TOMAWAC

Software for sea state modelling on unstructured grids over oceans and coastal seas

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CONTENTS

1. TOMAWAC– an overview

1.1. Introduction - Generals

TOMAWAC is a scientific software which models the changes, both in the time and in the spatial domain, of the power spectrum of wind-driven waves and wave agitation for applications in the oceanic domain, in the intracontinental seas as well as in the coastal zone. The model uses the finite elements formalism for discretizing the sea domain; it is based on the computational subroutines of the TELEMAC system as developed by the EDF R&D's Laboratoire National d'Hydraulique et Environnement (LNHE).

The acronym TOMAWAC being adopted for naming the software was derived from the following English denomination:

TELEMAC-based Operational Model Addressing Wave Action Computation

(in French: *Modèle opérationnel basé sur le système TELEMAC concernant le calcul de l'action d'onde pour les vagues*)

TOMAWAC is one of the models making up the TELEMAC system [Hervouet, 2007], which addresses the various issues that are related to both free surface (either river- or sea-typed) and underground flows, as well as the associated physical processes: bed-load transport, water quality, etc.

1.2. Implementing TOMAWAC

TOMAWAC models the sea states by solving the balance equation of the action density directional spectrum. To serve that purpose, the model should reproduce the evolution of the action density directional spectrum at each node of a spatial computational grid.

In TOMAWAC the wave directional spectrum is split into a finite number of propagation frequencies f_i and directions θ_i. The balance equation of wave action density is solved for each component (f_i, θ_i). The model is said to be a third generation model (e.g. like the WAM model [WAMDI, 1988] [Komen et al., 1994]), since it does not require any parameterization on the spectral or directional distribution of power (or action density). Each component of the action density spectrum changes in time under the effects of the software-modelled processes.

1.3. TOMAWAC general purposes

TOMAWAC can be used for three types of applications:

1. **Wave climate forecasting** a few days ahead, from wind field forecasts. This real time type of application is rather directed to weather-forecasting institutes such as Météo-France, whose one mission consists of predicting continuously the weather developments and, as the case may be, publishing storm warnings.
2. **Hindcasting** of exceptional events having severely damaged maritime structures and for which field records are either incomplete or unavailable.
3. **Study of wave climatology and maritime or coastal site features,** through the application of various, medium or extreme, weather conditions in order to obtain the conditions necessary to carry out projects and studies (harbour constructions, morphodynamic coastal evolutions, ...).

During the development of the TOMAWAC model, the LNHE laboratory has been interested mainly on the last two types of applications. It considered also the possibility to carry out research activities focused on the following topics:

- wave-currents and wave-overelevations interactions, especially in those places where tide plays a significant role,
- coastal morphodynamics,
- probability of floods in coastal zone,
- coastal structure stability and coast protection,
- assimilation of wind or wave satellite data during computation...

2. Representing waves in TOMAWAC

2.1. General definition of waves

As stated in paragraph 1.1, the purpose of the TOMAWAC software consists of modelling the generation and the spatio-temporal evolution of waves at the surface of the seas or of the oceans. Then, the main physical process of interest is **the wave** or **the sea states**, these two terms being used interchangeably in this document.

The word waves, generally means all the wind driven free surface waves propagating at the surface of the ocean and the period of which (denoted as T) typically ranges from 2.5 to 25 s, or even, equivalently, whose frequency f=1/T ranges from 0.04 to 0.4 Hz.

The sea state may take various forms, depending on whether the sea is still and quiet or, on the contrary, in a stormy phase, whether the waves are being formed (the so-called wind sea) or, on the contrary, are coming from the ocean after travelling several hundreds or thousand kilometres (the so-called "swell").

2.2. Plane monochromatic waves

The most commonly used way to introduce wave modelling consists of considering simple sinusoidal waves (they are often called regular waves). It is a monochromatic (one period or frequency) and plane (one propagation direction) wave. The free surface elevation, which is denoted as η, depends on the position (x, y) of the point being considered in space, as well as on time t. It is written as:

$$\eta(x, y, t) = a \cos \left[k(x.\sin \theta + y.\cos \theta) - \omega.t + \varphi \right] \quad (2.1)$$

wherein:

- a is the wave amplitude (in meters) and corresponds to the distance from the wave crest and the mean level at rest. The wave height, being measured from the crest to the trough of the wave, is used as well: $H=2a$.
- ω is the wave frequency (in rad/s). The period (in seconds) $T = 2\pi/\omega$ or the frequency f (in hertz) = $1/T = \omega/(2\pi)$ is used as well.
- k is the wave number (in rad/m). The wavelength (in meters): $L = 2\pi/k$ is used as well. The wave number k is given by the free surface wave linear dispersion relation, according to frequency ω and depth d:

$$\omega^2 = g.k.\tanh(k.d) \quad (2.2)$$

- θ is the wave propagation direction (in radians). Conventionally, this direction is measured herein clockwise with respect to Y axis.
- φ is the wave phase (in radians).

The energy per unit area of these progressive waves (which consists of kinetic energy and potential energy in halves) amounts to:

$$E = 1/2\, \rho\, g\, a^2 = 1/8\, \rho\, g\, H^2 \quad (2.3)$$

wherein:

- g is the gravity acceleration ($g \approx 9.81$ m/s^2)
- ρ is the water density (in kg/m^3) ($\rho \approx 1025$ kg/ m^3 for seawater).

2.3. Random multidirectional waves

A first representation of waves at the surface of the ocean is possible through the sinusoidal expression being used in the preceding paragraph. When watching an actual sea state, however, not all the waves have the same features, whether it is in terms of height, period or propagation direction. As a matter of fact, the free surface wave energy is distributed over a range of frequencies (waves are then said to be irregular or random) and over a range of propagation directions (waves are then called multidirectional). Mathematically, that irregularity is expressed by writing that a real sea state results from the superposition of an infinite (or large) number of elementary sinusoidal components (i.e. monochromatic and uni-directional components).
Thus, a random multidirectional wave field can be modelled through a superposition method, considering M plane monochromatic components:

$$\eta(x,y,t)=\sum_{m=1}^{M}\eta_m(x,y,t)=\sum_{m=1}^{M}a_m\cos\ [k_m(x.\sin\theta_m+y.\cos\theta_m)-\omega_m t+\varphi_m] \qquad (2.4)$$

A major point in the above expression concerns the phase distribution φ_m of elementary wave components. The approach used in the TOMAWAC model assumes that these phases are randomly distributed over the [0; 2π] range with a uniform probability density. The various wave components are then independent, i.e. a linear or phase averaged representation is used.
With the linear representation featuring TOMAWAC and using the random phase hypothesis, the energy per unit area of random multidirectional waves can then be expressed as:

$$E=\sum_{m=1}^{M}\frac{1}{2}\rho g a_m^2 \qquad (2.5)$$

It is noteworthy, however, that the distortions of shallow water wave profiles cannot be modelled with such a representation. This is because, as the water depth decreases, the non-linear processes linked to wave propagation and wave interactions with the sea bottom get some importance. The waves become steeper and dissymmetrical: they depart from a sinusoidal profile. A fine modelling of these non-linear effects involves non-linear wave theories (3rd- or 5th-order Stokes waves, cnoidal waves, …) and/or so-called "phase resolving" propagation models modelling the evolution of each wave from a train, with a spatial discretization of 20-50 points per wavelength (Boussinesq, Serre equations, ...).
TOMAWAC is a phase averaged model: it is therefore *a priori* hardly suitable for modelling these non-linear effects when the wave profile can no longer be considered as the superposition of a number of independent sinusoidal components. In Section 4, however, it will be explained how the non-linear effects can be processed and represented through source terms.

2.4. Sea state directional power spectrum

Real waves were introduced in the previous chapter as a discrete sum of elementary components. Actually, the power spectrum over both frequencies and propagation directions is a continuous function. The relevant variable for describing that sea state power spectrum is the **directional spectrum of wave energy** which is also known as wave **directional spectrum of energy** and will henceforth be denoted as E(f,θ).
It is a function (in Joule.$Hz^{-1}.rad^{-1}$) that depends on:

— wave frequency f (in Hertz), conventionally only positive (ranging from 0 to +∞)

— propagation direction θ, ranging within a 2π length interval.

Correspondence with the discrete case of the previous section is set considering the following equivalence:

$$\sum_{f}^{f+df} \sum_{\theta}^{\theta+d\theta} \frac{1}{2}\rho g a_m^2 = E(f,\theta)\ df\ \ d\theta \tag{2.6}$$

In case of a wave propagation in a zero-current medium, a balance equation of the wave energy directional spectrum can be written taking into account some source and sink terms for energy generation or energy dissipation.

2.5. Directional spectrum of sea state variance

The preferred variable for sea state representation and modelling is rather the **variance density directional spectrum**.

This function, noted as $F(f,\theta)$ and expressed in $m^2\ Hz^{-1}\ rad^{-1}$ is simply derived from the directional spectrum of wave energy by the relation:

$$F(f,\theta) = E(f,\theta)/(\rho g) \tag{2.7}$$

Then, in particular, we have: $$\sum_{f}^{f+df} \sum_{\theta}^{\theta+d\theta} \frac{1}{2}\rho g a_m^2 = E(f,\theta) df\, d\theta \tag{2.8}$$

The relation linking the variance density directional spectrum and the free surface elevation is then written in the following pseudo-integral form:

$$\eta(x,y,t) = \int_{f=0}^{\infty}\int_{\theta=0}^{2\pi} \sqrt{2F(f,\theta) df\, d\theta}\ cos\left[k\left(x.cos\,\theta + y.sin\,\theta\right) - \omega t + \varphi\right] \tag{2.9}$$

It should be reminded that the phases are randomly distributed in that expression over the range [0;2π] with a uniform probability density. As regards the amplitude of each elementary component, it is related to the variance density directional spectrum by:

$$a_m = \sqrt{2F(f,\theta) df\, d\theta} \tag{2.10}$$

The n-order (n = 0, 1, 2,...) moments m_n of the variance density directional spectrum are defined as:

$$m_n = \int_{f=0}^{\infty}\int_{\theta=0}^{2\pi} f^n F(f,\theta) df\, d\theta \tag{2.11}$$

Among these moments, the 0-order moment is equal to the variance of the free surface elevation:

$$<\eta^2> = \lim_{t_o \to \infty} \frac{1}{t_o}\int_0^{t_o} \eta^2(t) dt = m_0 = \int_{f=0}^{\infty}\int_{\theta=0}^{2\pi} F(f,\theta) df\, d\theta \tag{2.12}$$

In particular, that moment m_0 affects the determination of the significant spectral wave height H_{m0} (equal to the significant height $H_{1/3}$ assuming that the wave heights are distributed according to a Rayleigh's law) by the relation:

$$H_{mo} = 4\sqrt{m_o} \tag{2.13}$$

The average frequencies f_{01} and f_{02} and $f_{-10}=f_e$ are also used and computed as follows:

$$f_{01} = \frac{m_1}{m_0} \quad f_{02} = \sqrt{\frac{m_2}{m_0}} \quad f_e = \frac{m_0}{m_{-1}} \qquad (2.14)$$

Further derived parameters can be computed from the variance density directional spectrum (see e.g. in [AIRH, 1986]).

2.6. Sea state directional spectrum of wave action

In the general case of wave propagation in an unsteady medium (sea currents and/or levels varying in time and space), the directional spectrum of the variance density is no longer kept and a new quantity should be introduced, namely the **directional spectrum of wave action**.

That quantity, noted as $N(f,\theta)$, will remain constant (without considering the source and sink terms) even though the propagation medium is neither homogeneous nor steady [Komen et al., 1994] [Willebrand, 1975] [Phillips, 1977] [Bretherton, 1969].

The action density spectrum is related to the directional spectrum of variance density by the relation:

$$N = F/\sigma \qquad (2.15)$$

wherein σ denotes the relative or intrinsic angular frequency, i.e. the angular frequency being observed in a coordinate system moving at the velocity of current. Such a frequency is different from the absolute angular frequency ω observed in a fixed system of coordinates. The two frequencies are linked by the Doppler effect relation in the presence of a current $\vec{U}$:

$$\Omega(\vec{k},\vec{x},t) = \omega = \sigma + \vec{k}.\vec{U} \qquad (2.16)$$

2.7. Selecting the directional spectrum discretization variables

The directional spectra of wave energy, variance or action shall generally be considered as functions depending on five variables:

— time t;

— the pair of coordinates proving the spatial position of the point being considered. In TOMAWAC, these coordinates can be expressed either in a Cartesian coordinate system (x, y) or in a spherical coordinate system (latitude, longitude) according to the dimension of the computational domain;

— the pair of variables applied for directional spectrum discretization, for which several solutions are theoretically possible:

- (f_a,θ) = (absolute frequency; propagation direction)
- (f_r,θ) = (relative frequency; propagation direction)
- (k,θ) = (wave number; propagation direction)
- (k_x,k_y) = (k.sin θ; k.cos θ) = (wave number vector)

For the numerical resolution of equations, the model TOMAWAC uses the pair (f_r,θ) = (relative frequency; propagation direction).

The directional spectra output by TOMAWAC, however, are always expressed in (f_a,θ). The equations solved by TOMAWAC are thoroughly reviewed in section 4.

3. Hypotheses and application domain of TOMAWAC

3.1. Application domain of the model TOMAWAC

TOMAWAC is designed to be applied from the ocean domain up to the coastal zone. The limits of the application range can be determined by the value of the relative depth *d/L*, wherein *d* denotes the water height (in metres) and *L* denotes the wave length (in metres) corresponding to the peak spectral frequency for irregular waves.

The application domain of TOMAWAC includes:

- **the oceanic domain**, characterized by large water depths, i.e. by relative water depths of over 0.5. The dominant physical processes are: wind-driven wave generation, whitecapping dissipation and non-linear quadruplet interactions;
- **the continental seas and the medium depths**, characterized by a relative water depth ranging from 0.05 to 0.5. In addition to the above processes, the bottom friction, the shoaling (wave growth due to a bottom rise) and the effects of refraction due to the bathymetry and/or to the currents are to be taken into account;
- **The coastal domain,** including shoals or near-shore areas (relative water depth lower than 0.05). For these shallow water areas, such physical processes as bottom friction, bathymetric breaking, non-linear triad interactions between waves should be included. Furthermore, it could be useful to take into account the effects related to unsteady sea level and currents due to the tide and/or to the weather-dependent surges.

Through a so-called finite element spatial discretization, one computational grid may include mesh cells among which the ratio of the largest sizes to the smallest ones may reach or even exceed 100. That is why TOMAWAC can be applied to a sea domain that is featured by highly variable relative water depths; in particular, the coastal areas can be finely represented.

The application domain of TOMAWAC does not include the harbour areas and, more generally, all those cases in which the effects of reflection on structures and/or diffraction may not be ignored.

3.2. Wave interactions with other physical factors

Several factors are involved in the wave physics and interact to various extents with the waves changing their characteristics. The following main factors should be mentioned:

- bathymetry and sea bottom geometry (bottom friction, refraction, surf-breaking, non-linear effects of interactions with the bottom, sand rippling...);
- atmospheric circulation (wind and pressure effects);
- tide pattern (variation of currents and water heights);
- three-dimensional oceanic circulation currents;
- over/underelevations caused by exceptional weather events, resulting in sea levels variations up to several meters (storm, surges).

The fine modelling of the interactions between these various physical factors and the waves is generally rather complex and several research projects are currently focused on it. Within the application domain as defined in the previous paragraph, TOMAWAC models the following interactions:

- **wave-bathymetry interaction:** the submarine relief data input into TOMAWAC are constant in time, but the sea level can change in time. In addition to the effects of the sea level variations in time, TOMAWAC allows to take into account refraction, shoaling, bottom friction and bathymetric breaking;

- **wave-atmosphere interaction:** this interaction is the driving phenomenon in the wave generation, takes part in energy dissipation processes (whitecapping, wave propagation against the wind…) and is involved in the energy transfer. To represent the unsteady behaviour of this interaction, TOMAWAC requires 10 m wind fields (specification of the couple of horizontal velocity components) with a time step matched to the weather conditions being modelled. These wind fields can be provided either by a meteorological model or from satellite measurements;
- **wave-current interaction:** the sea currents (as generated either by the tide or by oceanic circulations) may significantly affect the waves according to their intensity. They modify the refractive wave propagation direction, they reduce or increase the wave height according to their propagation direction in relation to the waves and may influence the wave periods if exhibiting a marked unsteady behaviour. In TOMAWAC, the current field is provided by the couple of horizontal components of its average (or depth-integrated) velocity at the nodes of the computational grid. TOMAWAC allows to model the frequency changes caused either by the Doppler effect or by the unsteady currents, as well as by a non-homogeneous current field.

3.3. The physical processes modelled in TOMAWAC

Those interactions being taken into account by TOMAWAC have been reviewed and a number of physical events or processes have been mentioned in the previous paragraph. These processes modify the total wave energy as well as the directional spectrum distribution of that energy (i.e. the shape of the directional spectrum of energy). So far, the numerical modelling of these various processes, although some of them are now very well known, is not yet mature and keep on providing many investigation subjects. Considering the brief review of physical interactions given in the previous paragraph, the following physical processes are taken into account and digitally modelled in TOMAWAC:

—> *Energy source/dissipation processes:*

- wind-driven interactions with atmosphere. Those interactions imply the modelling of the wind energy input into the waves. It is the prevailing source term for the wave energy directional spectrum. The way that spectrum evolves primarily depends on wind velocity, direction, time of action and fetch (distance over which the wind is active). It must be pointed out that the energy that is dissipated when the wind blocks the waves is not taken into account in TOMAWAC;
- whitecapping dissipation or wave breaking, due to an excessive wave steepness during wave generation and propagation;
- bottom friction-induced dissipation, mainly occurring in shallow water (bottom grain size distribution, ripples, percolation...);
- dissipation through bathymetric breaking. As the waves come near the coast, they swell due to shoaling until they break when they become too steep;
- dissipation through wave blocking due to strong opposing currents.

—> *Non-linear energy transfer conservative processes:*

- non-linear resonant quadruplet interactions, which is the exchange process prevailing at great depths;

- non-linear triad interactions, which become the prevailing process at small depths.

––> *Wave propagation-related processes:*

- wave propagation due to the wave group velocity and, in case, to the velocity of the medium in which it propagates (sea currents);
- depth-induced refraction which, at small depths, modifies the directions of the wave-ray and then implies an energy transfer over the propagation directions;
- shoaling: wave height variation process as the water depth decreases, due to the reduced wavelength and variation of energy propagation velocity;
- current-induced refraction which also causes a deviation of the wave-ray and an energy transfer over the propagation directions;
- interactions with unsteady currents, inducing frequency transfers (e.g. as regards tidal seas).

These various processes are numerically modelled as presented in chapter 4.

It should be remembered that, due to the hypothesis adopted in paragraph 3.1 about the TOMAWAC application domain, the following physical processes are not addressed by the model (non-exhaustive list):

- diffraction by a coastal structure (breakwater, pier, etc…) or a shoal, resulting in an energy transfer towards the shadow areas beyond the obstacles blocking the wave propagation.
- reflection (partial or total) from a structure or a pronounced depth irregularity.

4. Mathematical modelling procedures used by TOMAWAC

4.1. Scope of sea state modelling

The directional spectrum of wave action density, as defined in paragraph 2.6, is considered as a function of five variables:

$N(\vec{x},\vec{k},t) = N(x,y,k_x,k_y,t)$

using, as discretization variables:

- the position vector $\vec{x}$ = (x, y) for spatial location in a Cartesian coordinate system;
- the wave number vector $\vec{k}$ = (k_x, k_y) = (k.sin θ, k.cos θ) for directional spectrum discretization, θ denoting the wave propagation direction (direction in which the waves travel);
- the time t.

Under the hypotheses made on the wave representation (see in paragraph 2.6) as well as on the model application domain and the modelled physical processes (see in paragraph 3.3), an equation of evolution of the directional spectrum of wave action can be written in the following form (see in [Willebrand, 1975] [Phillips, 1977] [Bretherton, 1969] for a detailed demonstration of the way that equation is arranged):

$$\frac{\partial N}{\partial t} + \frac{\partial(\dot{x}N)}{\partial x} + \frac{\partial(\dot{y}N)}{\partial y} + \frac{\partial(\dot{k}_x N)}{\partial k_x} + \frac{\partial(\dot{k}_y N)}{\partial k_y} = Q(k_x,k_y,x,y,t) \quad (4.1)$$

The equation expresses that, in the general case of waves propagating in a non-homogeneous, unsteady environment (currents and/or sea levels varying in time and space), the wave action is preserved to within the source and sink terms (designated by the term Q).

