Sensitivity of the propagation wave model Hiswa to the sea-state parameters in extreme wave conditions

MAST WAVEMOD PROJECT

DITI/GO/COM
Juin 96
Sensitivity of the propagation wave model HISWA to the sea-state parameters in extreme wave conditions

Agnès ROBIN, Marc Prevosto, Xavier AUFFRET, Eric THAMIN

No part of this document may be reproduced or transmitted in any form or by any means, whether electronic, mechanical, photocopying, recording or otherwise; not stored in any information retrieval system or any kind, nor used for tendering or manufacturing; nor communicated to any other person without the written permission of the Consortium of Contract CT92/0025 Steering Committee.
Sensitivity of the propagation wave model Hiswa to the sea-state parameters in extreme wave conditions

MAST WAVEMOD Project.

Océano-Météo pour l'Ingénierie
Département Génie Océanique
IFREMER Brest
1. Introduction

The objective of the WAVEMOD project is to develop a probabilistic methodology for coastal site investigations such as design conditions for coastal engineering problems. Different aspects are considered in the project: wave and current database (in situ measurements, hindcast predictions, remote sensing data), short term probabilistic models, long term probabilistic models and methodology for coastal site studies[1].

Concerning this last point, two main methodologies are under consideration: first, the offshore extrapolation of extreme sea state which is then propagated to the coastal site, including local wind and current effects; secondly, the propagation from offshore to coastal zone of an extensive set of sea state conditions (including local effects too) likely to generate severe nearshore conditions and then to extrapolate them to design conditions.

The validation of propagation model is not checked out in the project and is considered as a «black box». But a sensitivity analysis has to be performed as it can lead to limit the extend of offshore sea state conditions to propagate in the second methodology or it could show that the first methodology is sufficient. Furthermore it is an information on which precision is needed on the offshore data.

The object of this study is then to performed a sensitivity analysis with the HISWA model of some usual sea state parameters to variations of offshore sea conditions. The main parameters are the significant wave height, the mean wave period, the mean wave direction and the directional spread. Two sites are investigated: a Portuguese site and a Greek one. They correspond to the two fields campaign carried out by the project.

The description of the propagation model, the methodology used and the analysis of the results are presented in this report.

2. Description of HISWA model

HISWA (HIndcast Shallow water WAves) is a numerical model to predict stationary and short-crested waves in shallow water with ambient current. The model is based on the notion of spectral action balance or energy balance in the absence of mean current.

We present here a short description of HISWA with the main physical hypotheses and domain of validity. This description is highly based on the user manual [2]. A full description can be found in the list of references proposed in the user manual and especially in [3].

2.1 Spectral action balance and refraction

A spectral technique is used in HISWA with two main parameters for each spectral direction:

- the frequency-integrated action density

\[ A_0(\theta) = \int_{0}^{\pi} A(\omega, \theta) d\omega \] (1)
• the mean frequency \\[ \omega_0(\theta) = \frac{1}{A_0(\theta)} \int_0^\infty A(\omega, \theta) \omega d\omega \] (2)

For each wave component, two evolution equations based on conservation of zero-th and first-order moments of action density spectrum in each spectral direction, are written:

\[ \frac{\partial}{\partial x}(C_x Q) + \frac{\partial}{\partial y}(C_y Q) + \frac{\partial}{\partial \theta}(C_\theta Q) = P \] (3)

where \( Q \) is either \( A_0 \) or \( A_1 = A_0 w_0 \), \( P \) is a source term representing wave generation or dissipation and described hereafter, and \( C \) the propagation speed.

An explicit scheme is used for the propagation in \( x-y \) space and a fully implicit one in \( \theta \)-direction. The equations are solved on a grid and not with the conventional wave-ray approach.

The rectilinear propagation \( (C_x, C_y) \) is based on linear wave theory and includes bottom and current induced shoaling. Speeds are determined with the mean wave frequency for each spectral direction.

The refraction is a change in direction propagation due to variation of phase speed along the wave crest. It is accounted for in HISWA by shifting energy from one direction to another across the work grid. This is an Eulerian approach in opposite to the ray-technique.

No diffraction is taken into account in HISWA.

2.2 Source terms

The different physical phenomena involved in wave generation and dissipation and which are accounted for in the previous equations are described below.

2.2.1 Wind growth

Wave generation due to wind is based on the empirical formulations found in studies from the Sea Wave Modelling Project (SWAMP). The formulations correspond to idealized situation: unlimited ocean with homogenous and stationary wind. Furthermore an assumption is done on the directional spectral energy density which has a universal shape and only the total energy \( E_{tot} \) is expressed:

\[ E_{tot} = \int \int E(\omega, \theta) d\omega d\theta \] (4)

The time evolution of \( E_{tot} \) depends on the fetch length and the mean wind speed \( W \) at 10 m elevation. With the gravitational acceleration \( g \), the dimensionless time evolution is:

\[ \tilde{E}_{tot} = a \tanh(b \tilde{t}^c) \] (5)

where \( \tilde{E}_{tot} = \frac{g^2}{W^4} E_0 \) and \( \tilde{t} = \frac{gt}{W} \). \( t \) is the time duration where the maximum of energy is reached.

\( a, b, c, \) and \( d \) are empirical coefficients which are chosen in HISWA from the British Meteorological Office (BMO) model: the formulation in time is transformed in HISWA in a formulation in space and the default values of the coefficients should give reasonable approximation of standard growth.
curves for fetch limited growth. The previous formulation includes implicitly atmospheric input, white-capping dissipation and nonlinear wave-wave interaction.

