov 2007 – 14th Nov 2007
- 31st Jan 2008 – 03rd Feb 2008
- 29th Feb 2008 – 03rd Mar 2008

The data include information on wind speed and direction, integral wave parameters and water levels. In view of propriatory rights, the data can only be used within the framework of the NOPP project.

For the validation of the extended SWAN model data were also collected from the Duck measurement site, operated by the USACE Field Research Facility at Duck, North Carolina. The collection and validation of these measurements are described elsewhere.

Development of source term for wave breaking

The validation of the newly developed depth-induced wave breaking was finished, implemented in the new public release of the SWAN model. In this way the default Battjes-Janssen (1978) breaker formulation term is replaced by a better alternative. The main results were presented at the 34^{th} Int. Conference on Coastal Engineering, held in Korea, June 2014. Details on the newly developed breaking term can be found in the previous annual report and in Salmon et al. (2014a).

Development of source term for shallow water triad wave-wave interactions

As reported in the previous annual report an inconsistency was identified in the implementation of the LTA and DCTA models in SWAN arising from the extension to 2D spectra of 1D source terms. This inconsistency has been removed and the correct triad source term has been implemented in the new public release of the SWAN model. A similar approach was used in the implementation for the source terms for the SPB (Becq-Girard et al., 1999), and DCTA model (in energy conservative form) (Booij et al., 2009). Details of the methods and their implementation in SWAN can be found in Salmon et al. (2014b).

RESULTS

Additional validation studies were carried out to show the quality of the improved source terms. One of the cases comprised the well-known Haringvliet field case from 1982. Figure 2 shows the location of the Haringvliet and its measurement locations. In addition, results of the state-of the art at the beginning of this NOPP project (γ_{BJ}+LTA) and results of the newly developed breaking and triad term are shown in comparison with the measurements.

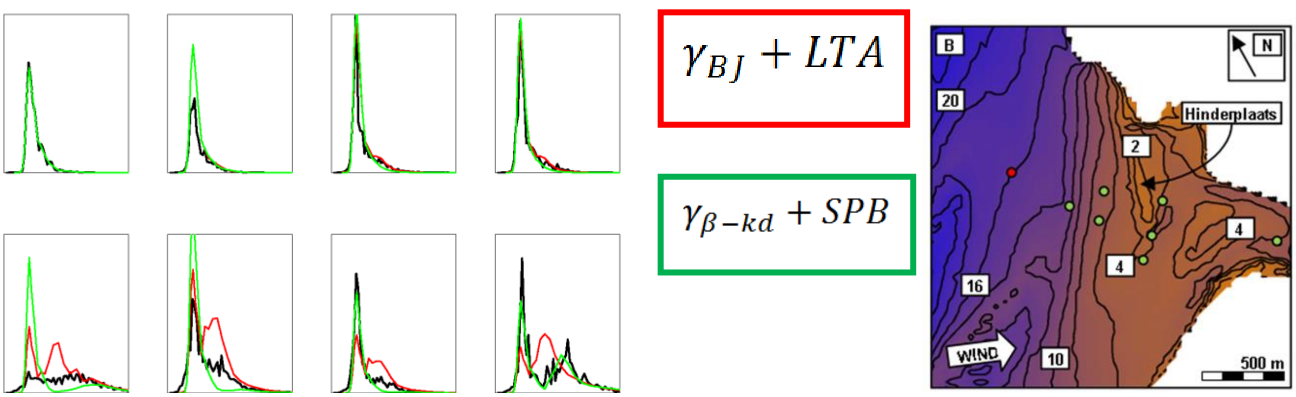

Figure 2: Location of the Haringvliet measurement locations (right panel) and the comparison of the old (γBJ+LTA, red) and new set of source terms (β-kd+SPB, green) for wave breaking and triad interaction in comparison with measurements (black).

To validate the newly developed shallow water source term a dedicated unstructured SWAN grid was made for the North Sea. In generating this grid, special attention was given to grid refinement in relatively shallow areas with relevant gradients in bathymetry. The wave boundary conditions for this grid are obtained from BMT ARGOSS global implementation of the WAVEWATCH III™ model. Both the Wavewatch and the SWAN model are driven with calibrated CFSR wind fields (Hulst and Van Vledder, 2013). The outline and distribution of triangular elements is shown in Figure 3.

