

Development of a Suite of Benchmark Tests for Oceanic and Coastal Wave Models

Roeland C. Ris and Ap R. van Dongeren
Delft Hydraulics
Rotterdamseweg 185, 2600 MH Delft, The Netherlands
Phone: +31 (15) 2858951 fax: +31 (15) 2858712 email: ap.vandongeren@wldelft.nl

Leo H. Holthuijsen and Nico Booij
Digital Hydraulics B.V.
Wilgewinde 22, 3317 ME Dordrecht, The Netherlands
Phone: +31 (78) 6186703

Contract number N00014-00-C-0153
<http://www.wldelft.nl>

LONG-TERM GOALS

The primary goal of this project is to develop, on the basis of the present SWAN benchmark suite, a first version of a generic community suite covering both oceanic (unsteady state), time-dependent) and coastal (steady state) conditions. This will provide the basis for a suite that will qualitatively and quantitatively compare the computational results of any wave model of the spectral type with objective data from theoretical sources (analytical solutions) and empirical sources (laboratory and field observations). The suite will be generic in the sense that a) a diversity of wave models can be evaluated against such data and that b) an internationally agreed-upon fixed set of tests is used so that the score of different models can be intercompared. The suite is a community tool and will be provided to the international community to enable operational institutes and researchers around the world to test their wave models in a joint framework with common data and common score definitions.

The SWAN benchmark suite which is mentioned above has been developed over the last few years as a steady-state benchmark suite (Ris et al., 1999; WL | Delft Hydraulics, 2000) to assist operational institutions and researchers to evaluate the scientific and numerical performance of (new versions of) the SWAN coastal wave model (Booij et al., 1999). In this suite the model performance is evaluated by comparing the computational results with data in academic cases (analytical solutions and laboratory data) and in real field cases (sandy coasts including the surf zone).

SCIENTIFIC OBJECTIVES

The main objective is a generic system that can evaluate numerical wave models to support the development of the best possible wave forecasting (and hindcasting). This requires the evaluation of a variety of wave models in a variety of conditions ranging from validation tests (academic) to verification tests (real field cases) and from large-scale (oceanic) conditions to small-scale (coastal) conditions. With the proposed development of a community suite with an internationally agreed-upon set of *generic tests cases* and *high quality data*, this evaluation can be carried out efficiently for any wave model of the spectral type. The tests will be standardised such that the score of one model can be

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE 30 SEP 2002		2. REPORT TYPE		3. DATES COVERED 00-00-2002 to 00-00-2002	
4. TITLE AND SUBTITLE Development of a Suite of Benchmark Tests for Oceanic and Coastal Wave Models				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Delft Hydraulics,,Rotterdamseweg 185, 2600 MH Delft, The Netherlands, , ,				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The primary goal of this project is to develop, on the basis of the present SWAN benchmark suite, a first version of a generic community suite covering both oceanic (unsteady state), time-dependent) and coastal (steady state) conditions. This will provide the basis for a suite that will qualitatively and quantitatively compare the computational results of any wave model of the spectral type with objective data from theoretical sources (analytical solutions) and empirical sources (laboratory and field observations). The suite will be generic in the sense that a) a diversity of wave models can be evaluated against such data and that b) an internationally agreed-upon fixed set of tests is used so that the score of different models can be intercompared. The suite is a community tool and will be provided to the international community to enable operational institutes and researchers around the world to test their wave models in a joint framework with common data and common score definitions.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

compared to that of another model. This development avoids the typically required *ad hoc* efforts involving extensive testing of two or more (versions of) models against observational data.

APPROACH

To facilitate the evaluation of a large diversity of wave models of the spectral type in oceanic and coastal applications, Delft Hydraulics will make the currently available suite of steady-state benchmark tests of the SWAN model generic and it will extend it to unsteady-state (oceanic) conditions. It will be made generic by providing fixed formats and example-converted input files. It will be extended with one available steady-state US field data set (i.e. observations of DUCK-DELILAH) and by adding up to eight unsteady-state data sets (primarily from US sources). The selection of the tests will be made in consultation with the WISE group and subject to the approval of ONR representatives.

Within the project the steady-state (coastal) model STWAVE (see e.g. Smith et al., 1999) will be added to the steady-state benchmark suite and the unsteady-state (oceanic) model WAVEWATCH-III (Tolman, 1991, 1998) will be added to the unsteady-state benchmark suite. The two versions of the suite (steady- and unsteady-state) will be fixed in the sense that no options will be available to the user so as to prevent deviations from the definitions of the benchmark scores. On the other hand, the code will be open enough that new or modified test cases and new or modified statistical scores are readily added (minimum flexibility for the operational use and maximum flexibility for continued development). Executing the benchmark suite for a specific wave model will only require a conversion of all I/O files for that model. Two such I/O conversions will be provided: one steady-state (STWAVE) plus one unsteady-state (WAVEWATCH-III).