HISWA assumes a universal relationship in a dimensionless form between $E_{tot}$ and the overall mean frequency $\omega_1 = \int \int E(\omega, \theta) \omega d\omega d\theta / E_{tot}$:

$$\tilde{\omega}_1 = a_1 \tilde{E}_{tot}$$

(6)

where $\tilde{\omega}_1 = W(\omega) / g$ and $a_1$, $b_1$ are coefficients. This relation may be adapted in HISWA if the wave field is not conform to it.

### 2.2.2 Bottom dissipation

It is based on a conventional formulation for periodic waves (quadratic friction law) with appropriate parameters adapted to suit a random wave field with an ambient current. For each wave component i.e. one spectral direction, the energy dissipation per second is:

$$S(\theta) = -U_{bot1}^2 (c_{fw} U_{bot2} + c_{fc} U_{cur}) / g$$

(7)

where $c_{fw}$ and $c_{fc}$ are the friction coefficient for the waves and current, $U_{bot1}$ and $U_{bot2}$ are the orbital velocities at the bottom and $U_{cur}$ the current velocity in the $\theta$ direction.

As the bottom friction affects essentially energy at low frequency, the evolution of the mean wave frequency assumes a particular spectrum shape function of the wave number $k$:

$$E = C k^\alpha$$ for $k \leq k_{peak}$

$$E = 0$$ for $k < k_{peak}$

(8)

### 2.2.3 Surf dissipation and added white-capping

The wind induced white-capping is already accounted for in the wave growth described in equation 5. The surf breaking and other white-capping is accounted for in HISWA by use of the Battjes and Jansen formulation in which a maximal wave height before breaking $H_m$ is introduced:

$$\left( \frac{dE_{tot}}{dt} \right)_{breaking} = \alpha \frac{1}{8\pi} Q_b \omega_0 H_m^2$$

(9)

where $Q_b$ represents the fraction of breaking waves and is determined from

$$\frac{1 - Q_b}{\log Q_b} = -8 \frac{E_{tot}}{H_m^2}$$

(10)

and where $H_m$ is related either to wave number $k$ either to depth $d$:

• deep water: \( H_m = \gamma_1/k \)  
\( \quad (11) \)
• shallow water: \( H_m = \gamma_2d \)  
\( \quad (12) \)
The default values of \( \alpha_1, \gamma_1 \) and \( \gamma_2 \) are respectively 1.2, 0.8 and 1.0. These last values agree with the fact that the wind induced white-capping is already accounted for.

### 2.2.4 Current dissipation (wave blocking)

In presence of a constant ambient current \( U \), the dispersion relation becomes

\[
\omega = \sqrt{g k \tan \gamma_1 k d + k \cdot \vec{U}}
\]

When it is an adverse current, the group velocity is modified as

\[
C_{g, \text{absolute}} = \frac{d\omega}{dk} = C_g - U
\]

When the relative group velocity of a wave component is less than the current speed \( U \), its energy cannot travel against the adverse current. It is the case of the high frequency components. The lowest critical frequency \( \omega_c \) that cannot travel against the current is determined by HISWA.

Then, after white-capping, the remained energy is

\[
E_2(\theta) = \int_{0}^{\omega_c} E(\theta, \omega) d\omega
\]

The current induced dissipation rate is then

\[
\frac{d}{dt} E(\theta) = \frac{1}{\tau} (E_2(\theta) - E_2(\theta))
\]

where \( \tau \) is the characteristic time of white-capping, \( \tau \) is equal to \( \omega_0^{-1} \).

### 2.2.5 Adverse wind

HISWA does not account for a specific dissipation due to adverse wind but the wind direction relative to the wave propagation direction is introduced in the wind growth source term.

### 2.3 Fundamental limitations of HISWA

As mentioned in the user manual [2], HISWA presents some fundamental limitations due either to the model assumptions either to the method of computation.

Due to a frequency-integrated energy propagation, no conclusion about a real shape spectrum is available and only directional distribution of energy and mean frequency are determined.
Furthermore HISWA is a stationary model and the time propagation should be small compared with the other time scales (wind, tides...). As the wind field is uniform, the dimensions of the computational region have to be small compared to the length scale of the wind field.

HISWA does not model diffraction thus it should not be used in case of high bottom slope and results will not be accurate behind obstacles.

Due to the numerical scheme (forward-step), reflecting or back-scattering waves are not accounted for.

3. Methodology

Two coastal sites with a simple bathymetry have been chosen for which no diffraction effect are expected. For each site, an offshore sea-state and wind and current conditions are selected. Around these median conditions, some variations of one of the describing parameters such as offshore \( HS \) or offshore direction propagation are imposed. The resultant nearshore sea states calculated with the HISWA propagation model give indication of the sensibility of propagation to different input parameters.

The site and variable parameters are described hereafter.

3.1 Site description

The two sites are the instrumented one for the WAVEMOD Project.

The first site is located on the exposed west coast of Portugal. The topography is simple with depth contours nearly parallel to the coast and a gently sloping bottom (around 0.3\%, figures 4 and 5). The area is swell dominated and winds are locally predominantly northerly to north westerly. Wave directions are then predominantly north westerly but also occasionally south westerly.

The second one is the Greek site which is located on the north-western coast of Crete. It is a small bay exposed to the north. The site is characterized by a relatively long fetch (~ 200 km) in the Aegean sea. The topography is not complex and the slope is around 2.5\% (figures 13 and 14). Wave directions are predominantly north west to north east. Tides are not significant and general circulation is low. Local currents are essentially wind generated.