The following notation is also used in (4.1):

$$\dot{g} = \frac{dg}{dt} = \frac{\partial g}{\partial t} + \frac{\partial x}{\partial t}\frac{\partial g}{\partial x} + \frac{\partial y}{\partial t}\frac{\partial g}{\partial y}$$

In that form (conservative writing in the form of a flux), equation (4.1) can be transposed to other coordinate systems and, for instance, (k, θ), (f_a, θ) or else (f_r, θ) can be used for the discretization of directional spectrum [Komen et al., 1994] [Tolman, 1991].

Working in (x, y, k_x, k_y), however, makes it possible to remain in the canonical coordinate system and to write, for the propagation equations (also named Hamilton's equations):

$$\dot{x} = \frac{\partial \Omega}{\partial k_x} \text{ and } \dot{y} = \frac{\partial \Omega}{\partial k_y} \quad (4.2.a)$$

$$\dot{k}_x = -\frac{\partial \Omega}{\partial x} \text{ and } \dot{k}_y = -\frac{\partial \Omega}{\partial y} \quad (4.2.b)$$

wherein Ω results from the Doppler relation applied to the wave dispersion relation for the general case with current:

$$\Omega(\vec{k},\vec{x},t) = \omega = \sigma + \vec{k}.\vec{U} \quad (4.3)$$

wherein: ω is the absolute angular frequency observed in a fixed coordinate system. $f_a = \omega/(2\pi)$ is named absolute frequency.

$\vec{U}$ denotes the current velocity (depth-integrated).

σ denotes the intrinsic or relative angular frequency, which is observed in a coordinate system moving at the velocity $\vec{U}$. It is given by the dispersion relation in the zero-current case:

$$\sigma^2 = g.k.\tanh(k.d) \tag{4.4}$$

$f_r = \sigma/(2\pi)$ is named intrinsic or relative wave frequency;

d denotes the water height.

Through the Hamilton's equations (4.2.a and 4.2.b), it can be demonstrated that we have:

$$\frac{\partial \dot{x}}{\partial x} + \frac{\partial \dot{y}}{\partial y} + \frac{\partial \dot{k}_x}{\partial k_x} + \frac{\partial \dot{k}_y}{\partial k_y} = 0 \tag{4.5.a}$$

or $\text{div}(\vec{V}) = 0$ when defining: $\vec{V} = (\dot{x}, \dot{y}, \dot{k}_x, \dot{k}_y)$ (4.5.b)

The evolution equation (4.1) can then alternatively be written in the following form (the so-called transport form):

$$\frac{\partial N}{\partial t} + \dot{x}\frac{\partial N}{\partial x} + \dot{y}\frac{\partial N}{\partial y} + \dot{k}_x\frac{\partial N}{\partial k_x} + \dot{k}_y\frac{\partial N}{\partial k_y} = Q(k_x, k_y, x, y, t) \tag{4.6.a}$$

$$\frac{\partial N}{\partial t} + \vec{V}.grad_{\vec{x},\vec{k}}(N) = Q \tag{4.6.b}$$

The transfer rates are given by the linear wave theory [Chaloin, 1989] [Komen et al., 1994] [Mei, 1983] [Tolman, 1991]:

$$\dot{x} = C_g \frac{k_x}{k} + U_x \tag{4.7.a}$$

$$\dot{y} = C_g \frac{k_y}{k} + U_y \tag{4.7.b}$$

$$\dot{k}_x = -\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial x} - \vec{k}.\frac{\partial \vec{U}}{\partial x} \tag{4.7.c}$$

$$\dot{k}_y = -\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial y} - \vec{k}.\frac{\partial \vec{U}}{\partial y} \tag{4.7.d}$$

C_g is the relative (or intrinsic) group velocity of waves, i.e. as is observed in a coordinate system moving at the velocity of the current:

$$C_g = \frac{\partial \sigma}{\partial k} = n\frac{\sigma}{k} \quad \text{with} \quad n = \frac{1}{2}\left(1 + \frac{2kd}{\sinh(2kd)}\right) \tag{4.8}$$

The relative (or intrinsic) phase velocity C of waves is also introduced: $C = \dfrac{\sigma}{k}$

The sea state spectral modelling will then consist of solving the evolution equations (4.1) or (4.6.a), using the kinematic equations (4.7.a – 4.7.d).

The transport equation formulation (4.6.a) or (4.6.b) has been adopted in TOMAWAC, since it is closely related to other equations applied in hydraulics, which have already been treated at the LNHE and for which methods and a know-how have been developed long ago.

As regards the discretization variables being used in TOMAWAC, we have already mentioned in paragraph 2.7 that:

- spatial discretization can be based either on a Cartesian coordinate system in (x, y) or on a spherical coordinate system at the Earth's surface in (λ, φ) = (longitude, latitude).
- Discretization of angular spectrum uses the pair (f_r, θ) = (relative frequency ; propagation direction).

The following conventions are adopted for writing the equations:

- the x-axis (in the Cartesian coordinate system) or the λ–axis of longitudes (in the spherical coordinate system) is assumed to be horizontal, directed to the right, whereas the y-axis (in the Cartesian coordinate system) or the φ-axis of latitudes (in the spherical coordinate system) is assumed to be vertical, upwardly directed. Then, in spherical coordinates, the vertical axis points at the north, whereas the horizontal axis points to the East.
- In either case, the wave propagation directions θ are defined with respect to the vertical axis in the clockwise direction.

These conventions are illustrated below in Figure 4.1. Those equations that correspond to the two spatial discretizations options are developed in the next paragraphs.

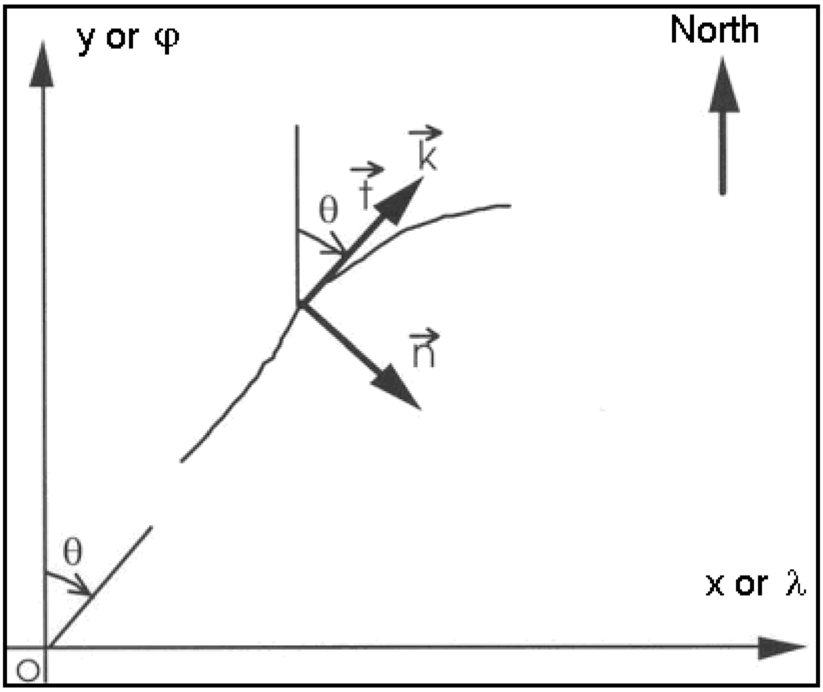

Figure 4.1: definition of location conventions as used in TOMAWAC

4.2. Equations solved

4.2.1. Equations solved in a Cartesian spatial coordinate system

By switching the variable from (x, y, k_x, k_y) to (x, y, f_r, θ), it can be shown that the following relation exists for the directional spectrum of wave action as expressed in both coordinate systems:

$$N(x,y,k_x,k_y,t) = \frac{CCg}{2\pi\sigma}\tilde{N}(x,y,f_r,\theta,t) = \tilde{B}.\tilde{F}(x,y,f_r,\theta,t) \qquad (4.9)$$

putting: $\tilde{B} = \frac{C\,Cg}{2\pi\sigma^2} = \frac{Cg}{(2\pi)^2 k\ f_r}$ (4.10)

The evolution equation (4.6.b) is then written as:

$$\frac{\partial(\tilde{B}\tilde{F})}{\partial t} + \dot{x}\frac{\partial(\tilde{B}\tilde{F})}{\partial x} + \dot{y}\frac{\partial(\tilde{B}\tilde{F})}{\partial y} + \dot{\theta}\frac{\partial(\tilde{B}\tilde{F})}{\partial\theta} + \dot{f}_r\frac{\partial(\tilde{B}\tilde{F})}{\partial f_r} = \tilde{B}.\tilde{Q}(x,y,\theta,f_r,t) \qquad (4.11)$$

with the following transfer rates, as computed from the linear wave theory:

$$\dot{x} = Cg.sin\theta + U_x \qquad (4.12.a)$$

$$\dot{y} = Cg.cos\theta + U_y \qquad (4.12.b)$$

$$\dot{\theta} = -\frac{1}{k}\frac{\partial\sigma}{\partial d}\tilde{G}_n(d) - \frac{\vec{k}}{k}.\tilde{G}_n(\vec{U}) \qquad (4.12.c)$$

$$\dot{f}_r = \frac{1}{2\pi}\left[\frac{\partial\sigma}{\partial d}\left(\frac{\partial d}{\partial t} + \vec{U}.\vec{\nabla}d\right) - Cg\ \vec{k}.\tilde{G}_t(\vec{U})\right] \qquad (4.12.d)$$

The operators $\tilde{G}_n$ and $\tilde{G}_t$ refer to the computation of a function gradient in directions that are respectively normal and tangential to the characteristic curve with the direction θ:

$$\tilde{G}_n(g) = \vec{n}.\vec{\nabla}g = cos\theta\frac{\partial g}{\partial x} - sin\theta\frac{\partial g}{\partial y} \qquad (4.13.a)$$

$$\tilde{G}_t(g) = \vec{t}.\vec{\nabla}g = sin\theta\frac{\partial g}{\partial x} + cos\theta\frac{\partial g}{\partial y} \qquad (4.13.b)$$

Besides, using the dispersion relation (4.4), is can be demonstrated that:

$$\frac{\partial\sigma}{\partial d} = \frac{\sigma k}{sinh(2kd)} \qquad (4.14)$$

The spatial transfer rates $\dot{x}$ and $\dot{y}$ (equations 4.12.a and 4.12.b) model the spatial wave propagation and the shoaling. The directional transfer rate $\dot{\theta}$ (equation 4.12.c) models the refraction-induced change of wave propagation direction. Refraction is generated by the spatial variations of those properties of the environment in which the waves propagate and can result either from a bathymetric variation (first term in 4.12.c) or from current gradients (second term in 4.12.c). The relative frequency transfer rate $\dot{f}_r$ (equation 4.12.d) models the relative frequency changes resulting from sea level variations both in space and time and/or from current variations in space.

It is noteworthy that this last term is zero in the case of zero-current and of no variation of sea level in time: the advection equation is then reduced to a three-dimensional equation.
Lastly, as regards the source terms, it should be mentioned that changing the coordinate system and using the factor $\tilde{B}$ allows to switch from the term Q to a term $\tilde{Q}$ that is directly expressed in terms of the directional variance spectrum with a variance $\tilde{F}$ (f_r, θ). The content of that term is explained in paragraph 4.2.3.

4.2.2. Equations solved in a spherical spatial coordinate system

By switching the variables from (x, y, k_X, k_Y) to (λ, φ, f_r, θ), it can be shown that the following relation exists for the directional spectrum of wave action as expressed in both coordinate systems:

$$N(x,y,k_x,k_y,t)=\frac{CCg}{2\pi\sigma R^2\cos\varphi}\hat{N}(\lambda,\varphi,f_r,\theta,t)=\hat{B}.\hat{F}(\lambda,\varphi,f_r,\theta,t) \qquad (4.15)$$

putting: $$\hat{B}=\frac{C\,Cg}{2\pi\sigma^2R^2\cos\varphi}=\frac{Cg}{(2\pi)^2k\ f_rR^2\cos\varphi} \qquad (4.16)$$

R denotes the Earth's radius ($R \approx 6400$ km) and, once more, λ and φ are respectively the longitude and the latitude of the point being considered.

The evolution equation (4.6.b) is then written as:

$$\frac{\partial(\hat{B}\hat{F})}{\partial t}+\dot{\lambda}\frac{\partial(\hat{B}\hat{F})}{\partial\lambda}+\dot{\varphi}\frac{\partial(\hat{B}\hat{F})}{\partial\varphi}+\dot{\theta}\frac{\partial(\hat{B}\hat{F})}{\partial\theta}+\dot{f}_r\frac{\partial(\hat{B}\hat{F})}{\partial f_r}=\hat{B}.\hat{Q}(\lambda,\varphi,\theta,f_r,t) \qquad (4.17)$$

with the following transfer rates:

$$\dot{\lambda}=\frac{1}{R\cos\varphi}\left(Cg.\sin\theta+U_\lambda\right) \qquad (4.18.a)$$

$$\dot{\varphi}=\frac{1}{R}\left(Cg.\cos\theta+U_\varphi\right) \qquad (4.18.b)$$

$$\dot{\theta}=\frac{1}{R}\left[Cg\ \sin\theta\ \tan\varphi-\frac{1}{k}\frac{\partial\sigma}{\partial d}\hat{G}_n(d)-\frac{\vec{k}}{k}.\hat{G}_n(\vec{U})\right] \qquad (4.18.c)$$

$$\dot{f}_r=\frac{1}{2\pi R}\left[\frac{\partial\sigma}{\partial d}\left(\frac{\partial d}{\partial t}+\frac{U_\lambda}{\cos\varphi}\frac{\partial d}{\partial\lambda}+U_\varphi\frac{\partial d}{\partial\varphi}\right)-Cg\quad\vec{k}.\hat{G}_t(\vec{U})\right] \qquad (4.18.d)$$

As in the previous case, the operators $\hat{G}_n$ and $\hat{G}_t$ refer to the computation of a function gradient in directions that are respectively normal and tangential to the characteristic curve with the direction θ:

$$\hat{G}_n(g)=\frac{\cos\theta}{\cos\varphi}\frac{\partial g}{\partial\lambda}-\sin\theta\frac{\partial g}{\partial\varphi} \qquad (4.19.a)$$

$$\hat{G}_t(g)=\frac{\sin\theta}{\cos\varphi}\frac{\partial g}{\partial\lambda}+\cos\theta\frac{\partial g}{\partial\varphi} \qquad (4.19.b)$$

As previously, the spatial transfer rates $\dot{\lambda}$ and $\dot{\varphi}$ (equations 4.18.a and 4.18.b) model the wave propagation in space and the shoaling. In that coordinate system, the directional transfer rate $\dot{\theta}$ has an additional term (the first term in equation (4.18.c)) compared to the case in Cartesian coordinates. That term results from the propagation in spherical coordinates, in such a way that waves are located with respect to the North change during the propagation over a large circle arc at the Earth's surface [WAMDI, 1988] [Komen et al., 1994]. Both second and third terms $\dot{\theta}$ (equation 4.18.c) model the refraction caused respectively by bathymetry and currents. The relative frequency transfer rate $\dot{f}_r$ (equation 4.18.d) models the changes of relative frequency resulting from variations of the sea level or of the current in both space and time. It is noteworthy that this last term is zero in the case of zero current and of no variation of the sea level in time: the advection equation is then reduced to a three-dimensional equation.

4.2.3. TOMAWAC source and sink terms

4.2.3.1. Generals

The source and sink terms that compose $\tilde{Q}$ and $\hat{Q}$ in the right-hand members of evolution equations (4.11) and (4.17) of directional spectrum of wave action gather the contributions from the physical processes listed in paragraph 3.3. for the application domain of TOMAWAC:

$$Q = Q_{in} + Q_{ds} + Q_{nl} + Q_{bf} + Q_{br} + Q_{tr}$$

wherein Q_{in}: wind-driven wave generation

Q_{ds}: whitecapping-induced energy dissipation

Q_{nl}: non-linear quadruplet interactions

Q_{bf}: bottom friction-induced energy dissipation

Q_{br}: bathymetric breaking-induced energy dissipation

Q_{tr}: non-linear triad interactions

These source and sink terms are numerically modelled and parameterized as detailed in the next paragraphs. For most of these processes, several models or formulations are proposed and available in TOMAWAC.

4.2.3.2. Wind input (term Q_{in})

Two models are available in TOMAWAC. The model to be activated is selected through the keyword *WIND GENERATION* in the steering file, which can take three values, namely:

- 0 no wind drift *(default value)*
- 1 Janssen's model [Janssen, 1989] [Janssen, 1991] (WAM cycle 4) (see in paragraph 4.2.3.2.1).
- 2 Snyder et al. model [Snyder et al., 1981] (see in paragraph 4.2.3.2.2).

4.2.3.2.1. Option 1 for wind drift: Janssen's model

With that option, the model implemented for the wind drift term is based upon the Janssen's works [Janssen, 1989] [Janssen, 1991]; Janssen proposed a quasi-linear theory for modelling the ocean/atmosphere interactions. The linear growth term is ignored and only an exponential energy growth is taken into account, following Miles' results [Miles, 1957].

A quasi-linear source term is obtained as a function of the directional variance spectrum:

$$Q_{in} = \sigma.\varepsilon.\beta.\left(\left[\frac{u_*}{C} + z_\alpha\right]\max[\cos(\theta - \theta_w);0]\right)^2 F \qquad (4.20)$$

with the following notations:

$\varepsilon = \rho_{air}/\rho_{water}$ is the ratio of air and water specific gravities ($\varepsilon \approx 1.25\ 10^{-3}$).

$C = \sigma/k$ is the wave phase velocity

θ_w is the local wind direction (direction in which it blows)

u_* is the friction velocity, being linked to the surface stress τ_s by the following relation:

$$u_* = \sqrt{\frac{\tau_s}{\rho_{air}}} \qquad (4.21)$$

z_α is a constant allowing to offset the growth curve.

The operator 'max' in the source term expression limits the wave generation for the propagation directions included within a ± 90° angular sector with respect to the local wind direction θ_w. For the wave directions making an angle in excess of 90° with respect to the wind direction θ_w, the wind drift term is void.

In the Janssen's model [Janssen, 1991], the Miles' parameter β is a function of two non-dimensional variables:

- the wave age: $A = \dfrac{u_*}{C}$
- the wind profile parameter: $\Omega = \dfrac{g.z_0}{u_*^2}$

It is written as $\beta = \dfrac{\beta_m}{\kappa^2}\mu ln^4\,\mu$ (4.22)

where κ is the Von Karman's constant

β_m denotes a coefficient set to 1.2 by Janssen [Janssen, 1991].

z_0 denotes the roughness length

μ denotes the non-dimensional critical height:

$$\mu = \min\left[\frac{g.z_0}{C^2}\exp\left(\frac{\kappa}{\left[\frac{u_*}{C} + z_\alpha\right]\cos(\theta - \theta_w)}\right);1\right] = \min\left[\Omega.A^2\exp\left(\frac{\kappa}{[A + z_\alpha]\cos(\theta - \theta_w)}\right);1\right] \qquad (4.23)$$

The Janssen's model [Janssen, 1989] [Janssen, 1991] is characterized by the method it uses for computing u_* and z_0. The surface stress τ_s is a function depending, on the one hand, on the wind velocity U_{10} at 10 m and, on the other hand, on the sea state roughness through the wave stress τ_w. It is obtained by solving the following system of equations:

$$U_{10} = \frac{u_*}{\kappa} ln\left(\frac{10 + z_0 + \tilde{z}_0}{z_0}\right) \approx \frac{u_*}{\kappa} ln\left(\frac{10}{z_0}\right) \qquad (4.24.a)$$

$$z_0 = \frac{\tilde{z}_0}{\sqrt{1-\tau_w / \tau_s}} \tag{4.24.b}$$

$$\tilde{z}_0 = \alpha \frac{u_*^2}{g} \tag{4.24.c}$$

$$u_* = \sqrt{\frac{\tau_s}{\rho_{air}}} \tag{4.24.c}$$

The solution of the system of equations through a Newton-Raphson's iterative method yields the surface stress τ_s, the friction velocity u_* and the roughness length z_0.