The comparison of the computational results with observations in this suite will be qualitative through the use of graphics and it will be quantitative by using statistical measures. The wave parameters to be considered are the significant wave height H_s , the peak wave period T_p , the mean wave periods T_{m01} and T_{m02} , and frequency spreading σ_σ for the steady-state test bed supplemented with the (overall) mean wave direction θ (if available in the observations) and the directional spreading θ_σ for the unsteady-state test bed. The statistical measures are the bias, the rms- and mae-error, the scatter index (except for directions), the operational performance index and the model performance index (if relevant). Brief documentation will be provided in the form of limited guidelines for experienced users. This will consist of: a) implementation and user manual, b) a description of the suite of bench mark tests and c) reporting protocol.

The benchmark tests (steady-state and unsteady-state) will be executed and the results will be reported.

The work will be carried out in close consultation with several leading model developers and users. Active support, assistance and advice on the project is provided by L. Holthuijsen, N. Booij and H. Tolman.

WORK COMPLETED

- The steady-state test bed has been completed and has been made available to interested researchers. Until the end of september, the test bed (3 CD-ROMS, a manual and two documents with example results) has been mailed to 28 researchers worldwide.

- Results of the test bed have been presented at the WISE 2002 meeting (May 2002, Bergen, Norway) and at the ICCE (Cardiff, Wales)
- The unsteady-state test bed is in its final stages. Most of the observational data has been made available by Bob Jensen of USACE, Vicksburg. At this moment the data are being integrated in the test bed. This task should be finished in two months time.

RESULTS

For example results we refer to the annual report of 2001.

IMPACT/APPLICATIONS

The development of a generic *community suite of benchmark tests* (agreed upon by leading model developers) for spectral wave models will promote the search for the best spectral wave model and the continued improvement of wave models. It provides a necessary component to enable researchers and operational institutes to evaluate the quality of new (versions of) wave models. This development agrees well with the current policy of ONR to promote the development of a *community wave model* as a common frame of reference for all related ONR projects. Results of related ONR-funded research projects, as and when implemented in wave models, are readily assessed with the proposed benchmark suite.

TRANSITIONS

The generic community benchmark suites with all their data and documentation are freely and unconditionally available (under the condition of proper referencing to ONR funding and to the sources of information) to active members of the WISE group on CD-ROM (with a maximum of 50 copies to be provided for distribution by ONR). The US Navy and the US Army are active WISE members. Industrial counterparts are welcome to use the benchmark suite free of charge to the extent that they are active WISE members. If an institute is not an active WISE member, the suite is available on CD-ROM at nominal costs from WL|Delft Hydraulics for a period of two years after the termination of the project.

RELATED PROJECTS

Listed below are various projects that are related to the present test bed project:

1. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory: *Virtual Test Bed*.
2. Oceanweather Inc.: *Virtual Test Bed for Evaluating Wave Prediction Technology*.
3. Delft University of Technology: *The continued development of the third-generation shallow water wave model SWAN*.

REFERENCES

Booij, N., R.C. Ris and L.H. Holthuijsen, 1999: A third-generation wave model for coastal regions, Part I, Model description and validation. *J. Geoph. Research*, 104, C4, 7649-7666.

Cardone, V.J., R.E. Jensen, D.T. Resio, V.R. Swail and A.T. Cox, 1996: Evaluation of contemporary ocean wave models in rare extreme events: The “Halloween Storm” of October 1991 and the “Storm of the Century” of March 1993, *J. of Atmosph. and Ocean Techn.*, 13, No 1, 198-230.

Ris, R.C., L.H. Holthuijsen and N. Booij, 1999: A third-generation wave model for coastal regions, Part II: Verification. *J. Geoph. Research*, 104, C4, 7667-7681.

Ris, R.C., L.H. Holthuijsen, J.M. Smith and N. Booij, 2001: A virtual test bed for spectral coastal wave models. Abstract submitted to ICCE.

Smith, J. McKee, D.T. Resio and A.K. Zundel, 1999: STWAVE; Steady-State Spectral Wave Model, Report 1, User’s Manual for STWAVE Version 2.0. Instruction Report CHL-99-1, US Army Corps of Engineers, Waterways Experiment Station, U.S.A.

Tolman, H. L., 1991: A third-generation model for wind waves on slowly varying, unsteady and inhomogeneous depths and currents. *J. Phys. Oceanogr.*, 21, 782-797.

Tolman, H. L., 1998: A new global wave forecast system at NCEP. *Ocean Wave Measurements and Analysis*, B.L. Edge and J.M. Helmsley Eds., ASCE, 777-786.

WL | Delft Hydraulics, 2000: Suite of bench mark tests for the shallow water wave model SWAN, SWAN Cycle 2, Version 40.01 and updates. Report H3528, Delft, The Netherlands.

PUBLICATIONS

Conferences:

Ris, R.C., L.H. Holthuijsen, J.M. Smith, N. Booij, A.R van Dongeren 2002: The ONR test bed for spectral coastal wave models. ICCE 2002, in press.

Presentations:

Oral presentation of final results test bed at the WISE 2002 meeting in Norway, May 2002.

Oral presentation of final results test bed at the ICCE 2002 meeting in Wales, July 2002.