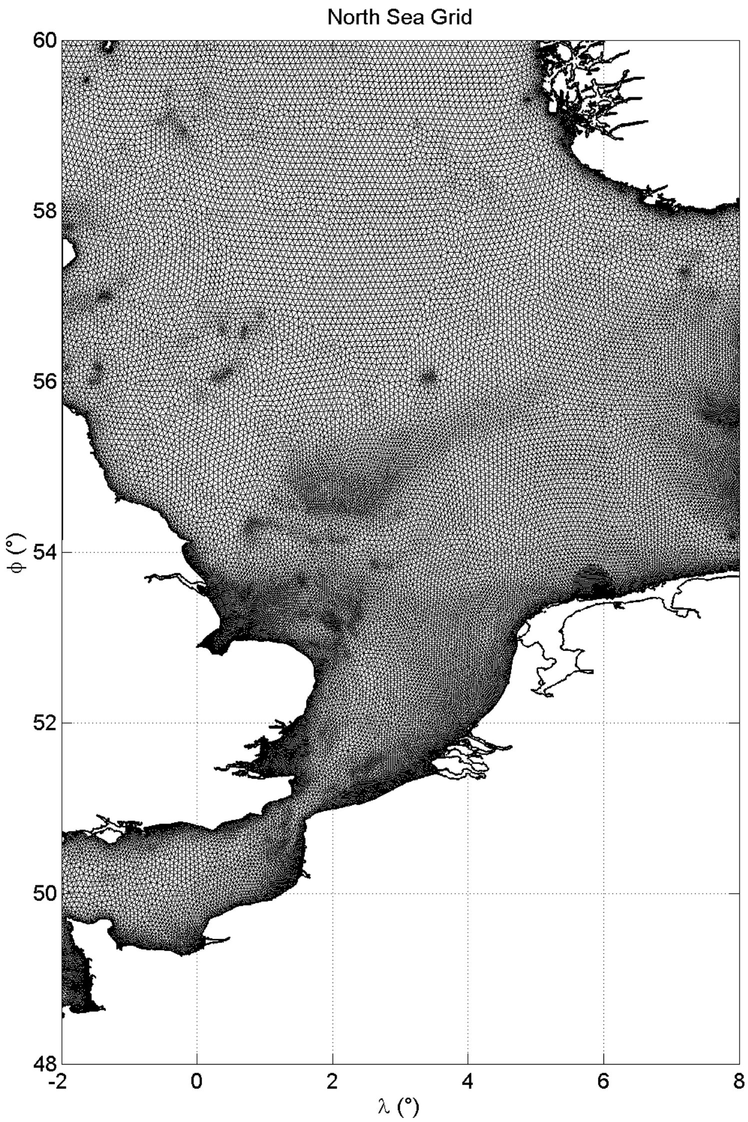

Figure 3: Unstructured grid for the North Sea

Results of the validation of SWAN for the 5 periods at the three measurement locations are now being processed and will be presented in Van Vledder et al. (2014).

In addition, preparations are made to perfrom a similar analysis for 10 storm periods using wave data collected at Duck, North Carolina. The preparations consist of creating a dedicated unstructured grid for the SWAN, which will be nested in global Wavewatch model (either of NCEP or from BMT ARGOSS). Manuscripts in preparation.

Implementation of source terms in SWAN and WAVEWATCH III™

In this NOPP project new source terms have been developed for deep and shallow water. On one hand new deep water source terms have been developed for wind input, whitecapping dissipation and quadruplet interactions and implemented in the WAVEWATCH III™ model. On the other hand, shallow water source terms have been developed for wave breaking and triad interactions and implemented and tested in the SWAN model of Delft University of Technology. Now the NOPP project is reaching its end, the mutual exchange of deep and shallow water source term is in progress. The new formulations for wind input, whitecapping and quadruplets are being implemented in the SWAN model, and validated in the Southern North Sea and Duck validation studies. The shallow water source terms for wave breaking and triad interactions are being implemented in the WAVEWATCH model for testing. The testing is needed to ensure a robust implementation of all new source terms in all wave models before the updated wave models are publicitly made available.

IMPACT/APPLICATIONS

Economic Development

The improvements to coastal wave prediction models as developed in this project, will contribute to various economic activities on the continental shelf and the coastal zone, such as fisheries, shipping harbor development and offshore industry. Further, the availability of improved nearshore wave prediction models will benefit coastal and ocean engineering companies e.g. in the design and operation of offshore and coastal structures, and the development of coastal management strategies.

Quality of life

The improvements to coastal wave prediction models as developed in this project, will improve modeling capability of coastal circulation, morphological development, surge prediction and transport processes, which will benefit coastal recreation (more reliable knowledge of wave heights, rip currents etc), coastal management, and help mitigate pollution hazards for humans (recreation) and coastal ecosystems.

TRANSITIONS

Economic Development

The developments in this project will be made available as open source software and as modules to widely used operational wave models. These models are used by NOAA/NCEP and other agencies involved in coastal development and management, and by many coastal and ocean engineering companies.

Quality of life

The software developed within this project will be disseminated in open source models used by local and federal agencies and companies involved in coastal recreation (surf prediction, rip currents, pollution, surge prediction), coastal management, and mitigation of coastal hazards.

RELATED PROJECTS

Coastal Wave Observations at FRF, Kitty Hawk, NC, USA. This project is carried out by Jeff Hanson, Kent, Hathaway and Harry Friebel. It is strongly related to our project for exchange of field data.

Modeling Wind Wave Evolution from Deep to Shallow Water; Nonlineary and Dissipation. Grant N0014-10-1-0453. PI's: Tim Janssen (San Francisco State University), Tom Herbers (Naval Postgraduate School) and Gerbrant van Vledder (Delft University of Technology).

SWAN and SWASH development teams, Delft University of Technology, Delft, The Netherlands. http://www.swan.tudelft.nl & http:// http://swash.sourceforge.net.

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Booij, N., R.C. Ris, and Holthuijsen, L. H. 1999: A third-generation wave model for coastal regions 1. model description and validation. J. Geophys. Res. 104, 7649–7666.

PUBLICATIONS

Hulst, S., and G.Ph. van Vledder, 2013: CFSR surface wind calibration for wave modelling purposes. Proc. 13th Int. Workshop on Wave Hindcasting and Forecasting. Banff, Canada.

Salmon, J.E., L.H. Holthuijsen, M. Zijlema and G.Ph. van Vledder, 2014a: Alternative source terms for SWAN in the coastal regions. Proc. 34th International Conference on Coastal Engineering

Salmon, J.E., L.H. Holthuijsen, M. Zijlema, and G.Ph. van Vledder, 2014b: Depth-induced wave-breaking for third-generation wave models 2. The beta-kd model, accepted for publication in Ocean Modelling.

Salmon, J.E., P.B. Smit and L.H. Holthuijsen, 2014: Triad interaction in third generation wave models. To be submitted to Ocean Modelling.