The initial value of friction velocity u_* being used in the iterative algorithm is obtained considering a constant drag coefficient:

$$u_* = \sqrt{C_D} U_{10} \qquad \text{where: } C_D = 1.2875\ 10^{-3} \text{ by default.}$$

The wave stress τ_w itself is computed from the variance spectrum F (via the source term Q_{in}) using the following relation:

$$\tau_w = \left| \iint \rho_{water}\, \sigma Q_{in}(f_r, \theta)(\cos\theta, \sin\theta) df_r\, d\theta \right| \tag{4.25}$$

That integral is numerically computed over the discretized portion of the spectrum and a parameterization, based upon a decrement of variance in f^{-n}, is used for the high frequencies portion of the spectrum.

In fact, that source term has eight parameters, namely:

- coefficient β_m (corresponding to the keyword *WIND GENERATION COEFFICIENT* in the steering file). Its default value is taken as 1.2, in accordance with the Janssen's proposal [Janssen, 1991] and the value adopted in the model WAM-Cycle 4;
- air specific gravity ρ_{air} (corresponding to the keyword *AIR DENSITY* in the steering file. Its default value is taken as 1.225 kg/m^3;
- water specific gravity ρ_{water} (corresponding to the keyword *WATER DENSITY* in the steering file). Its default value is taken as 1,000 kg/m^3;
- constant α (corresponding to the keyword *CHARNOCK CONSTANT* in the steering file). Its default value is taken as 0.01, in accordance with the Janssen's proposal [Janssen, 1991] and the standard value adopted in the model WAM-Cycle 4;
- constant κ (corresponding to the keyword *VON KARMAN CONSTANT* in the steering file). Its default value is taken as 0.41, i.e. the typical value;
- initial drag coefficient C_D (corresponding to the keyword *WIND DRAG COEFFICIENT* in the steering file). This drag coefficient is provided for initializing the iterative computation of friction velocity u_*. Its default value is taken as 1.2875 10^{-3};
- offset constant z_α (corresponding to the keyword *SHIFT GROWING CURVE DUE TO WIND* in the steering file). Its default value is taken as 0.011, in accordance with the value adopted in the model WAM-Cycle 4;
- elevation at which the wind is recorded (corresponding to the keyword *WIND MEASUREMENTS LEVEL* in the steering file). Its default value is taken as 10 m: it corresponds to the typical value and to the value being adopted in the above explanations.

4.2.3.2.2. Option 2 for wind drift: Snyder et al. model

In that option, the model implemented for the wind drift term is based upon the works conducted by Snyder *et al.* [Snyder et al., 1981], as amended by Komen et al. [Komen et al., 1984] to take into account the friction velocity u_* instead of the wind velocity at 5 m. It corresponds to the formulation being used in the cycle 3 release of WAM model. The formulation is simpler than the Janssen's theory, which Option 1 is based upon (see in preceding paragraph).

As in Option 1, the linear growth term is ignored and only an exponential energy growth is taken into account, following the Miles' results [Miles, 1957]:

$$Q_{in} = \beta F \quad \text{where: } \beta = max\left[0\ ;0.25\frac{\rho_{air}}{\rho_{water}}\left(28\frac{u_*}{C}cos(\theta-\theta_w)-1\right)\right]\sigma \tag{4.26}$$

The shear velocity value u_* used is obtained considering a drag coefficient linearly depending on the wind velocity:

$$u_* = \sqrt{C_D}U_{10} \qquad \text{where: } \begin{array}{ll} C_D = 6.5\ 10^{-5}\ U_{10} + 8\ 10^{-4} & \text{if } U_{10} > 7.5 \text{ m/s.} \\ C_D = 1.2875\ 10^{-3} & \text{if } U_{10} < 7.5 \text{ m/s.} \end{array}$$

That source term only uses two parameters, namely:

- air density ρ_{air} (corresponding to the keyword *AIR DENSITY»* in the steering file). Its default value is taken as 1.225 kg/m^3.
- water density ρ_{water} (corresponding to the keyword *WATER DENSITY* in the steering file). Its default value is taken as 1,000 kg/m^3.

4.2.3.3. Whitecapping-induced dissipations (term Q_{ds})

A single model is available in TOMAWAC. The whitecapping or the free surface slope-induced breaking is activated through the keyword *WHITE CAPPING DISSIPATION* in the steering file; the keyword can take two values, namely:

0 no whitecapping-induced dissipation *(default value)*

1 Komen et al. [Komen et al., 1984] and Janssen's [Janssen, 1991] dissipation model.

In deep water, that term is written as follows in TOMAWAC:

$$Q_{ds} = -\frac{1}{g^4}C_{dis}\bar{\sigma}^9 m_0^2\left(\delta\left(\frac{\sigma}{\bar{\sigma}}\right)^2 + (1-\delta)\left(\frac{\sigma}{\bar{\sigma}}\right)^4\right)F \tag{4.27}$$

With a finite water height, TOMAWAC uses the following formulation:

$$Q_{ds} = -C_{dis}\bar{\sigma}\bar{k}^4 m_0^2\left(\delta\frac{k}{\bar{k}} + (1-\delta)\left(\frac{k}{\bar{k}}\right)^2\right)F \tag{4.28}$$

m_0 denotes the total variance, $\bar{\sigma}$ denotes the average intrinsic frequency and $\bar{k}$ denotes the average wave number; they are respectively computed as followings:

$$m_0 = \int_{f_r=0}^{\infty}\int_{\theta=0}^{2\pi}F(f_r,\theta)df_r d\theta \tag{4.29.a}$$

$$\bar{\sigma} = \left(\frac{1}{m_0}\int_{f_r=0}^{\infty}\int_{\theta=0}^{2\pi}\frac{1}{\sigma}F(f_r,\theta)df_r d\theta\right)^{-1} \tag{4.29.b}$$

$$\bar{k} = \left(\frac{1}{m_0} \int_{f_r=0}^{\infty} \int_{\theta=0}^{2\pi} \frac{1}{\sqrt{k}} F(f_r,\theta) df_r d\theta \right)^{-2} \qquad (4.29.c)$$

The formulas for computing the average frequency and the average wave number are derived from those in use in WAM-cycle 4 [Komen et al., 1994]. These averages are not directly weighted by the variance spectrum, since it was found, when WAM-cycle 3 [WAMDI, 1988] was being developed, that the above expressions yielded more stable results than the conventional weighted averages. Lastly, it should be pointed out that in TOMAWAC the above average quantities are computed not only on the discretized portion of the variance spectrum, but also analytically on the high frequency portion (up to + ∞) considering a decreasing variance in f^{-n}.

That source term has two parameters:

- constant C_{dis} (corresponding to the keyword *WHITE CAPPING DISSIPATION COEFFICIENT* in the steering file). Its default value is taken as 4.5, in accordance with the proposal made by Komen et al. [Komen et al., 1984] and the standard value adopted in the model WAM-Cycle 4.
- weighting parameter δ (corresponding to the keyword *WHITE CAPPING WEIGHTING COEFFICIENT* in the steering file). Its default value is taken as the 0.5 average value.

4.2.3.4. Bottom friction-induced dissipations (term Q_{bf})

A single model is available in TOMAWAC. The bottom friction-induced dissipation is activated through the keyword *BOTTOM FRICTION DISSIPATION* in the steering file; the keyword can take two values, namely:

1. no bottom friction-induced dissipation *(default value)*
2. expression obtained during the JONSWAP campaign (Hasselmann et al. [Hasselmann et al., 1973]) and taken up by Bouws and Komen [Bouws, 1983].

The model used for the bottom friction-induced energy losses is an empirical expression globally representing the various contributions from the wave-bottom interaction (percolation, friction...):

$$Q_{bf} = -\Gamma \left(\frac{\sigma}{g.sinh(k.d)} \right)^2 F \qquad (4.35)$$

That (linear) expression is programmed in TOMAWAC using the following alternative form, which involves the dispersion relation:

$$Q_{bf} = -\Gamma \frac{2k}{g.sinh(2.k.d)} F \qquad (4.36)$$

That source term has a single parameter:

- constant Γ (corresponding to the keyword *BOTTOM FRICTION COEFFICIENT* in the steering file). Its default value is taken as 0.038 m^2s^{-3}, in accordance with what had been obtained during the JONSWAP campaign [Hasselmann et al., 1973] and with the standard value being used in the model WAM-Cycle 4.

4.2.3.5. Bathymetric breaking-induced dissipations (term Q_{br})

In TOMAWAC, four parametric formulas are proposed for reproducing the effects of the bathymetric breaking-induced energy dissipation on the spectrum. The bathymetric breaking-induced dissipation is activated through the keyword *DEPTH-INDUCED BREAKING DISSIPATION* in the steering file; the keyword can take five values:

0 No breaking-induced dissipation *(default value)*

1 Battjes and Janssen's model [Battjes, 1978]

2 Thornton and Guza's model [Thornton, 1983]

3 Roelvink's model [Roelvink, 1993]

4 Izumiya and Horikawa's model [Izumiya, 1984]

The first three models are parametric spectral models developed for studying the random waves, whereas the fourth one is a turbulence model initially developed for studying the regular waves.
The general principle of the parametric spectral models consists in developing an expression for the total dissipation of wave energy by combining a rate of breaker-induced dissipation with a breaking probability.
Whatever model is adopted, the directional spectrum version of the bathymetric breaking-induced dissipation term is based on the assumption that breaking does not affect the energy frequency and direction distributions.

4.2.3.5.1. Battjes and Janssen's model (1978)

The Battjes and Janssen's breaking model [Battjes, 1978] is based on the analogy with a hydraulic jump. Besides, it assumes that all the breaking waves have a height H_m, which is of the same order of magnitude as the water depth. The total energy dissipation term D_{br} is expressed as follows

$$D_{br} = -\frac{\alpha Q_b f_c H_m^2}{4} \tag{4.37}$$

where H_m denotes the maximum wave height being compatible with the water depth, Q_b is the fraction of breaking wave, f_c is a characteristic wave frequency and α is a numerical constant of order 1.
H_m can be computed either through the relation:

$$H_m = \gamma_2 d \tag{4.38}$$

or through a relation derived from the Miche's criterion

$$H_m = \frac{\gamma_1}{k_c}\tanh\left(\frac{\gamma_2 k_c d}{\gamma_1}\right) \tag{4.39}$$

where k_c is linked to f_c by the linear wave dispersion relation.
Q_b is estimated, according to the Battjes and Janssen's theory, as a solution of the implicit equation:

$$\frac{1-Q_b}{\ln Q_b} = -\frac{H_{m0}^2}{2H_m^2} \tag{4.40}$$

In TOMAWAC, that equation can be solved either in a dichotomous way or through explicit approximations as proposed by Dingemans [Dingemans, 1983]. The latter are expressed as follows when putting:

$$b = \frac{H_{m0}}{\sqrt{2}H_m}$$

- <u>version 1</u>: $Q_b = 0$ if $b < C_b$, ($C_b = 0.5$)

$$Q_b = \left(\frac{b - C_b}{1 - C_b}\right)^2 \qquad \text{if } b \geq C_b$$

- <u>version 2</u>: $q_0 = (2b-1)^2$ if $0.5 < b < 1$

$q_0 = 0$ if $b \leq 0.5$

$$q_1 = q_0 - b^2 \frac{q_0 - e^{\left[(q_0-1)/b^2\right]}}{b^2 - e^{\left[(q_0-1)/b^2\right]}}$$

$Q_b = 0$ if $b \leq C_b$, (C_b = 0.3)

$Q_b = q_1$ if $C_b < b < 0.9$

$Q_b = q_0$ if $0.9 \leq b \leq 1.0$

- <u>version 3</u>: $Q_b = 2.4 * b^7$

The directional spectrum version of the sink term is based on the assumption that breaking does not modify the frequency and directional distribution of energy. The source term Q_{br} is then written as:

$$Q_{br}(f,\theta) = -\frac{\alpha Q_b f_c H_m^2}{4} \frac{F(f,\theta)}{m_0} \qquad (4.41)$$

Three constants can be modified using keywords:

- constant α corresponds to the keyword *DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA* in the steering file. Its default value is taken as 1, in accordance with the value as recommended by Battjes and Janssen [Battjes, 1978].
- constant γ_1 corresponds to the keyword *DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1* in the steering file. Its default value is taken as 0.88, in accordance with the value as recommended by Battjes and Janssen [Battjes, 1978].
- constant γ_2 corresponds to the keyword *DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2* in the steering file. Its default value is taken as 0.8, in accordance to the value as recommended by Battjes and Janssen [Battjes, 1978].

The following keywords are for selecting the model options:

- The characteristic wave frequency is selected through the keyword *DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY*. Six values are possible:
  1. average frequency: $\bar{f} = \dfrac{\bar{\sigma}}{2\pi}$ (refer to equation (4.29.b));
  2. average frequency: f_{01}, computed from the spectrum moments m_0 and m_1 *(default value)*;
  3. average frequency: f_{02}, computed from the spectrum moments m_0 and m_2;
  4. discrete peak frequency: f_p;
  5. peak frequency computed through the Read's method to order 5: f_{R5};
  6. peak frequency computed through the Read's method to order 8: f_{R8}.
- The computation mode for breaking probability Q_b (exact computation or utilization of an explicit approximation as proposed by Dingemans [Dingemans, 1983]) is selected through the keyword *DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD.* By default, version 2 of the explicit formulations as proposed by Dingemans [Dingemans, 1983] is used (see above). For applications, it is recommended **not** to modify the value of that keyword.

- The computation mode for the maximum height compatible with the local water depth, H_m, is selected through the keyword *DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD.* Two values are possible:
    1. Relation: $H_m = \gamma_2 d$ *(default value)*;
    2. Miches' relation (see in (4.39) above)

4.2.3.5.2. Thornton and Guza's model (1983)

The Thornton and Guza's breaking model [Thornton, 1983] is based on the analogy with a hydraulic jump and on two types of breaking wave height distribution. The energy sink term is written according to the breaking wave height distribution being retained:

function 1: $$Q_{br1}(f,\theta) = -48\sqrt{\pi}B^3 f_c \frac{(2m_0)^{5/2}}{H_m^4 d} F(f,\theta) \quad (4.42.a)$$

function 2: $$Q_{br2}(f,\theta) = -12\sqrt{\pi}B^3 f_c \frac{(2m_0)^{3/2}}{H_m^2 d}\left[1-\left(1+\left(\frac{8m_0}{H_m^2}\right)\right)^{-5/2}\right] F(f,\theta) \quad (4.42.b)$$

f_c is the characteristic wave frequency (average frequency, f_{01}, f_{02} or peak frequency) and B is a parameter ranging from 0.8 to 1.5 (its default value in TOMAWAC is $B = 1.0$). The maximum wave height compatible with the water depth, H_m, is governed by the parameter γ($H_m = \gamma d$).

The breaking model as proposed by Thornton and Guza can then be parameterized by the user via the following 4 keywords:

- *« DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION* Two values are possible:
    1. weighting function 1 (see in (4.42.a));
    2. weighting function 2 (see in (4.42.b)) *(default value).*
- *« DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY.* Six values are possible:
    1. average frequency: $\bar{f} = \frac{\bar{\sigma}}{2\pi}$ (refer to equation (4.29.b));
    2. average frequency: f_{01}, computed from the spectrum moments m_0 et m_2;
    3. average frequency: f_{02}, computed from the spectrum moments m_0 et m_2;
    4. discrete peak frequency: f_p;
    5. peak frequency computed through the Read's method to order 5: f_{R5} *(default value)*;
    6. peak frequency computed through the Read's method to order 8: f_{R8};
- *DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B*, corresponding to the *B* variable. Its default value in the model is taken as 1.
- *« DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA,* corresponding to the γvariable. Its default value in the model is taken as 0.42.

4.2.3.5.3. Roelvink's model (1993)

The Roelvink's breaking model [Roelvink, 1993] is based on the analogy with a hydraulic jump and on two types of wave height distribution in the breaking zone (Weibull or Rayleigh). The energy sink term is written according to the wave height distribution in the breaking zone:

- Weibull's distribution:

$$Q_{br1}(f,\theta)=-\alpha f_c mA\sqrt{\frac{2}{m_0}}F(f,\theta)\int_0^\infty\left(\frac{H}{\sqrt{8m_0}}\right)^{2m+1} exp\left[-A\left(\frac{H}{\sqrt{8m_0}}\right)^{2m}\right].\left[1-exp\left(-\left(\frac{H}{\gamma d}\right)\right)^N\right]dH \quad (4.43)$$

$$\mathrm{A}=\left[\Gamma\left(1+\frac{1}{\mathrm{m}}\right)\right]^{\mathrm{m}} \text{ with } m=1+0.7\,tan^2\left(\frac{\pi}{2}\frac{1}{\gamma_2}\frac{\sqrt{8m_0}}{d}\right) \quad (4.44)$$

The coefficient γ_2 is usually set to 0.65.

- Rayleigh's distribution:

$$Q_{br2}(f,\theta)=-\alpha f_c\sqrt{\frac{2}{m_0}}F(f,\theta)\int_0^\infty\left(\frac{H}{\sqrt{8m_0}}\right)^3 exp\left[-\left(\frac{H}{\sqrt{8m_0}}\right)^2\right]\left[1-exp\left(-\left(\frac{H}{\gamma d}\right)\right)^N\right]dH \quad (4.45)$$

f_c denotes the characteristic wave frequency (average frequency, f_{01}, f_{02} or peak frequency), α is a numerical constant of order 1, γ is the proportional control factor between the allowable wave height and the water depth (by default, $\gamma = 0.54$) and N is an exponent in the wake breaking weighting function (typically N=10).

Thus, the Roelvink's breaking model can be parameterized by the user via the following 5 keywords:

- *« DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA,* corresponding to the α variable. Its default value in the model is taken as 1.0.
- *« DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA,* corresponding to the γ variable. Its default value in the model is taken as 0.54.
- *« DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2,* corresponding to the γ_2 variable. Its default value in the model is taken as 0.65.
- *« DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION* provided for retaining either a Weibull distribution (4.43) if the (default) value of the parameter is 1 or a Rayleigh distribution (4.45) if the parameter value is 2.
- *« DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION,* corresponding to the N variable. Its default value in the model is 10.
- *« DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY* Six values are possible:

  1. average frequency: $\bar{f}=\frac{\bar{\sigma}}{2\pi}$ (refer to equation (4.29.b));
  2. average frequency: f_{01}, computed from the spectrum moments m_0 et m_2;
  3. average frequency: f_{02}, computed from the spectrum moments m_0 et m_2;
  4. discrete peak frequency: f_p;
  5. peak frequency computed through the Read's method to order 5: f_{R5} *(default value)*;
  6. peak frequency computed through the Read's method to order 8: f_{R8}.

4.2.3.5.4. Izumiya and Horikawa's turbulence model (1984)

Izumiya and Horikawa [Izumiya, 1984] sought an estimate of the dissipation by breaking-induced turbulence in the case of regular waves. From the Reynolds' equations and only considering a onedimensional condition, they obtained an expression of the breaking-induced dissipation of wave energy in the following form:

$$\frac{d}{dx}\left(EC_g\right)=-\alpha\frac{E^{3/2}}{\rho^{1/2}d^{3/2}}\left(\frac{2C_g}{c}-1\right)^{1/2} \tag{4.46}$$

E denotes the total wave energy, C_g and c are respectively group and phase velocities associated to the characteristic wave frequency f_c (average frequency f_{01}, f_{02} or peak frequency), α is a parameter governing the magnitude of the energy dissipation to be determined. For any profile, a shoal may induce the wave reforming. In order to take that process into account, Izumiya and Horikawa express the factor α in terms of a deviation from a steady state:

$$\alpha=\beta_0\left(M_*^2-M_{*S}^2\right)^{1/2}$$

where M_* is a dimensionless quantity in the form: $M_*^2=\frac{Cg}{c}.\frac{E}{\rho g d^2}$

From laboratory data, Izumiya and Horikawa set M_{*S}^2 to 9 10^{-3} and β_0 to 1.8.