3.2 Definitions of parameters

Four sea state parameters have been selected to perform the sensitivity study. These parameters are simultaneously the offshore variables introduced as input of HISWA and also the nearshore parameters given as output by HISWA.
They are the significant wave height $H_S$, the mean period $T$, the mean direction $DIR$ and the directional spread $DSPR$ which is defined in equation (19).

HISWA assumes the directional wave spectrum to have the following form

$$E(f, \theta) = E(f)D(\theta)$$

with a specific directional spreading function $D(\theta)$:

$$D(\theta) = K\cos^{MS}(\theta - \theta_m) \quad \text{for} \quad |\theta - \theta_m| \leq \frac{\pi}{2}$$

$$D(\theta) = 0 \quad \text{else}$$

$\theta_m$ is the mean direction $DIR$, $K$ a normalizing factor and the exponent $MS$ is a user input called the spread parameter which influences the directional spread $DSPR$ (equal to the standard deviation) around the mean direction. If the distribution is centred at the mean direction, we have

$$DSPR^2 = \int_{-\pi/2}^{\pi/2} \left(2\sin^2\frac{\theta}{2}\right)^2 D(\theta) d\theta$$

When the spread parameter $MS$ decreases, the directional spread $DSPR$ increases. The figure 1 gives the relation between $DSPR$ and the parameter $MS$ of the selected directional spreading function. This function is shown for different values of $MS$ in the figure 2. As HISWA gives no information on the form of the directional spreading function near the coast, $MS$ is only an input parameter and the related output is $DSPR$.

Note that in HISWA $(H_S, T, DIR, MS)$ define entirely the offshore wave spectrum.

Additionally the effect of the wind (in the same direction as the waves) and current (opposite and transverse) velocities variations on the nearshore $H_S, T, DIR$ and $DSPR$ are also studied.

### 3.3 Choice of input parameters

They are based on the measurements performed for the WAVEMOD Project. For both sites the data from the more offshore buoy are used to give realistic $(H_S, T, DIR, MS)$ conditions although it has no real importance in this sensitivity study.

#### 3.3.1 Portugal

The selected $H_S$ corresponds to high sea states encountered during the measurement and is not an extrapolated value. $H_S$ is fixed to 7.5 m and the associated period is deduced from the data : 12 s. Three dominant mean directions of wave propagation are selected : 270, 290 and 315 degrees. Note that they are «coming from» directions. The $MS$ value is fixed to 2 but values of 5 and 20 are also accounted for in the sensitivity study to offshore direction.

So $(H_S = 7.5 \text{ m}, T = 12 \text{ s}, \text{DIR} = 290^\circ, MS = 2)$ is the main offshore sea state. The input conditions correspond to the offshore buoys at depth 72 m and the observed output sea states correspond to the nearshore buoy (depth 12.5 m) as shown on the figures 5 and 6.
3.3.2 Crete

The selected value of $HS$ is 8 m: it is roughly the extrapolated maximum $HS$ for a 5 years duration. An approximately associated period is determined from the data by using a quadratic fit as shown in figure 3. The associated period is then 7.5 s. A linear fit or other method could also have been used. The three dominant directions are 160, 180 and 200 degrees. In this case, they are «towards» directions. The $MS$ value is also fixed to 2 and additionally to 5 and 20.

Then $\{HS = 8 \text{ m}, T = 7.5 \text{ s}, \text{DIR} = 180^\circ, MS = 2\}$ is the offshore sea state around which variations parameters are performed (one parameter by one). The input conditions correspond to the offshore buoys (depth 100 m) and the observed output sea states correspond to the nearshore buoy (depth 20 m) as shown on the figure 15.

3.4 Numerical point of view

The two bathymetry grids are displayed on the figure 4 for the Portuguese site and on the figure 13 for the Cretan site.

The computational region is a rectangular grid such that the x-axis is chosen in the down-wave direction (figures 5, 6, 14 and 15). Due to the different cases of propagation, this grid had to turn relatively to the bathymetry grid. The numerical scheme introduce a stability condition on the step sizes in x and y. In cases without current the condition is

$$\frac{\Delta x}{\Delta y} \leq \frac{1}{\cot\theta}$$

where $\theta$ is the spectral wave propagation. A compromise between a large directional sector and a largest step size in x is often found with a sector of $120^\circ$ and $\Delta x \leq \Delta y/2$.

Furthermore the lateral boundaries are partially reflecting but no wave energy crosses them from outside. It is then necessary to have a computational grid sufficiently stretched in the normal direction to the wave propagation one.

4. Results

The Portuguese site results are first examined and eventual differences on the Cretan site are discussed. Each variation on offshore parameter ($HS$, $T$, $\text{DIR}$ and $MS$) around the reference offshore sea state is successively considered in section 4.2 to 4.7. The induced effects on nearshore parameters are analysed except the effect on nearshore mean wave frequency which is separately investigated in a first section.

In order to avoid confusion, an index «n» is added to nearshore parameters. Then the offshore input of HISWA are noted ($HS$, $T$, $\text{DIR}$ and $MS$ -or $\text{DSPR}$-) and the nearshore output ($HS_n$, $T_n$, $\text{DIR}_n$ and $\text{DSPR}_n$)
4.1 Evolution of mean frequency

Before considering the results on both sites, attention is turned on the evolution of the mean frequency in HISWA model. It is not affected in the case of steepness induced breaking. In case of bottom induced breaking, the mean frequency is affected in the same way as by bottom friction (section 2.2.2).

