Coastal Engineering Technical Note

SIMULATION OF ARBITRARY DEPTH OCEAN WAVE SPECTRA FOR TROPICAL AND EXTRATROPICAL STORMS COMPUTER PROGRAM: SHALWV

PROGRAM PURPOSE: SHALWV is a numerical model for the estimation of two-dimensional wave spectra for wave growth, propagation and transformation over arbitrary bathymetry.

BACKGROUND: The model is a two-dimensional discrete, time dependent, arbitrary depth spectral wave model. It simulates the growth, decay and transformation of a wave field over a spatial area (such as on ocean basin, a bay, a continental shelf or a lake) over a period of time. SHALWV is intended to provide hindcasts of wave climates or specific storms or simulation of idealized events like a standard project hurricane. Most importantly, it can accommodate realistic bathymetry.

The computer program is based on the solution of the inhomogeneous energy balance equation solved via finite difference methods utilizing a square grid mesh describing the bottom topography and also a wind field. The field equation represents the following mechanisms: wind-wave growth, refraction, shoaling, nonlinear wave-wave interactions, wave bottom interactions (bottom friction and percolation),high frequency energy dissipation, surf-zone breaking and the decomposition of the energy into wind-sea and swell wave components.

PROGRAM APPLICATION: SHALWV in its present form is one of the most versatile of CERC's wave models. It is particularly well suited for situations described by combinations of the following features in deep or finite water depths:

1. Enclosed bodies of water.
2. Open coasts (with additional codes, Hughes and Jensen, 1986)
3. Arbitrary bathymetry.
4. Nonsteady-state wind or wave conditions.
5. Shallow-water or deepwater wave growth.
6. Swell wave transformations.
7. Fetch- or duration-limited wave growth.
8. Unlimited fetch and/or unlimited duration cases.
9. Very lengthy time simulations (hindcasts).
10. Rapidly turning winds (e.g. hurricanes).

The model can be forced by several different types of input:

1. A time sequence of wind fields derived from weather maps or movement of a standard project hurricane across a shelf.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 1987		**00-00-1987 to 00-00-1987**

4. TITLE AND SUBTITLE	
Simulation Of Arbitrary Depth Ocean Wave Spectra For Tropical And Extratropical Storms Computer Program: SHALWV	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) **U. S. Army Engineer Waterways Experiment Station,Coastal Engineering Research Center,P. 0. Box 631,Vicksburg,MS,39160**	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 model is a two-dimensional discrete, time dependent,arbitrary depth spectral wave model. It simulates the growth, decay and transformation of a wave field over a spatial area (such as on ocean basin, a bay, a continental shelf or a lake) over a period of time. SHALWV is intended to provide hindcasts of wave climates or specific storms or simulation of idealized events like a standard project hurricane. Most importantly; it can accommodate realistic bathymetry.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

2. A time sequence of wave conditions along a model boundary derived from gage observations with an option for input of local winds.
3. Input of an idealized directional spectrum along a boundary run for steady state conditions.

The minimum number of input files to run SHALWV is three, but depending on the type of simulation, this number can be as large as five. The model can generate up to seven output files; four are always built. The instruction report on SHALWV gives a more rigorous description of the input and output file descriptions.

PROGRAM ADVANTAGES AND DISADVANTAGES: The computer program is written in a generalized fashion, hence most storm scenarios may be solved employing SHALWV. The limitations of SHALWV can be given in two categories. Physical limitations refer to those physical processes or situations which are not represented in the model and are given by:

1. Interactions with currents.
2. Interaction with coastal structures.
3. Diffraction (e.g. detailed diffraction behind islands cannot be handled although islands can be present and block wave propagation).
4. Variation of still water level with time (e.g. storm surge) which would affect the results in very shallow water.