Assuming that the breaking does not affect the frequency and direction distribution of energy, the dissipation term is lastly written as:

$$Q_{br}\left(f,\theta\right)=-\beta_0\left(\frac{Cg}{c}.\frac{m_0}{d^2}-M_{*S}^2\right)^{1/2}\frac{g^{1/2}m_0^{1/2}}{d^{3/2}}\left(\frac{2Cg}{c}-1\right)^{1/2}F\left(f,\theta\right) \tag{4.47}$$

Thus, the breaking model as proposed by Izumiya and Horikawa can be parameterized by the user through the three following keywords:

- *« DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0*, corresponding to the β_0 variable. The default value in the model is 1.8.
- *« DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR*, corresponding to the M_{*S}^2 variable. The default value in the model is 0.009.
- *« DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY*. Six values are possible:
    1. average frequency: $\bar{f}=\frac{\bar{\sigma}}{2\pi}$ (refer to equation (4.29.b));
    2. average frequency: f_{01}, computed from the spectrum moments m_0 et m_2;
    3. average frequency: f_{02}, computed from the spectrum moments m_0 et m_2;
    4. discrete peak frequency: f_p;
    5. peak frequency computed through the Read's method to order 5: f_{R5} *(default value)*;
    6. peak frequency as computed through the Read's method to order 8: f_{R8}.

4.2.3.6. Non-linear quadruplet interactions (term Q_{nl})

A single model is available in TOMAWAC. The non-linear quadruplet interactions are through the keyword *NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES* in the steering file; the keyword can take two values, namely:

0 no non-linear quadruplet interaction *(default value)*

1 Hasselmann et al. [Hasselmann et al., 1985] DIA method (Discrete Interaction Approximation) which is a discrete parameterization of the exact computation operator as proposed by Hasselmann [Hasselmann, 1962] [Hasselmann, 1962].

The method and its implementation in TOMAWAC have been the subject of a specific report [Benoit, 1997] which the reader is invited to refer to for further information. The major teachings of the DIA method are summarized below.

The exact expression of the deep water interactions term as set by Hasselmann [Hasselmann, 1962] [Hasselmann, 1962], expressed herein for convenience as a function of the wave number vector, is analogous to a Boltzmann integral:

$$Q_{nl}^{exact} = \iiint \sigma_4 . G . \delta\left(\vec{k}_1 + \vec{k}_2 - \vec{k}_3 - \vec{k}_4\right)\delta\left(\sigma_1 + \sigma_2 - \sigma_3 - \sigma_4\right)$$

$$\left[\frac{F(\vec{k}_1)}{\sigma_1}\frac{F(\vec{k}_2)}{\sigma_2}\left(\frac{F(\vec{k}_3)}{\sigma_3}+\frac{F(\vec{k}_4)}{\sigma_4}\right)-\frac{F(\vec{k}_3)}{\sigma_3}\frac{F(\vec{k}_4)}{\sigma_4}\left(\frac{F(\vec{k}_1)}{\sigma_1}+\frac{F(\vec{k}_2)}{\sigma_2}\right)\right]d\vec{k}_1 d\vec{k}_2 d\vec{k}_3 \quad (4.30)$$

The energy exchanges, in that integral (*a* priori rather uneasily computable), take place between quadruplets meeting the resonance conditions:

$$\sigma_1 + \sigma_2 = \sigma_3 + \sigma_4 \quad \text{and} \quad \vec{k}_1 + \vec{k}_2 = \vec{k}_3 + \vec{k}_4 \quad (4.31)$$

as evidenced by the two Dirac functions δ in the integral.

G denotes the value of the coupling term for the resonant quadruplet interactions $\left(\vec{k}_1, \vec{k}_2, \vec{k}_3, \vec{k}_4\right)$. Establishing and computing its expression is also an awkward task. Hasselmann [Hasselmann, 1962] proposed a computation mode that was also taken up and given a more concise form by such other authors as Webb [Webb, 1978].

The exact computation of the above Boltzmann integral is too complex and time-consuming for such a sea state operational model as TOMAWAC (see e.g. [Hasselmann, 1985]). That is why, starting from the experiment as developed in WAM [WAMDI, 1988] [Komen et al., 1994], TOMAWAC uses the DIA (« Discrete Interaction Approximation) approximate computation method as proposed by Hasselmann et al. [Hasselmann et al., 1985]. Whereas the exact computation requires the summation of the contributions from a great number of quadruplets, the approximate computation implements only a small number of quadruplet configurations that are all similar.

That standard interaction configuration is defined as follows:

- two of the wave numbers are alike: $\vec{k}_1 = \vec{k}_2 = \vec{k}$, which also involves that the two related frequencies are identical: $\sigma_1 = \sigma_2 = \sigma$
- the other two frequencies σ_3 and σ_4 are defined by:

  $\sigma_3 = (1+\lambda)\ \sigma = \sigma^+$

  $\sigma_4 = (1-\lambda)\ \sigma = \sigma^-$

  Through the value λ = 0.25, a good correlation with the exact computation of the integral [Hasselmann et al., 1985] could be achieved. That value is used in the model WAM [WAMDI, 1988] [Komen et al., 1994] and is taken up in TOMAWAC.
- since the wave vectors $\vec{k}_3 = \vec{k}^+$ and $\vec{k}_4 = \vec{k}^-$ should observe the resonance condition, it can be shown they are featured by angles θ_3 = 11.5° and θ_4 = -33.6° with respect to the common direction of $\vec{k}_1 = \vec{k}_2 = \vec{k}$ (refer to [Hasselmann et al., 1985]).
- Furthermore, the mirror image is taken into account by considering the vectors as symmetrical with respect to the direction of $\vec{k}_1 = \vec{k}_2 = \vec{k}$.

The standard interaction configuration (in full line) and its mirror image (in dotted line) are shown schematically in Figure 4.2.

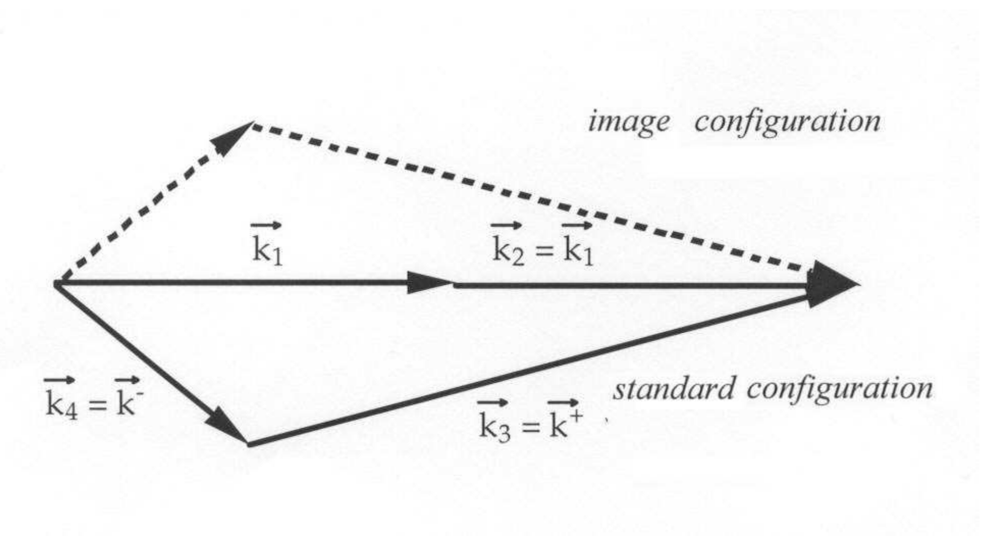

Figure 4.2: Schematic standard interaction configuration for the DIA method

With this standard configuration, the non-linear interaction term for all four resonant wave numbers is written as [Hasselmann et al., 1985]:

$$\begin{bmatrix} Q_{nl} \\ Q_{nl}^- \\ Q_{nl}^+ \end{bmatrix} = \begin{bmatrix} -2 \\ 1 \\ 1 \end{bmatrix} \Pi g^{-4} f_r^{11} \left(F^2 \left(\frac{F^+}{(1+\lambda)^4} + \frac{F^-}{(1-\lambda)^4} \right) - \frac{2FF^+F^-}{(1-\lambda^2)^4} \right) \tag{4.32}$$

With such a computation method, the vector $\vec{k}$ scans all the discretization nodes of the directional spectrum mesh. The number of configurations being considered is then twice as large as the number of points in that mesh. In relation to the full computation, the 5-dimensional space (three integration dimensions and two dimensions for $\vec{k}_4$) of all the possible resonant quadruples is reduced to a 2-dimensional space.

In a finite water depth, from exact computations of the Boltzmann integral, Herterich and Hasselmann [Herterich, 1980] suggested to make a deep water computation based on the previous method, then to multiply it by a coefficient *R* representing the effect of the finite water height:

$$Q_{nl}(d) = R.Q_{nl}(d=\infty) \tag{4.33}$$

Coefficient *R* is a function of the normalized water height $\bar{k}.d$ and is expressed as follows:

$$R(\chi) = 1 + \frac{5.5}{\chi}(1 - \frac{5}{6}\chi)exp\left(-\frac{5}{4}\chi\right) \quad \text{where: } \chi = \frac{3}{4}\bar{k}.d \tag{4.34}$$

The average wave number $\bar{k}$ was defined in the previous paragraph (see in (4.29.c)).

In its authors' opinion, that relation remains valid as long as $\bar{k}.d$ > 1. It is used as such in TOMAWAC for the finite water depth computations.

That source-term has a single parameter:

- constant λ (corresponding to the keyword *STANDARD CONFIGURATION PARAMETER* of the steering file). Its default value is taken as 0.25, in accordance with the proposal made by Hasselmann et al. [Hasselmann et al., 1985] and with the standard value in the model WAM-Cycle 4.

4.2.3.7. Non-linear transfers between triads (Qtr term)

4.2.3.7.1. LTA (Lumped Triad Approximation) model

A parametric model allowing to take into account the non-linear triad interactions in the averaged-phase models has been proposed by Eldeberky and Battjes [Eldeberky, 1995]. The LTA model is a parametric approach that is based on the Madsen and Sorensen's deterministic spectral model [Madsen, 1993]. Simplifying hypotheses are introduced for reducing the computation cost. Thus, a parametric formulation is given for the biphase as a function of the Ursell's number and the model is restricted to the self-interactions.

The source term is written as:

$$Q_{LTA}(f,\theta) = Q^{+}_{LTA}(f,\theta) + Q^{-}_{LTA}(f,\theta)$$

$$Q^{+}_{LTA}(f,\theta) = \alpha_{LTA}\, c\, C_g\, g^2 \frac{R^2_{(f/2,f/2)}}{S^2_f} \sin\left|\beta_{f/2,f/2}\right| \left[F^2(f/2,\theta) - 2F(f,\theta)F(f/2,\theta)\right] \qquad (4.48)$$

$$Q^{-}_{LTA}(f,\theta) = -2Q^{+}_{LTA}(2f,\theta)$$

α_{LTA} is the model adjustment coefficient; c and C_g denote the phase and group velocities, respectively.

R is the self-interaction coefficient: $R_{f,f} = (2k)^2\left[\frac{1}{2} + \frac{(2\pi f)^2}{gdk^2}\right]$ (4.49)

S is given by the relation: $S_f = -2k\left(gd + 2Bgd^3k^2 - (B+1/3)d^2(2\pi f)^2\right)$ (4.50)

The biphase β is given by the relation: $\beta(f,f) = -\frac{\pi}{2} + \frac{\pi}{2}\tanh\left(\frac{0.2}{Ur}\right)$ (4.51)

where Ur denotes the Ursell's number: $Ur = \frac{g}{8\pi^2\sqrt{2}}\frac{H_{m0}T_m^2}{d^2}$ (4.52)

with H_{m0} being the significant spectral height and T_m being the average wave time.

$Q^{\pm}_{LTA}$ denotes the negative and positive contributions of the self-interactions. Since Q^{+}_{LTA} denotes the positive contributions to the first upper harmonic, it should be positive. The negative values of Q^{+}_{LTA} are replaced by the zero value. In the numerical integration of the energy equation, the source term for the triad interactions is generally only computed for frequencies that are lower than $R_{fm}f_m$ (Ris [Ris, 1997]) where $R_{fm} = 2.5$.

Two constants can be modified through keywords:

- constant α_{LTA} corresponding to the keyword *TRIADS 1 (LTA) COEFFICIENT ALPHA.* Its default value is $\alpha_{LTA} = 0.5$
- constant R_{fm} corresponding to the keyword *TRIADS 1 (LTA) COEFFICIENT RFMLTA.* Its default value is $R_{fm} = 2.5$

4.2.3.7.2. SPB model

The SPB model was developed by Becq [Becq, 1998] from the extended Boussinesq equations as proposed by Madsen and Sorensen [Madsen, 1992]. The model is for simulating the effects induced by the collinear and non-collinear interactions of spectral components. The source term is written as:

$$Q(f,\theta)=\frac{B'g}{2S_{1,f}}\int_0^f\int_0^{2\pi}\int_0^f\int_0^{2\pi}df_1df_2d\theta_1d\theta_2T_{f_1,f_2}\delta\left(\theta_{\vec{k}}-\theta_{\vec{k}_1+\vec{k}_2}\right)\delta(f-f_1-f_2)$$
$$+\frac{B'g}{S_{1,f}}\int_0^\infty\int_0^{2\pi}\int_0^\infty\int_0^{2\pi}df_1df_2d\theta_1d\theta_2T_{-f_2,f_1}\delta\left(\theta_{\vec{k}_1}-\theta_{\vec{k}+\vec{k}_2}\right)\delta(f_1-f-f_2) \quad (4.53)$$

with: $$T_{f_1,f_2}=\frac{gK}{K^2+\Delta k^2}R_{f_1,f_2}\left[-\frac{R_{-f_2,f}}{S_{2,f_1}k_1}F\,F_2-\frac{R_{-f_1,f}}{S_{2,f_2}k_2}F\,F_1+\frac{R_{f_1,f_2}}{S_{2,f}k}F_1F_2\right] \quad (4.54.a)$$

$$B'=\frac{Cg}{2\pi k} \quad (4.54.b)$$

$$R_{f1,f2}=(k_1+k_2)^2\left[\frac{1}{2}+\frac{(2\pi)^2f_1f_2}{gdk_1k_2}\right] \quad (4.54.c)$$

$$S_f=-2k\left(gd+2Bgd^3k^2-(B+1/3)d^2(2\pi f)^2\right) \quad (4.54.d)$$

F denotes the variance spectrum in terms of frequencies and directions, $F(f,\theta)$. T_{f_1,f_2} and T_{-f_2,f_1} respectively correspond to the sum and difference interactions. K is the model adjustment parameter.

Since the model was designed for taking into account the energy transfers for all the possible triad configurations within the spectrum, the computation times are very long. In order to shorten these computation times, the interactions can be restricted over a range of spectral components that are included within a given angular sector. Thus, directional limits can be user-prescribed.

Three constants can be modified through keywords:

- constant K corresponding to the keyword *TRIADS 2 (SPB) COEFFICIENT K*. Its default value is $K=0.34$
- the lower and upper directional markers corresponding to the keywords *TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY* and *TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY*. Their respective default values are 0 and 360.

5. Discretizations used in TOMAWAC

The main aspects concerning the numerical discretization in TOMAWAC are presented and discussed herein for the two spatial variables (paragraph 5.1), for the two spectro-angular variables (paragraph 5.2) and for the time domain (paragraph 5.3).

5.1. Spatial discretization

The spatial coordinate system, whether it is Cartesian or spherical, is a planar two-dimensional domain that is meshed by means of triangular finite elements. Only the maritime portion of the computational domain is meshed, so that all the computational points of the spatial grid are provided with a water depth that is strictly above zero. Through this discretization technique, the mesh size may naturally be variable over the spatial domain, particularly enabling to get a fine grid in the areas of specific interest, featured either by complex geometries (straits, intracontinental seas, bays…) or by high bathymetric gradients. Furthermore, that spatial grid may include one or more islands.

The number of discretization points is only limited by the RAM capacities of the computing machine. The equation solved by TOMAWAC does not prescribe *a priori* any conditions about the number of grid points per wave length. The density of spatial discretization points is left at the user's will. It should match, however, both spatial and temporal scales of variation of the physical characteristics of the domain being studied, in particular bathymetry and wind field.

In the general case, this spatial grid is realised on a workstation using one of the mesh generators associated to the TELEMAC system (refer to the 7.2.2 for further details about the preparation of the grid). Two examples of spatial grids developed for TOMAWAC for simulated storms in the North Atlantic Ocean, the Channel and the North Sea are illustrated in Figure 5.1.

5.2. Spectro-angular discretization

5.2.1. Frequency discretization

In TOMAWAC, the frequency domain is discretized considering a series of *NF* frequencies in a geometric progression:

$$f_n = f_1 . q^{n-1} \text{ with } n \text{ ranging from 1 to } NF$$

The minimum frequency is then f_1 and the maximum frequency is $f_1 . q^{NF-1}$.

In order to define the frequency discretization, the user should specify as an input into the steering file:

- the frequency number: *NF* (corresponding to the keyword *NUMBER OF FREQUENCIES* in the steering file)
- the minimum frequency: f_1 (in Hertz) (corresponding to the keyword *MINIMAL FREQUENCY* in the steering file)
- the frequential ratio: *q* (corresponding to the keyword *FREQUENTIAL RATIO* in the steering file)

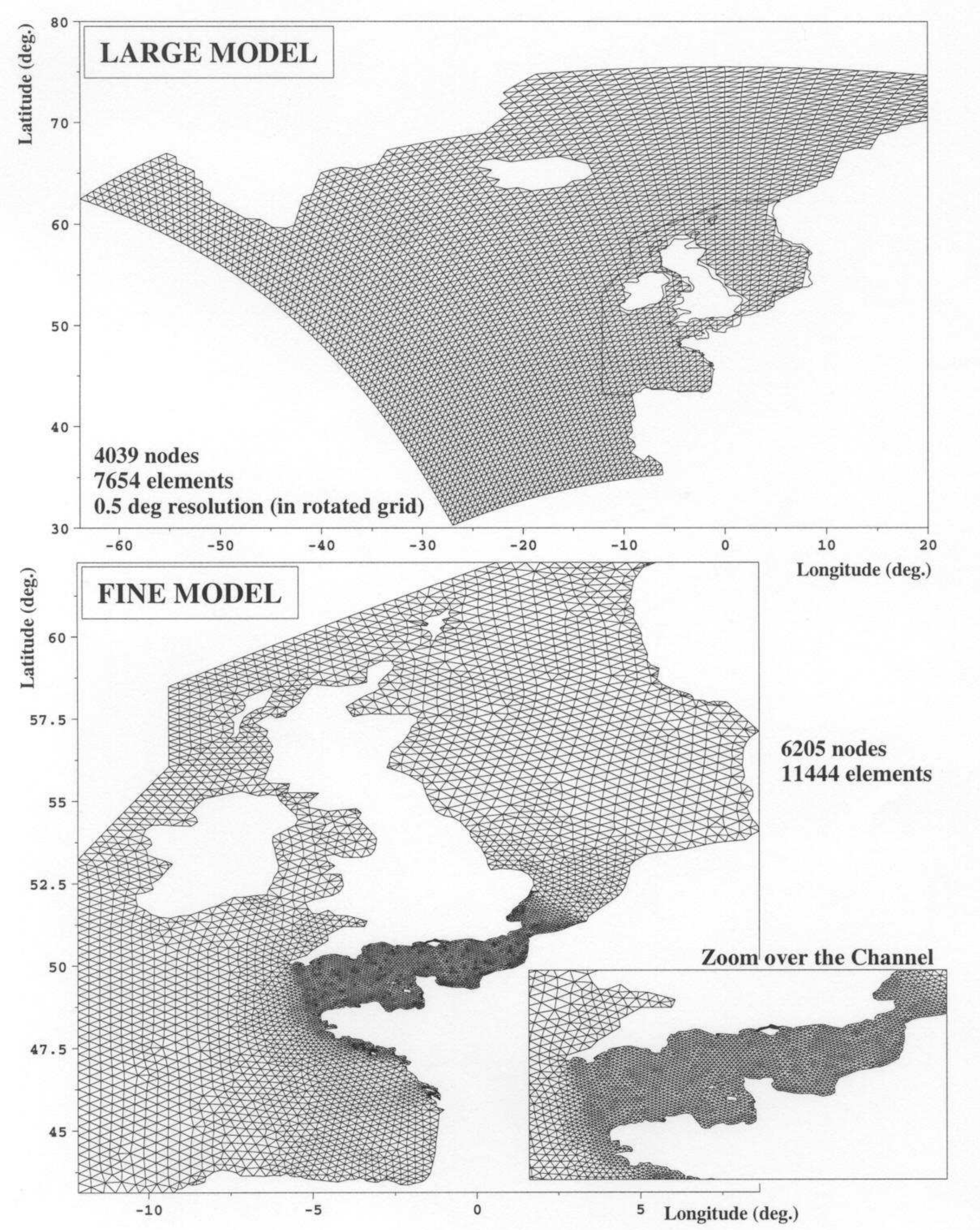

Figure 5.1: Examples of spatial grids in the Atlantic Ocean, the Channel and the North Sea

5.2.2. Directional discretization:

The interval of propagation direction [0, 360°] is discretized into *ND* evenly distributed directions, so that these directions are:

$\theta_m = (m-1).360/ND$ with m ranging from 1 to *ND*

In order to define the directional discretization, the user should specify as an input into the steering file:

- the direction number: *ND* (corresponding to the keyword *NUMBER OF DIRECTIONS* in the steering file).
- The direction convention selected for the input/output directional variables: either nautical or counterclockwise (corresponding to the keyword *TRIGONOMETRICAL CONVENTION* in the steering file, the default value of which is NO). The nautical convention sets the wave propagation directions (towards which the waves are propagating) in relation to the true North or the vertical axis and opposite to the counterclockwise direction. The counterclockwise convention sets the wave propagation directions in relation to the horizontal axis.
- Note that the convention selected for computing the directions within the FORTRAN code always defines the propagation directions in the clockwise direction from the true North, even though the keyword *TRIGONOMETRICAL CONVENTION* = YES !