Bottom friction is inactive in HISWA unless the user decides to active it explicitly. It is difficult to establish if this physical process is relevant or not and to fix on a right friction coefficient. For this reason, it was decide to maintain bottom friction inactive.

As a consequence, no modification of mean period from offshore to nearshore location should be observed in the following cases except with the influence of wind or current. It is not an unrealistic situation as it agrees with measured data in the Cretan site\(^1\).

It is confirmed by all the results: \(T\) remains absolutely constant in propagation cases without wind and current. The tests in presence of current or wind present only small variations on \(T_n\). The mean wave period seems then not being sensitive to errors on offshore inputs except, obviously to the period itself.

4.2 Sensitivity to significant wave height

The results are similar for the three cases of direction of wave propagation (figures 7-a to 7-c). The offshore HS ranges from 7 to 10 m for the Portuguese site test.

**DIR - DSPR.** No significant influence of offshore HS variation on nearshore wave direction \(DIR_n\) and directional spread \(DSPR_n\) is observed.

**HS.** Concerning the evolution of \(HS_n\) itself, a rise of 1 m is observed when the offshore HS increases from 7 to 10 m. Note that the slope declines for high offshore HS due certainly to steepness induced breaking. As a consequence, the effect of HS variation is greater between 7 and 8 m (increment of 60 cm on nearshore \(HS_n\)) than between 8 and 10 m (only 40 cm).

**Crete.** The results are entirely similar (figures 16-a to 16-c) and \(HS_n\) rises of 1.5 m when the offshore HS increases from 6 to 10 m.

4.3 Influence of mean wave period

The offshore mean wave period ranges from 10 to 14 s for the Portuguese site test.

**DIR - DSPR.** The wave period variations have a small effect on \(DIR_n\) and \(DSPR_n\) which are varying of less than 3° (figures 8-a to 8-c).

---

1. Wave-wind-current data collected on the north coast of Crete, WAVEMOD Project, Report TEC-1.3-03, 1995
HS. On the contrary the sensitivity is substantial for the nearshore $H_{Sn}$ as it increases of 1 m when the offshore period rises from 10 to 14 s. They correspond to offshore wave lengths from 150 m to 280 m and to nearshore wave lengths from 90 m to 140 m. As previously results are comparable for the three cases of offshore $DIR$ : 270, 290 and 315 degrees.

Crete. The results are comparable (figures 17-a to 17-c) except the evolution of $H_{Sn}$ which is more marked : from 4 to 6 m with a steadily rise near 6 m due to breaking of waves, when the offshore $T$ ranges from 6 to 9 s.

4.4 Influence of directional wave spread

The offshore $MS$ (resp. $DSPR$) ranges from 1 to 30 (resp. $37.5^\circ$ to $10.2^\circ$).

$DSPR$. The refraction tends to incure wave components to the perpendicular direction to the coastline. The rotation is more pronounced for component directions distant of this perpendicular while, at the extreme, a wave component approaching the coastline perpendicularly is only affected by shoaling. Although it is a rough description, we guess the directional spread to decrease with the propagation.

It is confirmed with the figures 9-a to 9-c right-bottom where $DSPR_n$ (solid line) is about half the offshore $DSPR$ (dashed line). A regression between offshore and nearshore $DSPR$ (not figured here) shows a linear relation with a slope of 0.48 in the cases $DIR = 270$ and $290^\circ$ and a slope of 0.36 when $DIR = 315^\circ$. The point line gives $DSPR_n$ for an offshore $MS$ of 100.

$DIR$. The effect on $DIR_n$ is not marked but increases slightly when the refraction becomes significant (figure 9-c, $DIR = 315^\circ$) especially for $MS$ lower than 10 with a variation of 6° on nearshore direction.

$HS$. A significant influence appears on nearshore $H_{Sn}$ with a variation around 30-40 cm (same figures as previous, left-top) with maximum effect when $MS$ is lower than 10.

Crete. The results are not comparable as the variation of $H_{Sn}$ reaches 1 m, the variation on $DIR_n$ is up to 15° (figures 18-a to 18-c) and the relation between offshore $DSPR$ and inshore $DSPR_n$ is no more linear but parabolic (not figured). It seems that the computational grid (figure 14) is not enough extended on the Y axis. As no energy is travelling through the lateral boundaries, the wave field is disturbed in the vicinity of these boundaries. This is more marked when the directional spread increases.

4.5 Influence of mean wave direction

It has been studied for the reference case (figure 10-a : $HS = 7.5$ m, $T = 12$ s, $MS = 2$), different values of $MS$ (figures 10-b and 10-c : $MS = 5$ and 20), different values of $HS$ (figures 10-d and 10-e : $HS = 10$ and 5 m) and different values of $T$ (figures 10-f and 10-g : $T = 15$ and 9 s). The results are comparable for all these different cases. The offshore $DIR$ ranges from 260° to 320° for the Portuguese site test and from 140° to 220° for the Cretan site test.
**DIR.** Due to the refraction, a linear relation appears between offshore and nearshore directions with a fixed point around 282° corresponding more or less to the perpendicular to the coastline. It is then obvious that an error on offshore direction would have a greater influence nearshore when it is far away from this sector (right-top of the figures).

**DSPR.** The offshore direction have no significant effect on DSPR$_n$ (variation of 1 or 2° : right-bottom of the figures).

**HS.** A deviation of 40° from the perpendicular sector (282°) leads to a decrease on HS$_n$ of 20 to 30 cm. As for DIR$_n$, it is more significant when the refraction increases and then far from sector 282°.