Some of the above limitations will be rectified by future code enhancements. Computational limitations are functions of the numeric scheme employed in the model, or they can be limitations resulting from large core memory requirements. Some computational limitations of the present version of SHALWV are that it

1. Allows no variable grids or boundary fitted grids.
2. Requires a large, fast computer.
3. Runs as a batch job.
4. Has stability dependent upon Courant number (i.e., smaller grid means smaller time-step which results in more expense). For example, approximate cost at CDC is $0.01 per computation point per time step and at the Naval Research Laboratory (NRL), the cost is $0.001 per computation point per time step.

PROGRAM VERIFICATION AND APPLICATION: To date, SHALWV has been verified to various idealized deepwater and shallow-water growth rate tests. The model results showed excellent agreement to JONSWAP estimates and are consistent with other model results, Jensen and Vincent (in preparation). The numerical model, SHALWV predicted actual wave conditions within 10 to 15 percent of the measured values, for four tropical and two extratropical storm tests. The comparisons ranged from deepwater conditions (2000 m depth) to extremely shallow-water depths (5 m depth). The model has been run with grid mesh sizes as small as 3km and as large as 50km. A summary of the comparisons is shown in Figure 1.

SHALWV has also been employed as the standard model in recent Wave Information Study hindcast efforts; a 20 year hindcast of the Gulf of Mexico for extratropical storm conditions, and hurricane wave simulations for the Atlantic coast, (Figure 2).

PROGRAM AVAILABILITY: SHALWV was developed and presently resides on the CDC computing system (present holder of the Corps-wide computing contract). It is written in Fortran IV. Program documentation and a users's manual are contained in WES Instruction Report CERC-86-2 (Hughes and Jensen (1986)). Technical questions concerning application of the model can be directed to Dr. Robert Jensen, at (601) 634-2101, *Robert.E.Jensen@erdc.usace.army.mil*.

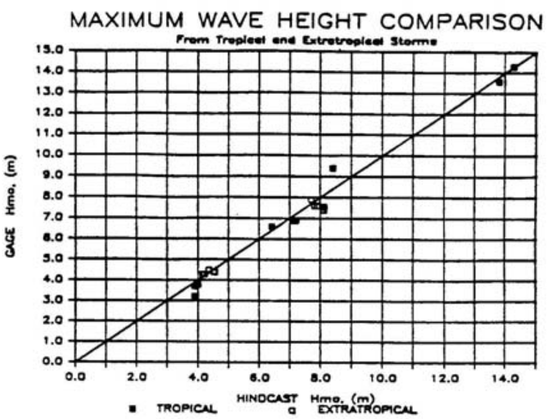

Figure 1. Comparison of maximum wave heights occurring in a storm sequence.

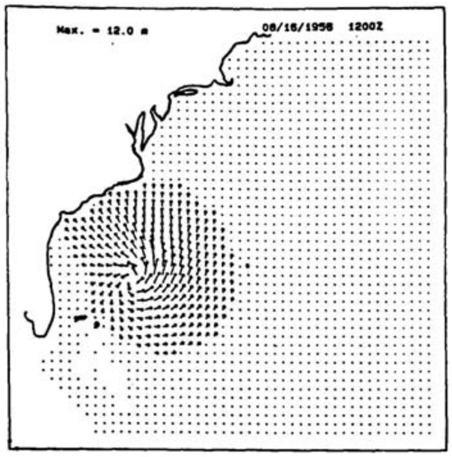

Figure 2. Snapshot of a hurricane generated wave height field from the WIS hindcast study for the Atlantic coast, heights greater than 2.0 m are plotted. Length of arrow is proportional to wave height, direction of arrow indicate mean wave angle. This simulation included 1700 computational points, 16 direction bands, 15 frequency bands and was run for 108 hours.

REFERENCES:

Hughes, S. A. and Jensen, R. E. 1986. "A USER'S Guide to SHALWV, Numerical Model for Simulation of Shallow-Water Wave Growth, Propagation and Decay," Instruction Report CERC-86-2, US Army Waterways Experiment Station, Vicksburg, MS

Jensen, R. E. and Vincent, C. L. (in preparation). "Hurricane Wave Model," Appendix R, Instruction Report CERC-86-2, US Army Waterways Experiment Station, Vicksburg, MS