5.2.3. Spectro-angular grid:

A two-dimensional grid for spectro-angular discretization is achieved by combining the above defined frequency and directional discretizations. That grid has *NF.ND* points.

A polar representation is used in TOMAWAC, where the wave frequencies are measured radially and where the propagation direction corresponds to the value of the angle in relation to the axis selected by the user as (vertical or horizontal) origin. An example of a spectro-angular grid having 25 frequencies and 12 directions is illustrated in Figure 5.2.

5.3. Temporal discretization

In TOMAWAC, each computation begins at the internal date 0, to which an actual date being defined by the keyword *DATE OF COMPUTATION BEGINNING* in the steering file can be associated. That date is specified as per the yymmddhhmm format which corresponds to the moment dd/mm/yy at hh:mm (for example, 9505120345 corresponds to May 12, 1995 at 3.45).

The evolution equation of the directional spectrum of wave action density is integrated with a constant time step, that is expressed in seconds through the keyword *TIME STEP* in the steering file. Sub-iterations of that time step can also be made for computing the source terms (refer to paragraph 6.3). That number of sub-time steps per time step is defined in the steering file through the keyword *NUMBER OF ITERATIONS FOR THE SOURCE TERMS.*

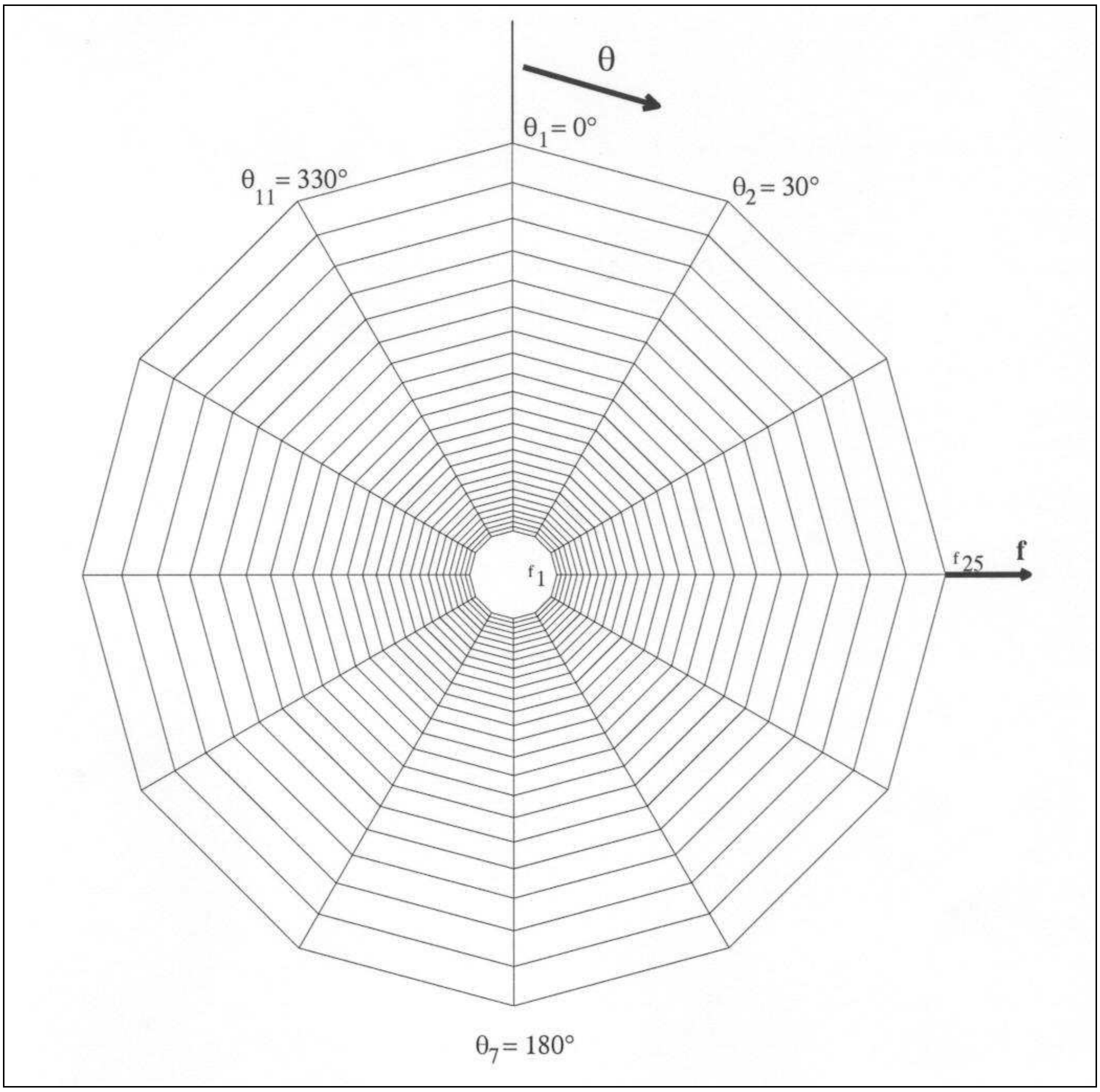

Figure 5.2: Example of a spectro-angular grid as used by TOMAWAC (25 frequencies and 12 directions in this case)

6. Numerical methods used in TOMAWAC

6.1. General solution algorithm

As stated in Section 4, the equation to be solved by the TOMAWAC software is a transport (convection) equation with source terms that can be written in the following general form:

$$\frac{\partial (B\,F)}{\partial t} + \vec{V}.\vec{\nabla}(B\,F) = B\,Q \qquad (6.1)$$

Both functions F and Q are functions of five variables and depend, e.g. in Cartesian coordinates, on x, y, θ, f_r and t. The above equation is then to be solved on a four-dimensional grid in (x, y, θ, f_r) and $\vec{V}$ is a transport vector, which is a dimension-4 vector in the general case. It is reduced, however, to a three-dimensional vector ($\dot{f}_r$ is zero) when there is neither a current nor a variation of water depth in time.

$$\vec{V} = \begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \\ \dot{f}_r \end{pmatrix} \qquad (6.2)$$

Equation (6.1) is solved in TOMAWAC through a fractional step method, i.e. the convection and the source term integration steps are solved successively and separately. Thus, the following steps are successively solved from a current state at the date $t = n.\Delta t$, in which the variance spectrum F^n is known in all points:

• a **convection step** without source terms (refer to paragraph 6.1.2):

$$\frac{\partial (B\,F)}{\partial t} + \vec{V}.\vec{\nabla}(B\,F) = 0 \qquad (6.3)$$

discretized as follows:

$$\frac{(B.F)^* - (B.F)^n}{\Delta t} = \left[\vec{V}.grad(B.F)\right]^n \qquad (6.4)$$

from which a value of $(B.F)^*$, then of F^*, intermediate after the convection step, is derived

• a **source term integration step** (refer to paragraph 6.1.3):

$$\frac{\partial F}{\partial t} = Q \qquad (6.5)$$

discretized as follows:

$$\frac{F^{n+1} - F^*}{\Delta t} = \frac{Q^{n+1} + Q^*}{2} \qquad (6.6)$$

since coefficient B is time independent.

The variance density spectrum F^{n+1} for a time step (time $t = (n+1).\Delta t$) is then obtained. That operation is then repeated for the next time step and as many times as necessary for covering the simulation period being considered.

6.2. Processing the propagation step

The propagation step is solved in TOMAWAC by means of the method of characteristics, which is largely used at the LNHE for processing various convection equations (refer for example to [Esposito, 1981]). The application of that method to TOMAWAC has a specific feature: the method should be applied to a dimension-4 space in the general case and to a dimension-3 space when there is no current and the depth is constant over time; furthermore the domain in propagation directions is periodic.

It should be reminded that equation (6.3) without source terms is processed in that step, being discretized as follows for a time step Δt_p:

$$\frac{(B.F)^* - (B.F)^n}{\Delta t_p} = \left[\vec{V}.grad(B.F)\right]^n \tag{6.7}$$

The convector field $\vec{V}$, whose expression was given in Section 4, is not time dependent when there is no tide, just like factor B (refer to paragraph 4). The equation to be processed can be simplified as follows in that case:

$$\frac{B.F^* - B.F^n}{\Delta t_p} = \vec{V}.\left[grad(B.F)\right]^n \tag{6.8}$$

This is a major advantage, since the characteristics can be traced back only once, at the beginning of the simulation. It is sufficient to store the origin of the characteristic pathlines and to retrieve them whenever the convection step is called. For each quadruplet (x_Q, y_Q, θ_Q, f_{rQ}) of the discretized spatial and spectro-angular variables, the characteristic curve is traced back to the time step Δt_p and the “arrival” point (x_P, y_P, θ_P, f_{rP}), which is called foot of the characteristic pathline, is stored. Actually, the numbers of the discretization elements (triangular elements for the spatial grid and quadrangular elements for the spectro-angular grid) including that foot of the characteristic pathline, as well as the linear interpolation coefficients allowing to obtain the values in that point from the values at the apices of the elements (barycentric coordinates), are kept. Thus, the convection step can be reduced in the form:

$$(B.F)^* (x_Q, y_Q, \theta_Q, f_{rQ}) = (B.F)^n (x_P, y_P, \theta_P, f_{rP}) \tag{6.9}$$

That step requires a short computation time since it only consists of an interpolation operation over each time step, once the characteristics have been traced back at the beginning of a computation.

When there is a tide, the principle remains unchanged, but the characteristics should be traced back after every depth and current update.

Such a method has the advantage of being unconditionally stable, enabling to revoke the condition that requires a Courant number below 1 and which is implemented, for example, in the upstream off-centred first-order propagation scheme being used in the WAM-cycle 4 model [WAMDI, 1988] [Komen et al., 1994]. The finite element grid generation technique is provided for achieving a locally finer computational grid in order to represent irregular bathymetric features or an irregular coastline. Thanks to the applied propagation scheme, the time step does not necessarily have to be much reduced, so that reasonable computation times can be kept. It should actually be clear that, rather than the propagation step, the source term integration step (particularly the computation of non-linear interactions) does consume most of the computation time. As regards the numerical schemes in which the propagation step implies a shorter time step when making the grid finer (e.g. as in the case of the WAM model), the overall computation time happens to become much longer because of the source terms and the model becomes less attractive for the practical applications.

Owing to the method of characteristic, on the contrary, the TOMAWAC model allows to overcome that restriction and is therefore attractive even for grids with a rather fine spatial resolution.
The method of characteristic, however, has some drawbacks due to the fact that, in the general case, it has a significant level of numerical diffusion and is not conservative.

6.3. Processing the source term integration step

6.3.1. Source term integration numerical scheme

The source and sink terms in the equation of variance density spectrum evolution are integrated using the following scheme, which can be changed by the user from fully explicit to fully implicit:

$$\frac{F^{n+1}-F^*}{\Delta t}=(1-\chi)Q^*+\chi Q^{n+1} \tag{6.10}$$

where the exponent * denotes the values of the variables after the propagation step (but before the source term integration step) and the exponent $^{n+1}$ denotes the values of the variables after the source term integration step. The parameter χ, set by the user through the keyword *IMPLICITATION COEFFICIENT FOR SOURCE TERMS* in the steering file, should lie in the range [0 ; 1]:

- $\chi = 0$ corresponds to the fully explicit scheme (only the value of source terms Q* are used). This option is not advised for practical applications.
- $\chi = 0.5$ corresponds to the semi-explicit scheme, used in the WAM-Cycle 4 model [WAMDI, 1988] [Komen et al., 1994]. It enables to use fairly long time steps (about 20-30 min in an oceanic environment). This value was the only one considered in earlier versions of TOMAWAC. It is the default value of the keyword.
- $\chi = 1$ corresponds to the fully implicit scheme, as used for instance in a modified version of WAM [Hersbach and Janssen, 1999].

Emphasis should be laid on the fact that the source term integration step is « local », i.e. it is carried out independently for each point in the 2D spatial grid.
The numerical implementation of the scheme is briefly presented below.
We first define $\Delta F = F^{n+1} - F^*$, the change in the spectrum value. Then the source/sink terms are classified as linear (Q_l) or non-linear terms (Q_{nl}) in the wave spectrum F:

$$Q = Q_l + Q_{nl} \tag{6.11}$$

- <u>As regards the source terms that are linear in F</u>, note that: $Q = \beta F$, hence we get:

$$Q_l^{n+1}=\beta^{n+1}F^{n+1}=\beta^{n+1}F^*+\beta^{n+1}\Delta F \tag{6.12}$$

- <u>As regards the source terms that are non-linear in F</u>, a Taylor's expansion is done keeping only the first-order term:

$$Q_{nl}^{n+1}\approx Q_{nl}^{*}+\frac{\partial Q_{nl}^{*}}{\partial F}\Delta F \tag{6.13}$$

$\frac{\partial Q_{nl}^{*}}{\partial F}$ is a matrix of differential increments that is broken down into a diagonal component [Λ*] and an extra-diagonal component [N*]:

$$\frac{\partial Q_{nl}^{*}}{\partial F} = \left[M^{*}\right] = \left[\Lambda^{*}\right] + \left[N^{*}\right] \tag{6.14}$$

Substituting into the expression of Q_{nl}^{n+1}, this yields:

$$Q_{nl}^{n+1} \approx Q_{nl}^{*} + \left(\left[\Lambda *\right] + \left[N *\right]\right)\Delta F \tag{6.15}$$

Adding the contributions from the linear and nonlinear terms, we obtain:

$$Q^{*} = \beta * F * + Q_{nl}^{*} \tag{6.16}$$

$$Q^{n+1} = Q_{l}^{n+1} + Q_{nl}^{n+1} = \beta^{n+1} F * + \beta^{n+1} \Delta F + Q_{nl}^{*} + \left(\left[\Lambda *\right] + \left[N *\right]\right)\Delta F \tag{6.17}$$

The variation of the variance density spectrum due to the source terms is written as:

$$\Delta F = F^{n+1} - F* = \Delta t\left((1-\chi)Q^{n+1} + \chi Q*\right) \tag{6.18}$$

i.e., after substitution of the source term expressions:

$$\Delta F = \Delta t\left\{(1-\chi)\left[\beta * F * + Q_{nl}^{*}\right] + \chi\left[\beta^{n+1} F * + \beta^{n+1}\Delta F + Q_{nl}^{*} + \left(\left[\Lambda *\right] + \left[N *\right]\right)\Delta F\right]\right\} \tag{6.19}$$

$$\Delta F\left[1 - \chi\Delta t\left(\beta^{n+1} + \left(\left[\Lambda *\right] + \left[N *\right]\right)\right)\right] = \Delta t\left(\left[(1-\chi)\beta * + \chi\beta^{n+1}\right]F * + Q_{nl}^{*}\right) \tag{6.20}$$

The matrix between brackets in the left-hand member of the latter equation cannot be easily inverted in the general case. The designers of the WAM model [WAMDI, 1988], however, demonstrated that the diagonal portion [Λ*] usually prevails over the extra-diagonal portion [N*]. Relying on comparative tests, they conclude that the extra-diagonal portion can be ignored in favour of the diagonal portion, even with time steps of 20 min or so. Due to that simplification, the inversion is much easier and we finally obtain:

$$\Delta F \approx \Delta t \frac{\left((1-\chi)\beta * + \chi\beta^{n+1}\right)F * + Q_{nl}^{*}}{1 - \chi\Delta t\left(\beta^{n+1} + \Lambda *\right)} \tag{6.21}$$

For the sake of convenience, that expression is rewritten as:

$$\Delta F = \frac{\Delta t . Q_{TOT}}{1 - \chi\Delta t Q_{DER}} \tag{6.22}$$

where: $Q_{TOT} = \left((1-\chi)\beta * + \chi\beta^{n+1}\right)F * + Q_{nl}^{*}$ denotes a total source term

and $Q_{DER} = \beta^{n+1} + \Lambda *$ denotes a source term derived with respect to F.

The contributions of the various source terms implemented in TOMAWAC and described in paragraph 4.2.3 are schematically illustrated in the Table 6.1.

The source term integration time step may be different from the propagation time step in TOMAWAC, but it should be a sub-multiple of it. Thus, several source term integration time sub-steps per propagation time step can be defined. That option is governed by the keyword *NUMBER OF ITERATIONS FOR THE SOURCE TERMS* in the steering file. The default value of that parameter is set to 1.

Source/sink terms	Linear or non-linear	Remarks	Type of contribution to Q_{DER}	Type of contribution to Q_{TOT}
Wind input	Linear or quasi-linear	β depends on time	β^{n+1}	$\left((1-\chi)\beta^* + \chi\beta^{n+1}\right)F^*$
Whitecapping	Quasi-linear	Slightly non-linear	Λ^*	$\Lambda^* F^*$
Bottom friction	linear	β does not depend on time	β	$\beta\ F^*$
Non-linear transfers between frequency quadruplets	non-lin.		Λ^*	Q^*_{nl4}
Bathymetric breaking	linear	β does not depend on time $\beta^{n+1} = \beta^n = \beta$	β	$\beta\ F^*$
Non-linear transfers between triads	non-lin		Λ^*	Q^*_{tr}

Table 6.1: Contributions of the different source/sink terms implemented in TOMAWAC.

It was found experimentally that the depth-induced breaking source term, which is sometimes very strong, can still be overestimated if the time step that was selected for the source term integration is too long. In order to avoid that, TOMAWAC gives an opportunity to make a number of time sub-steps that are specific to that source term. These time sub-steps are in a geometric progression. In order to limit that number of time sub-step, TOMAWAC first clips the wave height by setting a maximum H_{m0}/d ratio (d being the depth) to 1.
Subsequently, a Euler's explicit scheme is used at each time step:

$$\frac{F^{n+1} - F^*}{\Delta t_2} = Q^* \quad \text{i.e.} \quad \Delta F = \Delta t_2' Q^* \tag{6.23}$$

The H_{m0}/d ratio can be modified through the keyword *MAXIMUM VALUE OF THE RATIO HM0 ON D* (however, this it not advisable). The number of time sub-steps is specified through the keyword *NUMBER OF BREAKING TIME STEPS*. The geometric ratio is given by the keyword *COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING*.

6.3.2. Monitoring the growth of the wave spectrum

In order to limit the possible risks of numerical instabilities related to the source term integration, TOMAWAC is provided with various options for limiting the growth of the directional spectrum per source term integration time step. The choice of option is done by the user in the steering file through the keyword *WAVE GROWTH LIMITER*, which can bet set to 0, 1 (default value) or 2:

0 : no limiter is applied to the computed ΔF from the various source/sink terms.

1 : the limiter is directly inspired by the criterion proposed by the WAM group [WAMDI, 1988]. The absolute variation of the variance density spectrum as it was computed by the scheme in paragraph 6.3.1. should remain lower than a fraction of an equilibrium spectrum ΔF_{lim}:

$$\Delta F_{lim} = 6.4\ 10^{-7}\ g^{2}\ \frac{\Delta t}{1200}\ f^{-5} \tag{6.24}$$

This is presently the default value in TOMAWAC, as it was the only possibility in earlier versions of the code.