**Crete.** Due to the size of the computational area, results are to be taken with precaution (figures 19-a to 19-e). An additional problem appears as the computational grid has to turn with incoming waves but it was erroneously not the case on the Cretan site. It is then difficult to interpret the results particularly for DIR far from 180°.

### 4.6 Influence of wind

A wind field is imposed in the same direction (270°) as the wave propagation on the Portuguese site. The influence of an evolution of the wind speed between 30 and 45 knots is studied (figure 11).

**DIR - DSPR.** The effect is insignificant on the nearshore direction and direction spread. This result may be not the same if a different wind direction would have been chosen. This case correspond to extreme conditions where wind and waves are generally chosen collinear.

**HS.** We note an increase of 15 cm on the nearshore HS$_n$.

**Crete.** The wind speed ranges from 25 to 40 knots. The results are comparable (figure 20). However the rise of Hs between 30 and 35 knots seems rather sharp.

### 4.7 Influence of current

The current speed ranges from -2.5 m/s to 2.5m/s (resp. -1.5 m/s and 1.5 m/s) for the Portuguese site (resp. Cretan site).

**DIR.** The mean direction is not influenced by a collinear current and only weakly by a transverse one (figures 12-a and 12-b, right-top).

**DSPR.** The result is comparable but transposed for DSPR$_n$: it is not influenced by a transverse current and only weakly by a collinear current (figures 12-a and 12-b, right-bottom).

**HS.** HS$_n$ is weakly controlled by a transverse current (variation around 15 cm for +/- 2.5 m/s of current), more influenced by an opposite current (around 25 cm between -2.5 and 0 m/s) and
substantially controlled by a current in the same direction as the wave propagation (around 1 m between 0 and +2.5 m/s).

**T.** The effect of opposite current (wave blocking) appears slightly on figure 12-a, left-top with an increase of mean period when the current is greater than 1 m/s.

**Crete.** The results are different concerning the influence of a transverse current on the nearshore $DIR_n$ (figure 21-b) which decreases from 10° when the current changes from 0 to +1.5m/s. It was only 1° on the Portuguese site. It is not clear how to explain this difference and the effect of the size grid may be a reason.

### 5. Conclusion

A sensitivity analysis has been performed with the wave propagation model HISWA. Variations on input parameters which describes offshore sea state conditions were introduced. The effects on output parameters on nearshore location have been analysed.

Two sites have been considered : a Portuguese one and a Greek one, which was instrumented by the WAVEMOD project. Most of the results are coming from the Portuguese site. Indeed the validity of the computations achieved on the Greek site is questioned due to computational grid size and orientation.

A significant result is the influence of offshore parameters on the nearshore significant wave height $HS_n$. The offshore $HS$ of course, the mean wave period, the directional wave spread and a collinear current to wave propagation direction have an appreciable effect on $HS_n$. Offshore wave direction, wind and transverse current have a weakest effect.

The nearshore directional spread is highly influenced by the offshore one as they are linearly related. It is also weakly influenced by an in-line current.

The coastal wave direction seems to be controlled mainly by the offshore one. A transverse current has a weak influence. It is also the case of the directional spread when the refraction increases (propagation not normal to the coastline).

The output mean wave period is maintained constant in our computation with HISWA as no bottom friction was activated. Only high values of opposite current have a slight effect (wave blocking).
The table 1 gives the local slopes $\Delta_{output}/\Delta_{input}$ at the median condition of the Portuguese site:

TABLE 1. Local slopes $\Delta_{output}/\Delta_{input}$ around \{Hs = 7.5m, T = 12s, DIR = 290°, MS = 2\}

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>HS ($\Delta_{HS} = 1m$)</th>
<th>T ($\Delta_{T} = 1s$)</th>
<th>DIR ($\Delta_{DIR} = 10^\circ$)</th>
<th>DSPR ($\Delta_{DSPR} = 10^\circ$)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS (m)</td>
<td>0.55 m/m</td>
<td>0.25 m/s</td>
<td>0.003 m/°</td>
<td>0.01 m/°</td>
<td></td>
</tr>
<tr>
<td>T (s)</td>
<td>0 s/m</td>
<td>1 s/s</td>
<td>0 s/°</td>
<td>0 s/°</td>
<td></td>
</tr>
<tr>
<td>DIR (°)</td>
<td>0.03 °/m</td>
<td>0.13 °/s</td>
<td>0.5 °/°</td>
<td>0.05 °/°</td>
<td></td>
</tr>
<tr>
<td>DSPR (°)</td>
<td>0.03 °/m</td>
<td>0.7 °/s</td>
<td>0.02 °/°</td>
<td>0.3 °/°</td>
<td></td>
</tr>
</tbody>
</table>

(* equivalent here to $\Delta_{MS} = 2$)

The highest influences are from each offshore parameter on the same inshore parameter but not only and it can be noted that the addition of the following variations: $\Delta_{HS} = 50$ cm, $\Delta_{T} = 1$ s, $\Delta_{MS} = 2$, could lead to a variation of the nearshore $HS$ greater than 65 cm. Nevertheless, it seems that the nearshore propagation concentrates the range of $HS$ and DSPR and then does not amplify a lack of accuracy on these parameters.

As these results may have been different for another site or other offshore median conditions, they have not to be taken as absolute. But this study reflects the investigations which could be performed on each coastal site, whatever the propagation model is. Such a survey has to be achieved early as it can influence highly the choice of general methodology in the coastal site study and indicates which offshore parameters have to be accurately given.
References

Figures

Figure 1, “Directional spreading DSPR and MS parameter”, page 15
Figure 2, “Directional spreading function \( D(\theta) = \cos(\theta)m \)”, page 16
Figure 3, “Empirical relation \( H_s - T_z \) on the Crete site”, page 17

Portugal site results : page 18
Crete site results : page 41
FIGURE 1. Directional spreading DSPR and MS parameter

Directional spread DSPR function of MS

<table>
<thead>
<tr>
<th>MS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSPR</td>
<td>37.5</td>
<td>31.5</td>
<td>27.6</td>
<td>24.9</td>
<td>22.9</td>
<td>21.2</td>
<td>19.9</td>
<td>18.8</td>
<td>17.9</td>
<td>17.1</td>
<td>14.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1</td>
<td>12.4</td>
<td>10.2</td>
<td>8.9</td>
<td>8.0</td>
<td>7.3</td>
<td>6.8</td>
<td>6.4</td>
<td>6.0</td>
<td>5.7</td>
</tr>
</tbody>
</table>
FIGURE 2. Directional spreading function $D(\theta) = \cos(\theta)^{\text{ms}}$
FIGURE 3. Empirical relation $H_s$-$T_z$ on the Crete site

Data

$y = ax + b$ (for $x > 2.5m$)

$y = ax^2 + bx + c$ (for $x > 2.5m$)
Portugal site

Figure 4, “Bottom of Portugal site”, page 19
Figure 5, “Bathymetry and computational area on Portugal site”, page 20
Figure 6, “Zoom on Portugal site and buoys location”, page 21

Figure 7-a, “Hs variation, DIR = 290 deg.”, page 22
Figure 7-b, “Hs variation, DIR = 270deg.”, page 23
Figure 7-c, “Hs variation, DIR = 315deg.”, page 24

Figure 8-a, “Mean wave period variation, Dir = 290 deg.”, page 25
Figure 8-b, “Mean wave period variation, Dir = 270 deg.”, page 26
Figure 8-c, “Mean wave period variation, Dir = 315deg.”, page 27

Figure 9-a, “MS variation, Dir = 290 deg.”, page 28
Figure 9-b, “MS variation, Dir = 270 deg.”, page 29
Figure 9-c, “MS variation, Dir = 315 deg.”, page 30

Figure 10-a, “Mean wave direction (Dir) variation, Hs = 7.5 m, Tz = 12 s, MS = 2”, page 31
Figure 10-b, “Mean wave direction variation, MS = 5”, page 32
Figure 10-c, “Mean wave direction variation, MS = 20”, page 33
Figure 10-d, “Mean wave direction variation, Hs = 10 m”, page 34
Figure 10-e, “Mean wave direction variation, Hs = 5m”, page 35
Figure 10-f, “Mean wave direction variation, Tz = 15 s”, page 36
Figure 10-g, “Mean wave direction variation, Tz = 9 s”, page 37

Figure 11, “Wind effect”, page 38

Figure 12-a, “In-line current effect”, page 39
Figure 12-b, “Transverse current effect”, page 40
FIGURE 4. Bottom of Portugal site
FIGURE 5. Bathymetry and computational area on Portugal site

Computational area: actual X-Y scale

X (~ 17 km)

Y

(~ 50 km)
FIGURE 6. Zoom on Portugal site and buoys location
FIGURE 7-a. Hs variation, DIR = 290 deg.

Offshore parameters: MS = 2, T = 12 s, DIR = 290 deg.
FIGURE 7-b. Hs variation, DIR = 270deg.

Offshore parameters: MS = 2, T = 12 s, DIR = 270 deg.
FIGURE 7-c. Hs variation, DIR = 315deg.

Offshore parameters: MS = 2, T = 12 s, DIR = 315 deg.
FIGURE 8-a. Mean wave period variation, Dir = 290 deg.

Offshore parameters: Hs = 7.5 m, MS = 2, DIR = 290 deg.
FIGURE 8-b. Mean wave period variation, Dir = 270 deg.

Offshore parameters: Hs = 7.5 m, MS = 2, Dir = 270 deg.
FIGURE 8-c. Mean wave period variation, Dir = 315deg.

Offshore parameters: Hs = 7.5 m, MS = 2, DIR = 315 deg.
FIGURE 9-a. MS variation, Dir = 290 deg.

Offshore parameters: Hs = 7.5 m, T = 12 s, DIR = 290 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 9-b. MS variation, Dir = 270 deg.

Offshore parameters: Hs = 7.5 m, T = 12 s, Dir = 270 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 9-c. MS variation, Dir = 315 deg.

Nearshore parameters: Hs = 7.5 m, T = 12 s, DIR = 315 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 10-a. Mean wave direction (Dir) variation, $H_s = 7.5\, m$, $T_z = 12\, s$, $MS = 2$
FIGURE 10-b. Mean wave direction variation, MS = 5

Offshore parameters: Hs = 7.5 m, T = 12 s, MS = 5
FIGURE 10-c. Mean wave direction variation, MS = 20

Offshore parameters: $H_s = 7.5$ m, $T = 12$ s, MS = 20
FIGURE 10-d. Mean wave direction variation, Hs = 10 m

Offshore parameters: MS = 2, T = 12 s, Hs = 10 m

- Nearshore Hs (m)
- Nearshore T (s)
- Nearshore DSPR (deg.)
FIGURE 10-e. Mean wave direction variation, Hs = 5m

Offshore parameters: MS = 2, T = 12 s, Hs = 5 m
FIGURE 10-f. Mean wave direction variation, $T_z = 15$ s