2 : the limiter is computed with an updated expression, proposed by Hersbach and Janssen [Hersbach and Janssen, 1999]:

$$\Delta F_{lim} = 3.0\ 10^{-7}\ g\ \max(u^*,\ g\ \tilde{f}_{PM}/f)\ f^{-4}\ f_{NF}\ \Delta t \tag{6.25}$$

where u^* is the friction velocity at the water surface and $\tilde{f}_{PM} = 5.6\ 10^{-3}$ is the dimensionless Pierson–Moskowitz peak frequency.
This option should now be preferably used for practical applications.

6.4. Processing the boundaries – Boundary conditions

6.4.1. Spatial grid:

Two types of boundary conditions are considered in TOMAWAC for the finite element spatial grid:

- The former corresponds to a free boundary condition, i.e. that absorbs the whole wave energy. It may be a sea boundary, hence it is assumed that the waves propagate beyond the domain and nothing enters it. It may be a solid boundary, hence it is assumed that the coast absorbs completely the wave energy (no reflection).
- The latter corresponds to a prescribed value boundary condition. The whole wave spectrum is then prescribed at each point along that boundary and for each step. Energy enters into the computational domain.

6.4.2. Spectro-angular grid:

As regards the propagation directions, the grid generation is periodical over the range [0 ; 360°]: hence there are no directional boundary conditions.
As regards the wave frequencies that are discretized, the minimum and maximum frequency markers are considered as “open boundary limits”, where the energy can be transferred to lower or higher frequencies, exiting the discretized frequency range.

7. Inputs-outputs

7.1. Preliminary remark

During a computation, the TOMAWAC software uses a number of files, some of which are optional, as inputs and outputs.
The input files are:

- The steering or CAS file (mandatory),
- The mesh or geometry file (mandatory),
- The boundary conditions or CONLIM file (mandatory),
- The seabed, bottom or bathymetry file (optional),
- The FORTRAN or PRINCI file (optional),
- The currents file (optional),
- The winds file (optional),
- The previous computation file (optional),
- The binary user file (optional),
- The formatted user file (optional).

The output files are:

- The 2D results or grid file (mandatory),
- The punctual results or spectra file (mandatory),
- The next computation file (optional),
- The listing printout (either on the display screen or in the file, see APPENDIX 1),
- The binary user file (optional),
- The formatted user file (optional).

7.2. The files

7.2.1. The steering (or CAS) file

The steering file name is specified in the steering file through the keyword: *STEERING FILE.*
It is a text file created by means of a text editor. In a way, it serves as the computation control panel. It includes a set of keywords to which values are assigned. If a keyword does not appear in this file, then TOMAWAC will assign to it the default value as defined in the dictionary file (refer to the description in APPENDIX 3). If such a default value is not defined in the dictionary, then the computation will come to a halt and display an error message. For instance, the command *NUMBER OF DIRECTIONS* = 12 is for specifying that the direction spectrum of wave action or its moments will be discretised over 12 propagation directions.
TOMAWAC reads the steering file at the beginning of the computation.
Both dictionary file and steering file are read by the so-called DAMOCLES utility which is included in TOMAWAC. The syntactic rules of DAMOCLES should then be observed upon the creation of the steering file. These rules are described here below.
The write rules are as follows:

- The keywords can be of the Integer, Real, Logical or Character format type.
- The keyword sequence order in the steering file is of no importance.

- Each line has a maximum of 72 characters. However, as many linefeeds as one wants are allowed provided that the keyword name does not run from one line to the next.
- For the table-like keywords, the successive values are separated by a semi-colon. A number of values equal to the table dimension should not necessarily be given; in such a case, DAMOCLES returns the number of values being read. For example:
  ABSCISSAE OF SPECTRUM PRINTOUT POINTS = 1.2;3.4
  (that keyword is declared as a 99-valued table)
- The symbols ":" or "=" are indiscriminately used to separate a keyword from its value. They can be either preceded or followed with any number of blanks. The value itself may appear on the next line. For example:
  NUMBER OF DIRECTIONS = 12
  or
  NUMBER OF DIRECTIONS: 12
  or else
  NUMBER OF DIRECTIONS =
  12
- The characters occurring between a pair of "/" on one line are regarded as comments. Likewise, the characters occurring between a "/" and a the end of a line are regarded as comments. For example:
  TYPE OF BOUNDARY DIRECTIONAL SPECTRUM = 1 / Jonswap spectrum
- A whole line beginning with a "/" in the first column is regarded as a comment, even though another "/" occurs on the line. For example:
  / The geometry file is ./maillage/geo
- Integer writing: Do not exceed the maximum size being allowed by the machine (in a machine with 32 bit architecture, the values range from -2 147 483 647 to + 2 147 483 648. Do not enter a blank between the sign (optional for the + sign) and the number. A dot at the end of the number is tolerated.
- Real writing: A dot or a comma is allowed as a decimal point, as well as the FORTRAN E and D formats (1.E-3 0.001 0,001 1.D-3 denote the same value).
- Logical value writing: The values 1, YES, OUI, .TRUE., TRUE, VRAI on the one hand, and 0, NO, NON, .FALSE., FALSE, FAUX on the other hand are allowed.
- Character string writing: Those strings including blanks or reserved symbols ("/",":", "=", "&") should be put in single quotes ('). The value of a character keyword may include up to 144 characters. As in FORTRAN, the quotes occurring within a string should be doubled. A string may neither begin nor end with a blank. For example:
  TITLE = 'HOULE D''OUEST'

In addition to the keywords, a number of directives or metacommands that are interpreted during the sequential readout of the steering file may be used as well:

- The *&FIN* command indicates the end of file (even though the file is not completed). Thus, some keywords can be disabled simply by placing them behind that command for easily making it possible to enable them again subsequently.
- The *&ETA* command prints the list of keywords and the relevant values at the time when DAMOCLES meets that command. This display will occur at the beginning of listing printout.
- The *&LIS* command prints the list of keywords. This display will occur at the beginning of listing printout.

- The *&IND* command prints the detailed list of keywords. This display will occur at the beginning of listing printout.
- The *&STO* command causes the interruption of the program, the computation does not go on.

7.2.2. The geometry file

The geometry file name is specified in the steering file through the keyword: *GEOMETRY FILE*.
It is a SERAFIN-formatted binary file: it can be read by FUDAA PRE-PRO or RUBENS and it can be created by the STBTEL module from the file(s) as produced by the mesh generator. The SERAFIN format structure is described in APPENDIX 8.
This file includes the complete information about the horizontal mesh, i.e. the number of mesh points (variable `NPOIN2`), the number of elements (variable `NELEM2`), the `X` and `Y` vectors containing the co-ordinates of all the points and, lastly, the `IKLE2` vector containing the connectivity table.
Furthermore, this file may also include bathymetry information in each point of the mesh, provided that the interpolation of the bathymetry was carried out during the execution of the STBTEL module or during the generation of the mesh.
TOMAWAC reproduces the information regarding the geometry at the beginning of the 2D results. Any computation results file can then be used as a geometry file when one wants to perform a further simulation on the same mesh.

7.2.3. The boundary conditions file.

The boundary conditions file name is specified in the steering file through the keyword: *BOUNDARY CONDITIONS FILE.*
It is a formatted file that can be created automatically by STBTEL and can be modified by means of a text editor. Each line in this file is assigned to one point of the boundary and listed in sequential order in terms of the boundary node numbers. The numbering of the boundary points first delineates the domain contour in the counterclockwise direction, then the islands in the clockwise direction.
This file is described in detail in 8.5.1.

7.2.4. The currents file

According to its type – binary or formatted- the currents file name is specified in the steering file through the keywords: *BINARY CURRENTS* FILE and *FORMATTED CURRENTS FILE.*
It is the file from which TOMAWAC reads the current field components. The current field may be either stationary or non-stationary. The current field will be non-stationary when the keyword *CONSIDERATION OF TIDE* is set to TRUE. When the current field is stationary, the keyword *CONSIDERATION OF A STATIONARY CURRENT* should be set to TRUE. By default, both keywords will be set to FALSE. When both are set to TRUE, the keywords will be inconsistent, and the program will halt.
Several commonly used formats can be read. This selection is made through the integer keyword *CURRENTS FILE FORMAT*. It can be set to a value from 1 to 4

- The format is 1: it is a finite-difference-typed format (as described in APPPENDIX 8). The file is formatted and the file name should be assigned to the keyword: *FORMATTED CURRENTS FILE*
- The format is 2: it is a point pattern-type SINUSX format (as described in APPENDIX 8). This file is formatted and the file name should be assigned to the

keyword: *FORMATTED CURRENTS FILE*. This format cannot be used for reading a non-stationary current.

- The format is 3: it is a TELEMAC result file of the SERAFIN standard. It is a binary file and its name should be assigned to the keyword: *BINARY CURRENTS FILE*. If the current is assumed to be stationary, then the additional keyword *TIME INCREMENT NUMBER IN TELEMAC FILE* should be used in order to find the time step number related to the desired record. TELEMAC data other than the current components e.g. water levels, can also be read by means of this format (refer to 8.2.5).
- The format is 4: data written in a different format can be read provided that the user supplies the relevant subroutine in the relevant FORTRAN file (see 8.2.3 and 8.2.6).

7.2.5. The tidal water level file

According to its type – binary or formatted- the tidal water level file name is specified in the steering file through the keywords: *BINARY TIDAL WATER LEVEL FILE* or *FORMATTED TIDAL WATER LEVEL FILE.*

This is the file from which TOMAWAC reads the tidal water level being referred to the *INITIAL STILL WATER LEVEL*. Several commonly used formats can be read. This selection is made by means of the integer keyword *TIDAL WATER LEVEL FILE FORMAT*. It can be set to a value from 1 to 3.

- The format is 1: it is a finite-difference-typed format (as described in APPENDIX 8). The file is formatted and the file name should be assigned to the keyword: *FORMATTED TIDAL WATER LEVEL FILE*.
- The format is 2: it is a TELEMAC result file of the SERAFIN standard. It is a binary file and its name should be assigned to the keyword: *BINARY TIDAL WATER LEVEL FILE*.
- The format is 3: data written in a different format can be read provided that the user supplies the relevant subroutine in the relevant FORTRAN file (see in 8.2.6).

7.2.6. The winds file

According to its type – binary or formatted- the wind file name is specified in the steering file through the keywords: *BINARY WINDS FILE* or *FORMATTED WINDS FILE.*

This is the file from which TOMAWAC reads the information about the wind fields. As in the case of the current, several read formats are allowed. The integer keyword *WINDS FILE FORMAT* can be set to values from 1 to 4.

- The format is 1: it is a WAM-cycle 4 format type (as described in APPENDIX 8). The file is formatted and the file name should be assigned to the keyword: *FORMATTED WINDS FILE*
- The format is 2: it is a point pattern-type SINUSX format (as described in APPENDIX 8). The file is formatted and the file name should be assigned to the keyword: *FORMATTED WINDS FILE*.
- The format is 3: it is a TELEMAC result file of the SERAFIN standard. It is a binary file and its name should be assigned to the keyword: *BINARY WINDS FILE*. If the wind is assumed to be stationary, then the additional keyword *TIME STEP NUMBER IN TELEMAC FILE* should be used in order to find the time step number related to the desired record.
- The format is 4: data written in a different format can be read provided that the user supplies the relevant subroutine in the relevant FORTRAN file (see in 8.2.4).

7.2.7. The previous computation file

This previous computation file name is specified in the steering file through the character keyword: *PREVIOUS COMPUTATION FILE.*

If a *NEXT COMPUTATION* is done, TOMAWAC fetches this file in order to initialize the directional spectrum of wave action at every point. This file's format, which is specific to TOMAWAC, is described in APPENDIX 8. It is a binary file.

7.2.8. The global results file

The global results file name is specified in the steering file through the keyword: *GLOBAL RESULTS FILE.*

This file is created when a *GLOBAL OUTPUT AT THE END* is requested. It saves the wave action density directional spectrum at every point in the last time step. This file format is described in APPENDIX 8.

7.2.9. The 2D results file

The 2D results file name is specified in the steering file through the character keyword: *2D RESULTS FILE.*

This is the file into which TOMAWAC writes the results of the 2-dimensional variables during the computation. It is a binary file of the SERAFIN standard. The data contained in it are in the following order:

1- all the data about the mesh geometry;
2- the names of the variables being stored;
3- for each time step, the time and the values of the variables are given for each point of the 2D mesh.

Its content varies according to the values of the following keywords:

- *NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS:* provided for determining from which time step will the data storage desirably begin, so that the file size will not be too large.
- *PERIOD FOR GRAPHICS PRINTOUTS*: sets the period, as a number of propagation time increments, of printouts so that the file size will not be too large.
- *VARIABLES FOR 2D GRAPHICS PRINTOUTS*: provided for specifying the list of variables to be stored into the 2D results file. Each variable is identified by 2, 3 or 4 letters. Table 7.1 lists the available variables. A more detailed description of the 2D variables is provided in APPENDIX 7.

M0	Total variance
HM0	Spectral significant wave height
DMOY	Mean wave direction
SPD	Mean directional spreading
ZF	Sea bottom level
WD	Water depth
UX	Current along X
UY	Current along Y
VX	Wind along X
VY	Wind along Y
FX	Driving force along X
FY	Driving force along Y

SXX	Radiation stress along xx
SYY	Radiation stress along yy
SXY	Radiation stress along xy
UWB	Bottom celerity
POW	Wave power (per meter along wave crest)
FMOY	Mean frequency FMOY
FM01	Mean frequency FM01
FM02	Mean frequency FM02
FPD	Discrete peak frequency
FPR5	Peak frequency by Read method of order 5
FPR8	Peak frequency by Read method of order 8
US	Surface friction velocity u*
CD	Surface drag coefficient CD
Z0	Surface roughness length Z0
WS	Surface wave stress
TMOY	Mean period Tmoy
TM01	Mean period Tm01
TM02	Mean period Tm02
TPD	Discrete peak period
TPR5	Peak period by Read method of order 5
TPR8	Peak period by Read method of order 8
PRI	Private table
BETA	Breaking waves coefficient

Table 7.1: List of 2D results variables

For instance, if the significant wave heights, the water depths and the average wave propagation directions are desired,
VARIABLES FOR 2D GRAPHICS PRINTOUTS = HM0,WD,DMOY
must be entered in the steering file.

7.2.10. The punctual or spectrum results file

This file's name is specified in the steering file through the character keyword: *PUNCTUAL RESULTS FILE.*
This is the file into which the directional spectra of wave action at some previously specified points are stored by TOMAWAC during the computation. These points are selected by means of the following keywords:

- *ABSCISSAE OF SPECTRUM PRINTOUT POINTS* and *ORDINATES OF SPECTRUM PRINTOUT POINTS*: they are chart keywords. The maximum number of points is 99, i.e. a maximum of 99 printout points. The spectrum will be recorded at the closest point to the specified position, no spatial interpolation is made.
- This file is a SERAFIN formatted file. It first includes all the data about the spectral mesh geometry, then the names-codes of displayed points. This name-code is of the type: *Fa_PT2Db*, where *a* denotes the point's sequence order number within the list written in the steering file and *b* denotes the number of the closest 2D point to the specified position. Subsequently, for each graphic printout, it contains the time and the value of the directional spectrum of wave action for each pair (direction, frequency) in the spectral mesh.

The keywords *PERIOD FOR GRAPHICS PRINTOUTS* and *NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS* are shared by the two results files; thus, the printouts are synchronous for either file.

7.2.11. The printout listing

This file contains all the messages as generated by TOMAWAC during the computation. It is the main report of a TOMAWAC run. Its content depends on the value of the following keyword:

- *PERIOD FOR LISTING PRINTOUTS*: this sets the time between two time steps of message transmission. This value is given in terms of the number of iterations. For example, the following sequence:

TIME INCREMENT = 30.
PERIOD FOR LISTING PRINTOUTS = 2
will result in a print in the output listing every 60 seconds of simulation.

The listing is either displayed on the monitor or saved in a file. The file name is defined by the user at the execution of the TOMAWAC simulation (refer to APPENDIX 1).

7.2.12. The User FORTRAN file

This User FORTRAN file name is specified in the steering file through the character keyword: *FORTRAN FILE*.
The FORTRAN contains all the user-modified TOMAWAC subroutines as well as the specifically developed routines for that computation.
This file is compiled and linked during run time in order to generate the executable being used for the simulation.

7.2.13. The auxiliary files

Other input/output files may be used by TOMAWAC.

- A binary data or results file: its name is specified through the character keyword *BINARY FILE 1*.
- A formatted data or results file: its name is specified through the character keyword *FORMATTED FILE 1*.

These files can be used either for supplying data to the program or for allowing data to be processed that are not available in the standard results files; obviously, the user must manage the read and write operations of these files within the FORTRAN program.

7.2.14. The dictionary file

This dictionary file contains all the information about the keywords (French/English name, default values, type). This file can be viewed in a text editor by the user, but it must not be modified in any way.

7.2.15. The libraries

At the beginning of a computation, the main user-written FORTRAN routine is compiled, then linked in order to generate the executable program that is subsequently run.
The following libraries are used during the link editing operation:

- `TOMAWAC` library: contains the specific subroutines of the TOMAWAC computation model.

- `telemac` library: contains the specific subroutines of the TELEMAC-2D computation model.
- `damocles` library: contains the subroutines handling the steering file reading.
- `BIEF` library: contains the computation modules related to the finite element-typed operations (operations on both matrixes and vectors). This library is shared by all the simulation models as developed by the LNHE within the TELEMAC structure (BIEF means "BIbliothèque d'Eléments Finis", i.e. Finite Element Library).

7.3. Binary files

Binary files are an efficient way to store data on disk. However, binary files written on different computers may differ. TOMAWAC recognizes three types of binary files, namely:

- the native binary of the computer,
- IBM binary (so that a file that has been generated on an IBM computer can be read), and
- IEEE binary, so that these files can be read on a workstation (provided that the suitable subroutines are set up when installing TOMAWAC on the computer).

The following keywords can be used:

- *GEOMETRY FILE BINARY*, for the geometry file,
- *2D RESULTS FILE BINARY* for the 2D results file.
- *PUNCTUAL RESULTS FILE BINARY* for the punctual results file.
- *GLOBAL RESULTS FILE BINARY*, for the global results file,
- *PREVIOUS COMPUTATION FILE BINARY*, for the previous computation file,
- *CURRENTS FILE BINARY*, for the currents and/or TELEMAC results file.
- *TIDAL WATER LEVEL FILE BINARY*, for the tidal water level file,
- *WINDS FILE BINARY*, for the winds file.
- *BINARY 1 FILE BINARY* for binary file.

In all the cases, the default value as specified in the dictionary file is 'STD' (default value of the machine being used). The other possible values are 'IBM' and 'I3E'.

7.4. Files standard

Almost all files that were in Serafin format in previous versions of TOMAWAC, have been given a key-word for the file format.

If the name of the file is: “GEOMETRY FILE” (“FICHIER DE GEOMETRIE”), the new keyword will be: “GEOMETRY FILE FORMAT” (“FORMAT DU FICHIER DE GEOMETRIE”).

This format is given in 8 characters. Three choices are possible so far:

1. ‘SERAFIN ‘(do not forget the space at the end): it is the default standard within the TELEMAC processing chain. The format is recognized by the FUDAA PRE-PRO graphics post-processor. The RUBENS graphics post-processor reads the SERAFIN format as well, but it won't be developed anymore and it is bound to disappear. The SERAFIN file format is described in detail in APPENDIX 8.
2. ‘SERAFIND’: Serafin format, but with double precision. Can be used for a more accurate “computation continued” or for more accurate validations. Neither FUDAA PRE-PRO nor Rubens can read this format.
3. ‘MED ‘: this is an EDF-CEA format used in the Salomé platform, that enables to use the post-processors of this platform. It is based on hdf5. This new format is not activated if you use the

default subroutine med.f provided, which is mostly void. If you take instead the file med.edf and rename it med.f, med formats will be available, but two additional libraries are necessary to use this format and have to be specified in the systel.ini file. Full instructions will be given in further releases, this is so far for internal use at EDF.