Offshore parameters: $H_s = 7.5$ s, $MS = 2$, $T = 15$ s
FIGURE 10-g. Mean wave direction variation, Tz = 9 s

Offshore parameters: Hs = 7.5 s, MS = 2, T = 9 s
FIGURE 11. Wind effect

Offshore parameters: $H_s = 7.5$ m, $MS = 2$, $T = 12$ s, $DIR = 270$ deg.
FIGURE 12-a. In-line current effect

Nearshore parameters: Hs = 7.5 m, MS = 2, T = 12 s, DIR = 270 deg.
FIGURE 12-b. Transverse current effect

Offshore parameters: $H_s = 7.5$ m, $MS = 2$, $T = 12$ s, $DIR = 270$ deg.
Crete site

Figure 13, "Bottom of Crete site (axis units: meters)", page 42
Figure 14, "Bathymetry and computational area on Crete site", page 43
Figure 15, "Zoom on Crete site and buoys location", page 44

Figure 16-a, "Hs variation, DIR = 180 deg.", page 45
Figure 16-b, "Hs variation, DIR = 160deg.", page 46
Figure 16-c, "Hs variation, DIR = 200 deg.", page 47

Figure 17-a, "Mean wave period variation, Dir = 180 deg.", page 48
Figure 17-b, "Mean wave period variation, Dir = 160 deg.", page 49
Figure 17-c, "Mean wave period variation, Dir = 200 deg.", page 50

Figure 18-a, "MS variation, Dir = 180 deg.", page 51
Figure 18-b, "MS variation, Dir = 160 deg.", page 52
Figure 18-c, "MS variation, Dir = 200 deg.", page 53

Figure 19-a, "Mean wave direction (Dir) variation, Hs = 8 m, Tz = 7.5 s, MS = 2", page 54
Figure 19-b, "Mean wave direction variation, MS = 5", page 55
Figure 19-c, "Mean wave direction variation, MS = 20", page 56
Figure 19-d, "Mean wave direction variation, Tz = 6 s", page 57
Figure 19-e, "Mean wave direction variation, Hs = 6 m", page 58

Figure 20, "Wind effect", page 59

Figure 21-a, "In-line current effect", page 60
Figure 21-b, "Transverse current effect", page 61
FIGURE 13. Bottom of Crete site (axis units : meters)
FIGURE 14. Bathymetry and computational area on Crete site

Bottom of Crete site/Isobath −200:10:0 m

Computational area

X (~ 3.5 km)

Y (~ 4 km)

Computational area : actual X-Y scale
FIGURE 15. Zoom on Crete site and buoys location

Bottom of Crete site/Isobath −140:10:0 m

Computational area

Buoy(100m)

Buoy(10m)
FIGURE 16-a. Hs variation, DIR = 180 deg.

Offshore parameters : MS = 2, T = 7.5 s, DIR = 180 deg.
FIGURE 16-b. Hs variation, DIR = 160deg.

Offshore parameters: MS = 2, T = 7.5 s, DIR = 160 deg.
FIGURE 16-c. Hs variation, DIR = 200 deg.

Offshore parameters: MS = 2, T = 7.5 s, DIR = 200 deg.
FIGURE 17-a. Mean wave period variation, Dir = 180 deg.

Offshore parameters: Hs = 8 m, MS = 2, DIR = 180 deg.
FIGURE 17-b. Mean wave period variation, Dir = 160 deg.

Offshore parameters: Hs = 8 m, MS = 2, DIR = 160 deg.
FIGURE 17-c. Mean wave period variation, Dir = 200 deg.

Offshore parameters: Hs = 8 m, MS = 2, DIR = 200 deg.
FIGURE 18-a. MS variation, Dir = 180 deg.

Offshore parameters: $H_s = 8\, m$, $T = 7.5\, s$, Dir = 180 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 18-b. MS variation, Dir = 160 deg.

Offshore parameters: Hs = 8 m, T = 7.5 s, DIR = 160 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 18-c. MS variation, Dir = 200 deg.

Offshore parameters: Hs = 8 m, T = 7.5 s, DIR = 200 deg.

The point line refers to MS = 100 close to the one-directional wave spectrum.
FIGURE 19-a. Mean wave direction (Dir) variation, $H_s = 8 \text{ m}$, $T_z = 7.5 \text{ s}$, $MS = 2$

Offshore parameters: $H_s = 8 \text{ m}$, $T = 7.5 \text{ s}$, $MS = 2$
FIGURE 19-b. Mean wave direction variation, MS = 5

Offshore parameters: Hs = 8 m, T = 7.5 s, MS = 5
FIGURE 19-c. Mean wave direction variation, MS = 20

Offshore parameters: Hs = 8 m, T = 7.5 s, MS = 20
FIGURE 19-d. Mean wave direction variation, Tz = 6 s

Offshore parameters: Hs = 8 m, MS = 2, T = 6 s
FIGURE 19-e. Mean wave direction variation, Hs = 6 m

Offshore parameters: MS = 2, T = 7.5 s, Hs = 6 m
FIGURE 20. Wind effect

Offshore parameters: $H_s = 8$ m, $MS = 2$, $T = 7.5$ s, $DIR = 180$ deg.
FIGURE 21-a. In-line current effect

Offshore parameters: $H_s = 8$ m, $MS = 2$, $T = 7.5$ s, $DIR = 180$ deg.
FIGURE 21-b. Transverse current effect