A new file structure has been added to library BIEF for simplifying the opening/closing and reading/writing operations with these file formats, as well as for simplifying the coupling between programmes. The description of this file structure and of the operations on those files are given in APPENDIX 9.

As specified in section 7.2.7, a fourth binary format exists, which is specific to TOMAWAC and is used only for saving the results when they are used to initialize a next computation. This binary file format cannot be read by the RUBENS post-processor, or by FUDAA PRE-PRO graphics post-processor.

7.5. Bathymetry data

The bathymetry information can be supplied to TOMAWAC at two levels:

- Directly in the geometry/mesh file by a bathymetry value being assigned to each node in the mesh. In this case the bathymetry data have been processed previously, running the STBTEL module or mesh generator. For example, STBTEL reads the information from one or more bottom topography files (up to 5 files) and performs an interpolation at every point within the domain;
- In the form of an irregular pattern of spot heights without any necessary relation to the mesh nodes, during the TOMAWAC computation. The interpolation is then performed directly by TOMAWAC with the same algorithm as used by STBTEL. The bathymetry file name is given by the character keyword *BOTTOM TOPOGRAPHY FILE*. Unlike STBTEL, TOMAWAC only handles one bottom topography file. The file can be in SINUSX format or can consist of three columns X,Y,Z.

TOMAWAC also provides an opportunity to carry out a smoothing of the bathymetry in order to get a more consistent geometry. The smoothing algorithm can be iterated several times in order to achieve more or less extensive smoothing. The number of iterations is set using the keyword *BOTTOM SMOOTHINGS* and is carried out within the `CORFON` subroutine. This keyword's default value is 0. (also refer to the programming of the `CORFON` user subroutine in 8.6.1).

NOTE: the bathymetry data should preferably be supplied to TOMAWAC in the form of water depth and not of water height. If necessary, a conversion can be performed in the `CORFON` subroutine.

8. Controlling the simulation

8.1. General parameterisation

The general parameterisation of the computation is controlled using the steering file.

8.1.1. Computation title

The computation case title is specified by the keyword *TITLE*

8.1.2. Parallel computing

The release 6.0 of TOMAWAC includes the possibility to carry out parallel computing. The number of processors used in a TOMAWAC simulation is defined by the keyword *PARALLEL PROCESSORS.* For more detail see APPENDIX 10.

8.1.3. Computation time

The time data are prescribed using the two keywords *TIME STEP* (real) and *NUMBER OF TIME INCREMENTS* (integer). The former sets the elapsed time, in seconds, between two consecutive computation instants (but not necessarily two outputs in the results file). The number of time steps is for setting the overall computation time (which is obviously equal to the time increment value multiplied by the number of time steps).

An additional keyword also refers to time. This is the *DATE OF COMPUTATION BEGINNING*, which is used to identify the time in relation to the date/times written in the *WINDS FILE* (refer to APPENDIX 8, WAM-typed format). The convention adopted for writing the *DATE OF COMPUTATION BEGINNING* is yymmddhhmm. For instance, 0311051110 corresponds to November 5th, 2003, at 11.10 AM.

Note that when a computation is resumed, the initial time of the new computation corresponds to the last time increment in the previous computation (i.e. the computation is not resumed at time zero).

8.1.4. Spectral discretisation

The spectral discretisation is defined by the following 5 keywords:

- *NUMBER OF DIRECTIONS*,
- *NUMBER OF FREQUENCIES*,
- *MINIMUM FREQUENCY*,
- *FREQUENTIAL RATIO*,
- *SPECTRUM TAIL FACTOR.*

It should be reminded that the directions are evenly distributed from 0 to 360 degrees. Two conventions can be chosen by the user for expressing the wave propagation by means of the keyword *TRIGONOMETRICAL CONVENTION* (logical). The trigonometrical convention locates the wave propagation from the positive X axis and the direction of rotation is in a counterclockwise direction. The default convention is the nautical convention (*TRIGONOMETRICAL CONVENTION* = NO) that locates the propagation direction in relation to the true "North", i.e. the Y axis. The selected direction of rotation is a clockwise direction. The direction will then correspond to the "heading" in the sense of the navigational maps, i.e. the direction the waves are propagating towards.

The frequencies are distributed geometrically in accordance with the following relation:

$f_k = f_0 \, r^{k-1} \quad (k = 1, NF)$

where f_0 is the *MINIMUM FREQUENCY*

r is the *FREQUENTIAL RATIO*

NF is the *NUMBER OF FREQUENCIES*

In order to take the contribution of high frequencies (higher than the maximum discretized frequency) into account in the computations, it is assumed that the decay of the spectrum follows a law that is of the type f^{-n}. The keyword *SPECTRUM TAIL FACTOR* corresponds to the value of n.

8.1.5. Release

When generating the executable, the release number of libraries being used for editing the links is indirectly provided by the keyword *TOMAWAC RELEASE NUMBER*. By default, TOMAWAC release 6.0 utilises the 6.0 releases of the TELEMAC system libraries.

8.1.6. Environment

When a vector computer is used, the CPU vector length used in the forced vectorisation technique can be specified by means of the keyword *VECTOR LENGTH*. The default value is 1 and is appropriate for scalar machines such as the present workstations. If a value of 1 is used on a vector machine, then the advantage of the vectorisation loops (although they are few in TOMAWAC) is lost.

8.2. Computation options

8.2.1. Co-ordinate system

Cartesian co-ordinates (expressed in meters) are used by default. For domains of a large extent, working in spherical co-ordinates may become necessary. The value of the logical keyword *SPHERICAL COORDINATES* should then be set to "TRUE". The co-ordinates are then expressed in degrees.

8.2.2. Finite depth

In nearshore areas, wave conditions will be influenced by the water depth and therefore the bottom effect can no longer be ignored. This is the default case in TOMAWAC: the keyword *INFINITE DEPTH* is set to “FALSE”. In situations where depths effects are to be explicitly ignored the keyword *INFINITE DEPTH* should be set to "TRUE".

8.2.3. Taking a stationary current into account

A stationary current can be taken into account in the TOMAWAC release 6.0. The relevant logical keyword is *CONSIDERATION OF A STATIONARY CURRENT*. The current affects mainly the convection step.

The current can be specified in various ways.

When the current is either constant over the domain or can be described analytically, the `ANACOS.f` subroutine can be included in the FORTRAN file and modified accordingly. In this subroutine the `UC` and `VC` are `NPOIN2`-sized (number of points in the horizontal mesh) vectors and correspond to the components along the `X` and `Y` axes of the current, respectively. This is how the current is specified when the keyword *FORMATTED CURRENTS FILE* or *BINARY CURRENTS*

FILE is not specified, whereas the keyword *CONSIDERATION OF A STATIONARY CURRENT* is "TRUE".
TOMAWAC can also take into account a current provided in a binary or formatted file. The keyword *BINARY CURRENTS FILE* or *FORMATTED CURRENTS FILE* should then be given a value (the name of the file). Three different formats are available to read this data. The value corresponds to the keyword *CURRENTS FILE FORMAT* (see 7.2.4). When the currents file is taken from TELEMAC-2D, then an additional keyword should be specified, namely the *TIME INCREMENT NUMBER IN TELEMAC FILE*. This locates the desired record.
If the predefined formats cannot be used, the `COUUTI.f` subroutine can be included in the FORTRAN and modified accordingly, specifying the format 4 for the `INDIC` FORTRAN variable in the CAS file. The current data are read from the file and are interpolated onto the nodes of the computation mesh.

8.2.4. Taking a wind into account

Consideration of a wind is specified by the logical keyword *CONSIDERATION OF A WIND*. The wind may be either stationary or variable in time and is specified by means of the logical keyword *STATIONARY WIND*.
When the wind can be described analytically, the user subroutine `ANAVEN.f` can be used. The wind is fully specified when the keywords *FORMATTED WINDS FILE* and *BINARY WINDS FILE* do not have any value, whereas the keyword *CONSIDERATION OF A WIND* is "TRUE".
TOMAWAC can also take into account a wind given in a binary or formatted file. In this case a value (the name of the file) should be assigned to the keyword *FORMATTED WINDS FILE* or *BINARY WINDS FILE*. The available formats for reading out these data correspond to the keyword *WINDS FILE FORMAT* (see in section 7.2.6. and APPENDIX 8).
When these predefined formats cannot be used, the subroutine `VENUTI.f` can be included in the FORTRAN file and modified accordingly, specifying the format 4 for the `INDIV` FORTRAN variable. On completion of reading the winds file, the wind components are used as such if provided on the computational mesh, or interpolated over that mesh if provided on a different grid.
NOTE: an interpolation between two different meshes of equivalent sizes is usually computationally very expensive. Although possible, it is highly inadvisable, particularly as regards to the wind, since this is a time-varying data item. In such cases a pre-interpolation over the computation mesh, e.g using STBTEL is recommended, followed by the reading of the wind data in format 3. Alternatively this pre-interpolation can be performed by means of the `FASP` subroutine from the *BIEF* library.

8.2.5. Recovering a TELEMAC data item

Recovering a 2D result data item from a TELEMAC-2D hydrodynamic computation might be of interest, e.g. the value of wind-driven surge at every point. To avoid an increase in the number of files the *BINARY CURRENTS FILE* is used to specify this input file. The keyword *CURRENTS FILE FORMAT* should then be set to 3. This option is further specified using the logical keyword *RECOVERY OF TELEMAC DATA ITEM*. The data item is located within the file through the *TIME INCREMENT NUMBER IN TELEMAC FILE* and the *RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED* that corresponds to desired variable's sequence number in the record. The needed data are read from the file and interpolated over the computation mesh.
NOTE: a TELEMAC data item and the components of a current can both be read simultaneously provided that they occur in the same file at the same record.
The recovered variable, which is interpolated over the mesh, can be utilised in the subroutine `VARTEL`.

8.2.6. Taking the tide into account

Tide-induced effects, i.e. unsteady/non-stationary water levels and currents can be taken into account. The relevant logic keyword is *CONSIDERATION OF TIDE*.

In order to take tide into account, a current and a tide water depth that is referenced in relation to the "INITIAL STILL WATER LEVEL" must be specified. These data can be initialized in various ways:

Should the tide be easy to describe analytically, the `ANAMAR.f` subroutine, can be included in the FORTRAN file and modified accordingly. In the subroutine the terms `UC` and `VC`, `ZM` and `DZHDT` are `NPOIN2`-sized (number of points in the horizontal mesh) vectors and correspond to the current components along the `X` and `Y` axes, the tidal water level in relation to the "INITIAL STILL WATER LEVEL" and the water depth variation in time, respectively. An analytical expression must be assigned to all of these vectors.

TOMAWAC can also take into account a current that is given in a binary or formatted file. A value (the name of the currents file) should be assigned to the keyword *BINARY CURRENTS FILE* or *FORMATTED CURRENTS FILE*. Two different formats are available for reading these data. This format is specified using the keyword *CURRENTS FILE FORMAT* (see 7.2.4). When these predefined formats cannot be used, the user subroutine `COUUTI.f` can be included in the FORTRAN file and modified accordingly. In such cases the *CURRENTS FILE FORMAT* (FORTRAN variable `INDIC`) must be set to 4 in the CAS file. Once the data of the currents file are read, the current components are interpolated over the computation mesh.

The tidal water level can be also provided in a binary or formatted file. A value (the name of the water level file) should be assigned to the keyword *BINARY TIDAL WATER LEVEL FILE* or *FORMATTED TIDAL WATER LEVEL FILE*. Two different predefined formats are available for reading this data. The format type is specified using the keyword *TIDAL WATER LEVEL FILE FORMAT* (refer to 7.2.5). If the user chooses the Serafin format (i.e. TELEMAC-2D format), then the *RANK OF THE WATER LEVEL DATA IN THE TELEMAC FILE* must also be specified. When the predefined formats cannot be used, the user subroutine `MARUTI.f` file can be included in the FORTRAN file and modified accordingly. In such cases the *TIDAL WATER LEVEL FILE FORMAT* (the `INDIM` FORTRAN variable) must be set to 4 in the CAS file.

Both currents and tidal water levels will be updated upon each *TIDE REFRESHING PERIOD*. This keyword corresponds to an integer multiple of the propagation *TIME STEP*, i.e. the currents and tidal levels cannot be specified at time steps less than the model TIME STEPS..

8.2.7. Convection step

For specific validation tests, for example, it may be interesting to drop the convection step and only consider the effect of the source terms. To do this requires assigning the "FALSE" value to the keyword *CONSIDERATION OF PROPAGATION*.

8.3. Parameterising the source term integration step

8.3.1. Introduction

When it is required to take into account the source/sink terms, the logic keyword *CONSIDERATION OF SOURCE TERMS* should be set to "TRUE".

It has been shown that the source term integration may require a shorter time step than the time step that is used for convection. The *TIME STEP* in the steering file corresponds to the convection time step. The source term integration step is controlled using the integer keyword *NUMBER OF ITERATIONS FOR THE SOURCE TERMS.* This keyword is set to the number of source terms

integration time steps that will be conducted after each convection step (default value = 1). The effective time-step used for source term integration is thus:
(TIME STEP)/(NUMBER OF ITERATIONS FOR THE SOURCE TERMS).
Depending on the source/sink terms, two different schemes are used for time integration:

- For the source/sink terms that are dominant in large and medium water depths (namely wind input, white-capping dissipation, nonlinear quadruplet interactions and bottom friction) a scheme with variable implicitation level is used (see section 8.3.2).
- For the source/sink terms that are dominant in shallow water depths (namely depth-induced breaking and, nonlinear triad interactions) an explicit scheme is used, possibly with sub-steps to cover one source term time-step (see section 8.3.3).

8.3.2. Source/sink terms in large and medium water depth

8.3.2.1. Wind input

If the keyword *WIND GENERATION* is set to 0, no wind input will be taken into account. If, on the other hand, a strictly positive value (1, 2, …) is chosen, the corresponding wind input formulation will be taken into account.
In TOMAWAC the Janssen's formulation (see section 4.2.3.2 for details) has been implemented and is activated using the value 1 for the WIND GENERATION keyword. Janssen's formulation requires several additional data, specified by the following keywords:

AIR DENSITY,
WATER DENSITY,
WIND GENERATION COEFFICIENT,
VON KARMAN CONSTANT,
CHARNOCK CONSTANT,
SHIFT GROWING CURVE DUE TO WIND,
WIND DRAG COEFFICIENT,
WIND MEASUREMENT LEVEL.

As a general rule, the default values for these keywords shall not be modified.

8.3.2.2. White capping dissipation

If the integer keyword *WHITE CAPPING DISSIPATION* is set to 0, this source term will be ignored. If a strictly positive value (1, 2, …) is selected, the corresponding formulation will be taken into account.
The only formulation implemented is Komen's formulation (see section 4.2.3.3 for details) and corresponds to the value 1 of the *WHITE CAPPING DISSIPATION* keyword. This formulation requires two complementary data, specified by the following keywords:

WHITE CAPPING DISSIPATION COEFFICIENT
WHITE CAPPING WEIGHTING COEFFICIENT.

As a general rule, the default values for these keywords shall not be modified.

8.3.2.3. Bottom friction dissipation

If the integer keyword *BOTTOM FRICTION DISSIPATION* is set to 0, this source term will be ignored. If a strictly positive value (1, 2, …) is chosen, the corresponding formulation will be taken into account. This source term is only taken account if the keyword *INFINITE DEPTH* is set to "FALSE".

The only formulation implemented is from Hasselmann (see section 4.2.3.4 for details) This formulation is specified by setting the *BOTTOM FRICTION DISSIPATION* keyword to 1. This formulation requires the specification of the keyword:

BOTTOM FRICTION COEFFICIENT.

As a general rule, the default value for this keyword shall not be modified.

8.3.2.4. Non-linear transfers between quadruplets

If the integer keyword *NON-LINEAR TRANSFERS BETWEEN FREQUENCIES* is set to 0, this source term will not be taken into account. If a strictly positive value (1, 2, ...) is chosen, the corresponding formulation will be taken into account.

Only the formulation from Hasselmann (see in section 4.2.3.6) has been implemented and corresponds to the value 1 for the *NON-LINEAR TRANSFERS BETWEEN FREQUENCIES* keyword. This formulation does not require any additional data to be specified by the user.

8.3.3. Source/sink terms in shallow water depth

8.3.3.1. Time integration scheme and time step

As mentioned above, the depth-induced breaking and nonlinear triad interaction terms are time-integrated with an explicit scheme.

As found practically, contributions from these source terms can be overestimated if the selected time step for source term integration is too long. In order to avoid this, TOMAWAC can perform a number of time sub-steps which are specific to these source terms through the keyword *NUMBER OF BREAKING TIME STEPS*.

These time sub-steps are arranged in a geometrical progression, i.e. they are defined in the following way:

$$\delta t_{i+1} = q\ \delta t_i$$

where the geometrical ratio q is specified through the keyword: *COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING*

In order to limit this number of time-steps, TOMAWAC first clips the wave height by setting a maximum H_{m0}/D ratio (D is the water depth) to 1. This ratio can be modified by means of the keyword *MAXIMUM VALUE OF THE RATIO HM0 TO D*. However, this is generally not advisable.

8.3.3.2. Wave breaking dissipation

If the integer keyword *DEPTH-INDUCED BREAKING DISSIPATION* is taken as 0, this source term will be ignored. If a strictly positive value (1, 2, …) is chosen, the corresponding formulation will be taken into account.

Four formulations have been implemented (see section 4.2.3.5 for details):

1: Battjes and Janssen's model (1978)

This formulation requires additional data to be provided, specified by the following keywords:

DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY

DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD

2: Thornton and Guza's model (1983)
This formulation requires additional data to be provided, specified by the following keywords:
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY

3: Roelvink's model (1993)
This formulation requires additional data to be provided, specified by the following keywords:
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY

4: Izumiya and Horikawa's model (1984)
This formulation requires additional data to be provided, specified by the following keywords:
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY

8.3.3.3. Triad interactions

If the integer keyword *TRIAD INTERACTIONS* is set to 0, this source term will be ignored. If a strictly positive value (1, 2, ...) is specified, the corresponding formulation will be taken into account.
Two formulations (see section 4.2.3.7) have been implemented.

1: LTA model
This formulation requires additional associated data to be specified using the following keywords:
TRIADS 1 (LTA) COEFFICIENT ALPHA
TRIADS 1 (LTA) COEFFICIENT RFMLTA

2: SPB model
This formulation requires additional associated data to be specified using the following keywords:
TRIADS 2 (SPB) COEFFICIENT K
TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY
ATTENTION: the SPB model is very time-consuming; compared to the LTA model formulation, it requires a computational time approximately 700 times higher.

8.4. Prescribing the initial conditions

Initial conditions can be prescribed using the integer keyword *TYPE OF INITIAL DIRECTIONAL SPECTRUM*Table 8.1 shows all the available options in TOMAWAC for computing the frequency and directional distribution of wave action. It should be remembered that the variance density directional spectrum is computed as the product:

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

where *E(f)* here denotes the variance density spectrum and $D(\theta)$ denotes the angular distribution function.

It is reminded that the parameterised JONSWAP spectrum is defined as:

$$E(f) = \alpha_{phil} H_{mo}^2 \frac{f_p^4}{f^5} exp\left[-\frac{5}{4}\left(\frac{f_p}{f}\right)^4\right] \gamma^{exp\left[-\frac{(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$

where: $\sigma = \sigma_a$ for $f < f_p$ and $\sigma = \sigma_b$ for $f > f_p$

$$\alpha_{phil} = \frac{0.0624}{0.23 + 0.0336\gamma - \frac{0.185}{1.9+\gamma}}$$

and that the TMA spectrum is a depth-corrected JONSWAP-type spectrum.

A parameterised spectrum with two directional peaks can also be generated. In such case, both main propagation directions (θ_1 and θ_2) as well as the weighting factor (λ) between the two power peaks:

$$D(\theta) = \frac{\lambda}{\Delta_1}\tilde{D}(\theta - \theta_1) + \frac{1-\lambda}{\Delta_2}\tilde{D}(\theta - \theta_2)$$

must be specified.

Δ_1 and Δ_2, in the equation above, are automatically computed by TOMAWAC in order to normalize the angular distribution function.