Offshore parameters: $H_s = 8$ m, $MS = 2$, $T = 7.5$ s, $DIR = 180$ deg.
**Sensitivity of the propagation wave model HISWA to the sea-state parameters in extreme wave conditions**

**RST**

**Numéro d'identification du rapport :** DITI/GO/COM/96-01

**Diffusion :** libre [ ] restreinte [ ] interdite [ ]

**Validé par:**

**Adresse électronique :**
- chemin UNIX :
- adresse WWW :

**Titre et sous-titre du rapport :**
Sensitivity of the propagation wave model HISWA to the sea-state parameters in extreme wave conditions

**Titre traduit :**
Etude de sensibilité du modèle de propagation HISWA aux paramètres d'états de mer en conditions extrêmes

**Auteur(s) principal(aux) :**
- ROBIN Agnès
- PREVOSTO Marc
- AUFFRET Xavier
- TAMAIN Eric

**Organisme/Direction/Service, Laboratoire :**
- IFREMER/DITI/GO/COM
- IFREMER/DITI/GO/COM
- IFREMER/DITI/GO/SOM
- IFREMER/DITI/GO/SOM

**Collaborateur(s) :**

**Organisme commanditaire :**

**Titre du contrat :**

**n° de contrat Ifremer :**

**Organisme(s) réalisateur(s) :**

**Convention :**
CONTRACT CT92/0025

**Autres (préciser) :** numéro « WAVEMOD » du rapport :
TEC 4.4-03

**Cadre de le recherche :**

Programme : MAST 2

**Projet :** WAVEMOD

**Campagne océanographique :**
(nom de campagne, année, nom du navire)
Résumé :
Dans le cadre du projet européen MAST «WAVEMOD», une étude de sensibilité du modèle de propagation de houle HISWA est effectuée, vis-à-vis de paramètres d’entrée offshore (hauteur significative, période moyenne, direction moyenne, étallement directionnel) ou locaux (vent, courant), ceci autour de conditions sévères d’états de mer. L’influence de variations des paramètres d’entrée sur ces mêmes paramètres observés à la côte (hauteur significative,…) est analysée.
Deux sites côtiers correspondant aux campagnes de mesures effectuées durant WAVEMOD ont été étudiés. Le premier est situé sur la côte portugaise, les entrées d’HISWA étant fixées au niveau du fond de 80 m et les sorties sur fond de 12 m. Le deuxième est situé en Grèce sur la côte nord de la Crète, avec des entrées et sorties du modèle respectivement sur fond de 100 m et 20 m. Les bathymétres simples évitent la présence de diffraction.
Le modèle HISWA lui-même n’est pas l’objet de l’étude et est considéré comme une «boîte noire». Les mesures ont permis uniquement de choisir des entrées offshore réalistes.
Les résultats obtenus et l’influence des différents paramètres d’entrées sont analysés et discutés. Dans le cas du site crétois, la validité des calculs est remise en cause pour certains des cas traités du fait de la taille de la grille de calcul et de son orientation.
Ce type d’analyse, dont les résultats sont liés au site et aux conditions offshore imposées, est à généraliser et fait partie intégrante de la méthodologie à appliquer dans l’étude d’un site côtier.

Abstract :
This work is a contribution to the MAST project «WAVEMOD». A sensitivity analysis by use of the wave propagation model HISWA is performed. The influence of variations around severe sea-state conditions of offshore inputs (significant wave height, mean wave period, mean direction, directional spread) and local inputs (wind, current) on the nearshore outputs is investigated.
The two campaign fields of the project are selected as coastal test sites. The first one is located on the Portugal coast, the HISWA inputs are fixed in the area of 80 m depth and the outputs at 12 m depth. The second one is located on the north coast of Crete, with inputs and outputs respectively present at 100 m and 20 m depth. The bathymetry of both sites is simple and avoids diffraction problems.
The HISWA model is not itself studied and is considered as a «black box». Measurements allow only realistic choice of extreme offshore sea-sates.
Results and influence of the different input parameters are analysed and discussed. In the Greek site test, the validity of computations is questioned for some of the treated cases because of the size and orientation of the computational grid
All the previous results depends on the site and on the imposed offshore conditions. But this type of investigation has to be generalised and it is a part of the general methodology to perform in a coastal site study.

Mots-clés :
houle, modèle de propagation, réfraction, HISWA, étude de sensibilité, hauteur significative, période, direction, étallement directionnel, site côtier

Keywords :
wave, propagation model, refraction, HISWA, sensitivity study, significant wave height, wave period, wave direction, directional wave spread, coastal wave

Commentaire :

Liste de diffusion

Fiches Documentaires
DITI/D  G. Herrouin

1 exemplaire en circulation
DITI/GO  B. Barnouin
DITI/GO/COM  M. Olagnon
DITI/D  J. Labeyrie
DITI/GO/SOM  P. Chauchot
DITI/GO/HA  J.P. Morel
DEL/CCM  P. Le Hir

1 exemplaire
IST  Prof. Carlos Guedes Soares
IFREMER  Dr. Marc Prevosto
LHF  Dr. Patrick Sauvaget
MARTEDEC  Dr. Christos Solomonidis
NTUA  Prof. Gerassimos Athanassoulis
SINTEF  Dr. Harald Krogstad
OCEANOR  Dr. Stephen Barstow
PCM  Dr. José Carlos Nieto Borges
DUT  Dr. Leo Holthuijsen
STNMTE  Dr. Gérard Goasguen
STCPMVN  Dr. Frédéric Raout
IH

2 exemplaires
bibliothèque du SDB