Three angular distribution functions may be chosen using the keyword *INITIAL ANGULAR FUNCTION DISTRIBUTION*, which correspond to the following options:

1: model in $cos^{2s}(\theta - \theta_0)$; $\theta \in [\theta_0 - \pi/2 ; \theta_0 + \pi/2]$

2: model in $exp\left(-0.5((\theta-\theta_0)/s)^2\right)$; $\theta \in [\theta_0 - \pi/2 ; \theta_0 + \pi/2]$

3: model in $cos^{2s}((\theta-\theta_0)/2)$; $\theta \in [\theta_0 - \pi ; \theta_0 + \pi]$ [Mitsuyasu et al.,1975]

with θ_0 being the main sea-state propagation direction and *s* being the directional spread.

The forementioned constants can be specified using the following of keywords:

H_{m0}: *INITIAL SIGNIFICANT WAVE HEIGHT,*
f_p: *INITIAL PEAK FREQUENCY,*
γ: *INITIAL PEAK FACTOR,*
σ_a: *INITIAL VALUE OF SIGMA-A FOR SPECTRUM,*
σ_b: *INITIAL VALUE OF SIGMA-B FOR SPECTRUM,*
α_{phil}: *INITIAL PHILLIPS CONSTANT,*
Fetch: *INITIAL MEAN FETCH VALUE,*
f_{pmax}: *INITIAL MAXIMUM PEAK FREQUENCY,*
θ_1: *INITIAL MAIN DIRECTION 1,*
s_1: *INITIAL DIRECTIONAL SPREAD 1,*
θ_2: *INITIAL MAIN DIRECTION 2,*
s_2: *INITIAL DIRECTIONAL SPREAD 2,*
λ: *INITIAL WEIGHTING FACTOR FOR ADF,*

The keyword *SPECTRUM ENERGY THRESHOLD* is used whatever option is chosen. It is only useful for comparisons with the WAM model.
Specific initial conditions can be prescribed directly for the directional spectrum of wave action using the `condiw.f` subroutine which can be called from the `speini`.f subroutine.

8.5. Prescribing the boundary conditions

The boundary conditions are prescribed over the relative spectrum of wave action, i.e. expressed in co-ordinate system that moves with the current.
Only two kinds of boundary conditions are available in TOMAWAC.
The first one corresponds to a free boundary i.e. a boundary that fully absorbs the wave energy. It may be a liquid boundary: it is then assumed that the waves propagate beyond the domain and nothing else enters it. It may be a solid boundary: it is then assumed that the shore fully absorbs the wave energy.
The second one corresponds to a boundary with a prescribed value. In this case the wave action spectrum is then strictly imposed at each point along that boundary. This boundary condition allows wave energy to enter the computational domain.
The boundary conditions are specified using the boundary conditions (CONLIM) file, the steering (CAS) file and the `LIMWAC.f`.

8.5.1. The boundary conditions file

The boundary condition (CONLIM) file is normally supplied by STBTEL (or other TELEMAC mesh generators), but it can also be generated by means of a text editor. Each line in this file is assigned to one point of the boundary and listed in sequential order in terms of the boundary node numbers. The numbering of the boundary points first delineates the domain contour in a counterclockwise direction, then the islands in the clockwise direction. The total number of edge points is noted as `NPTFR.`
13 values are given for each point. Only data in columns 1, 12 and 13 are used by TOMAWAC:

- The 13th data column (integer variable `IPTFR`) corresponds to the boundary point number ranked in terms of the boundary point numbering.
- The 12th data column (integer variable `IPOIN`) corresponds to the global number of the point in the 2D mesh.

Lastly, the 1st data column (integer variable `LIFBOR`) corresponds to the kind of boundary condition. Consistent with TELEMAC-2D, its value is 2 (Variable `KSORT=2`) in the case of a free boundary and 5 (Variable `KENT=5`) in the case of a boundary with a prescribed value.

Key-word value		Spectrum	Constants being used
0		Zero spectrum	none
1	Wind $\neq$ 0	- Frequencies: Jonswap according to wind - Directions: unimodal about the wind ($\theta_1 = \theta_w$)	f_{pmax}, γ, $\sigma_a \sigma_b$, Fetch, s_1
	Wind = 0	Zero spectrum	none
2	Wind $\neq$ 0	- Frequencies: Jonswap according to wind - Directions: unimodal about the wind ($\theta_1 = \theta_w$)	f_{pmax}, γ, σ_a,σ_b, Fetch, s_1
	Wind = 0	- Frequencies: parameterised Jonswap (α, f_p) - Directions: parameterised unimodal (same spectrum at every point)	α_{phil}, f_p, γ, σ_a,σ_b, s_1, θ_1
3	Wind $\neq$ 0	- Frequencies: parameterised Jonswap (α) - Directions: unimodal about the wind ($\theta_1 = \theta_w$)	α_{phil}, f_p, γ, σ_a,σ_b, s_1
	Wind = 0	Zero spectrum	none
4	Wind $\neq$ 0	- Frequencies: parameterised Jonswap (α, f_p) - Directions: parameterised angular distribution function. Same spectrum at every point	α_{phil}, f_p, γ, σ_a,σ_b, s_1, θ_1, s_2, θ_2, λ
	Wind = 0		
5	Wind $\neq$ 0	- Frequencies: parameterised Jonswap (H_{m0}) - Directions: unimodal about the wind ($\theta_1 = \theta_w$)	H_{m0}, f_p, γ, σ_a,σ_b, s_1
	Wind = 0	Zero spectrum	none
6	Wind $\neq$ 0	- Frequencies: parameterised Jonswap (H_{m0}, f_p) - Directions: parameterised angular distribution function. Same spectrum at every point	H_{m0}, f_p, γ, σ_a,σ_b, s_1, θ_1, s_2, θ_2, λ
	Wind = 0		
7	Wind $\neq$ 0	- Frequencies: parameterised TMA (H_{m0}, f_p) - Directions: parameterised angular distribution function. Same spectrum at every point	H_{m0}, f_p, γ, σ_a,σ_b, s_1, θ_1, s_2, θ_2, λ
	Wind = 0		

Table 8.1: Summary table of the spectrum types as proposed in TOMAWAC

8.5.2. Prescribing the boundary conditions in the CAS file

Boundary conditions prescribed using the CAS file will necessarily be homogeneous all along the domain entry boundaries (KENT=5).

The boundary conditions can be prescribed by means of the integer keyword *TYPE OF BOUNDARY DIRECTIONAL SPECTRUM*

Table 8.1 (see section 8.4) presents all the spectrum types available in TOMAWAC. The constants given in Table 8.1 can be prescribed using the following keywords:

H_{m0}: *BOUNDARY SIGNIFICANT WAVE HEIGHT,*
f_p: *BOUNDARY PEAK FREQUENCY,*
γ: *BOUNDARY PEAK FACTOR,*
σ_a: *BOUNDARY SPECTRUM VALUE OF SIGMA-A,*
σ_b: *BOUNDARY SPECTRUM VALUE OF SIGMA-B,*
α_{phil}: *BOUNDARY PHILLIPS CONSTANT,*
Fetch: *BOUNDARY MEAN FETCH VALUE,*
f_{pmax}: *BOUNDARY MAXIMUM PEAK FREQUENCY,*
θ_1: *BOUNDARY MAIN DIRECTION 1,*
s_1: *BOUNDARY DIRECTIONAL SPREAD 1,*
θ_2: *BOUNDARY MAIN DIRECTION 2,*
s_2: *BOUNDARY DIRECTIONAL SPREAD 2,*
λ: *BOUNDARY WEIGHTING FACTOR FOR ADF,*

Three angular distribution functions have been implemented and can be selected using of the keyword: *BOUNDARY ANGULAR DISTRIBUTION FUNCTION*, which corresponds to the following options:

1: model in $cos^{2s}(\theta-\theta_0)$; $\theta \in [\theta_0-\pi/2 ; \theta_0+\pi/2]$
2: model in $exp\left(-0.5((\theta-\theta_0)/s)^2\right)$; $\theta \in [\theta_0-\pi/2 ; \theta_0+\pi/2]$
3: model in $cos^{2s}((\theta-\theta_0)/2)$; $\theta \in [\theta_0-\pi ; \theta_0+\pi]$ [Mitsuyasu et al., 1975]

Since the boundary spectrum computation procedures are similar to those for the initial spectrum, refer to section 8.4 for further details.

8.5.3. The `LIMWAC` user subroutine

It should be reminded that the spectrum is discretized over both frequencies and directions and that it is a <u>relative</u> spectrum, i.e. expressed in a coordinate system that moves with the current.

The subroutine LIMWAC, in its original version, allows to impose the spectrum components at each point of a boundary with a prescribed value. The spectrum components are calculated from the parameters specified in the CAS file (see section 7.2.1). This subroutine, however, can easily be modified to specify e.g. non-homogeneous (in space) boundary conditions. When such specific boundary conditions are required, these will ideally be incorporated in the user part provided in the code of the `LIMWAC` procedure. The keyword *BOUNDARY SPECTRUM MODIFIED BY USER* must also be set to YES.

8.6. Some useful subroutines

8.6.1. Modification of bottom topography: CORFON subroutine

The seabed levels can be modified in two different ways, as already stated in section 7.5.
The seabed levels can be modified at the beginning of the computation using the CORFON subroutine, which is called once at the beginning of the computation. This subroutine allows the value of the ZF variable to be modified at each mesh point. For this purpose, a number of variables such as, for instance, the point coordinates, the element area values, the connectivity table, etc., are provided.
By default, the CORFON subroutine performs the same number of bottom smoothing iterations as LISFON, i.e. the same value as specified by the integer keyword *BOTTOM SMOOTHINGS.*
Note that the CORFON subroutine is not called in case the computation is initialized with the result of a former TOMAWAC run ("hot start").
This subroutine is part of the TELEMAC-2D library and is listed in APPENDIX 2.

8.6.2. Modifying the co-ordinates: CORRXY subroutine

TOMAWAC allows the mesh point co-ordinates to be modified at the beginning of the computation, so that an up-scaling (switching from a small scale model to a full-size model), a rotation or a translation can be performed.
Such changes are made using the CORRXY subroutine from the BIEF library, which is called in at the beginning of the computation. This subroutine is void by default and provides, in the form of a comment, an example of programming relevant to a change of scale and origin. It is part of the TELEMAC-2D library and is listed in APPENDIX 2.

8.6.3. Operations on vectors: OV subroutine

The BIEF library has a range of very useful subroutines including, in particular, subroutines for operations on vectors. A number of relations have been programmed so that loops can be replaced by a mere procedure call.
The syntax is as follows:

```
CALL OV(OP, X, Y, Z, C, NPOIN)
```

Where OP is a string of exactly 8 digits that is indicative of the operation about to be performed on the X, Y, Z vectors and the constant C. The result is the vector X.
Example:

```
CALL OV('X=X+Y ', X, Y, Z, C, NPOIN)
```

Y is added to X, the result will be stored in X.

A full list of available operations is given in the documentation of BIEF, which is part of the TELEMAC system.

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APPENDIX 1: Launching a TOMAWAC computation at a workstation

A computation can be launched through the TOMAWAC control at a workstation.
That control activates the execution of an Unix script that is shared by all the computation modules in the TELEMAC processing chain.
That control's syntax is as follows:

TOMAWAC [-s] [-D] [-b| -n| -d heure] [cas]

- s: if the program is launched in an interactive mode the check listing is stored on the disk (by default, the check listing is only displayed on the screen).
- D: compilation and execution mode under debugger.
- b: batch launching (immediate start)
- n: night batch launching (start at 8.00 p.m.)
- d: delayed batch start (start at the specified time)

cas: steering file name.

When the steering file name is not specified, the procedure uses the name 'cas'. By default, the procedure performs the computation in an interactive mode.
Examples:

- TOMAWAC: immediately launches a computation in a interactive mode by reading the steering file cas. The listings are displayed on the screen.
- TOMAWAC -b test2: start computation immediately in batch mode using the test2 steering file.
- TOMAWAC -d 22:00 modtot launches a computation in a batch mode at 10.00 p.m. on the very night by reading the steering file modtot.
- telemac2d –n: start computation at 20:00 the same evening in batch mode using the cas steering file.

The main operations performed by that script are as follows:

- Creation of a temporary directory,
- Duplication of the dictionary and the steering file in that directory,
- Execution of the DAMOCLES software in order to determine the work files names,
- Creation of the computation launching script,
- Allocation of the files,
- Compilation of the FORTRAN file and link edit,
- Computation launching,
- Retrieval of the results files and deletion of the temporary directory.

The procedure operation differs slightly according to the selected options.
A detailed description of this procedure may be obtained by using the command TOMAWAC –H.

APPENDIX 2: List of useful subroutines

The following subroutines can be modified by the user:

- `ANACOS.f:` Specification of an analytical stationary current.
- `ANAMAR.f:` Specification of an analytical tide (current and water level).
- `ANAVEN.f:` Specification of an analytical wind.
- `CORFON.f:` Modification of bottom topography.
- `CORRXY.f:` Modification of coordinates.
- `COUUTI.f:` Currents file reading from a user-defined format.
- `LIMWAC.f:` Specification of the boundary conditions.
- `MARUTI.f:` Tide level file reading from a user-defined format.
- `VARTEL.f:` Processing of a TELEMAC data.
- `VENUTI.f:` Winds file reading from a user-defined format.

When these subroutines are used, they should be integrated into the user's FORTRAN file, then modified.

APPENDIX 3: Alphabetical list of keywords

2D RESULTS FILE

Type:	Character
Dimension:	1
Default value:	'resu2d'
FORTRAN variable:	WAC_FILES(WACRES)%NAME
French translation:	FICHIER DES RESULTATS 2D

Name of the file to which the results of the two-dimensional computation will be written.

Associated keywords:	2D RESULTS FILE BINARY
	VARIABLES FOR 2D GRAPHIC PRINTOUTS
	PERIOD FOR GRAPHIC PRINTOUTS
	NUMBER OF FIRST ITERATION FOR GRAPHIC PRINTOUTS

2D RESULTS FILE BINARY

Type:	Character
Dimension:	1
Default value:	'STD'
FORTRAN variable:	BINRES
French translation:	BINAIRE DU FICHIER DES RESULTATS 2D

Type of the binary used for writing the 2D results file. That type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords:	2D RESULTS FILE

ABSCISSAE OF SPECTRUM PRINTOUT POINTS

Type:	Real
Dimension:	Variable
Default value:	0.;0.;0.;0.;0.;0.;0.;0.;0.
FORTRAN variable:	XLEO
French translation:	ABSCISSES DES POINTS DE SORTIE DU SPECTRE

Array providing the abscissa of the SERAFIN spectrum printout points with a maximum dimension of 10. The chosen spectrum points are the closest 2D points to the specified co-ordinates.

Associated keywords:	ORDINATES OF SPECTRUM PRINTOUT POINTS
	PUNCTUAL RESULTS FILE

AIR DENSITY

Type:	Real
Dimension:	1
Default value:	1.225
FORTRAN variable:	ROAIR
French translation:	DENSITE DE LAIR

The ratio ROAIR/ROEAU is used in the wind generation

Associated keywords: WIND GENERATION
WATER DENSITY

BINARY CURRENTS FILE

Type:	Character
Dimension:	1
Default value:	‘ ‘
FORTRAN variable:	WAC_FILES(WACCOB)%NAME
French translation:	FICHIER DES COURANTS BINAIRE

Name of the current data file (if binary).

Associated keywords: CONSIDERATION OF A STATIONARY CURRENT
CONSIDERATION OF TIDE
FORMATTED CURRENTS FILE
CURRENTS FILE FORMAT

BINARY DATA FILE 1 FORMAT

Type:	Character
Dimension:	1
Default value:	‘SERAFIN‘
FORTRAN variable:	'WAC_FILES(WACBI1)%FMT
French translation:	FORMAT DU FICHIER DE DONNEES BINAIRE 1

Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5

BINARY FILE 1

Type:	Character
Dimension:	1

Default value: ‘ ‘
FORTRAN variable: WAC_FILES(WACBI1)%NAME
French translation: FICHIER BINAIRE 1

Binary-coded data file made available to the user.

Associated keywords: CONSIDERATION OF A STATIONARY CURRENT
CONSIDERATION OF TIDE
FORMATTED CURRENTS FILE
CURRENTS FILE FORMAT

BINARY FILE 1 BINARY

Type: Character
Dimension: 1
Default value: ‘STD’
FORTRAN variable: BINBI1
French translation: BINAIRE DU FICHIER BINAIRE 1

Type of the binary used for writing the binary file1. This type depends on the machine in which the file was generated. The possible values are the same as for the geometry file.

Associated keywords: BINARY FILE 1

BINARY TIDAL WATER LEVEL FILE

Type: Character
Dimension: 1
Default value: ‘ ‘
FORTRAN variable: WAC_FILES(WACMAB)%NAME
French translation: FICHIER DU NIVEAU DE LA MAREE BINAIRE

Name of the water level data file (if binary).

Associated keywords: CONSIDERATION OF TIDE
FORMATTED TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE FORMAT
TIDE REFRESHING PERIOD
TIDAL WATER LEVEL FILE BINARY

BINARY WINDS FILE

Type: Character
Dimension: 1
Default value: ‘ ‘
FORTRAN variable: WAC_FILES(WACVEB)%NAME

French translation: FICHIER DES VENTS BINAIRE

Name of wind data file (if binary).

Associated keywords: CONSIDERATION OF WIND
FORMATTED WINDS FILE
WINDS FILE FORMAT

BOTTOM FRICTION COEFFICIENT

Type: Real
Dimension: 1
Default value: 0.038
FORTRAN variable: CFROT1
French translation: COEFFICIENT DE FROTTEMENT SUR LE FOND

Bottom friction coefficient.

Associated keywords: INFINITE DEPTH
BOTTOM FRICTION-INDUCED DISSIPATION

BOTTOM FRICTION DISSIPATION

Type: INTEGER
Dimension: 1
Default value: 0
FORTRAN variable: SFROT
French translation: DISSIPATION PAR FROTTEMENT SUR LE FOND

Selection of the modelling type of the bottom friction source term. If its value is 0, the bottom friction dissipation is ignored; if its value is 1, it is integrated in accordance with a formula that is similar to that of WAM cycle 4.

Associated keywords: INFINITE DEPTH
BOTTOM FRICTION COEFFICIENT

BOTTOM SMOOTHINGS

Type: INTEGER
Dimension: 1
Default value: 0
FORTRAN variable: LISFON
French translation: LISSAGES DU FOND

Number of smoothings made on bottom features. Each smoothing, being made by means of a mass matrix, is conservative. To be used when the bathymetric data yield too irregular data after interpolation. Also refer to the CORFON subroutine.

BOTTOM TOPOGRAPHY FILE

Type:	Character
Dimension:	1
Default value:	‘ ‘
FORTRAN variable:	WAC_FILES(WACFON)%NAME
French translation:	FICHIER DES FONDS

Name of any file containing the bathymetric data associated to the SINUSX-formatted grid. If this keyword is used, these bathymetric data shall be used for the computation.

BOUNDARY ANGULAR DISTRIBUTION FUNCTION

Type:	INTEGER
Dimension:	1
Default value:	1
FORTRAN variable:	FRABL
French translation:	FONCTION DE REPARTITION ANGULAIRE AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum. The following angular distribution functions are allowed:

1: cos^2s(T-T0) ; T in range [T0-pi/2;T0+pi/2]

2: exp(-0.5((T-T0)/s)^2) ; T in range [T0-pi/2;T0+pi/2]

3: cos^2s((T-T0)/2) (Mitsuyasu type)

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY CONDITIONS FILE

Type:	Character
Dimension:	1
Default value:	dynam
FORTRAN variable:	WAC_FILES(WACCLI)%NAME
French translation:	FICHIER DES CONDITIONS AUX LIMITES

Name of the file containing the boundary conditions types.

BOUNDARY DIRECTIONAL SPREAD 1

Type:	Real
Dimension:	1
Default value:	2.
FORTRAN variable:	SPRE1L
French translation:	ETALEMENT DIRECTIONNEL 1 AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY DIRECTIONAL SPREAD 2

Type: Real

Dimension: 1

Default value: 2.

FORTRAN variable: SPRE2L

French translation: ETALEMENT DIRECTIONNEL 2 AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY MAIN DIRECTION 1

Type: Real

Dimension: 1

Default value: 0.

FORTRAN variable: TETA1L

French translation: DIRECTION PRINCIPALE 1 AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY MAIN DIRECTION 2

Type: Real

Dimension: 1

Default value: 0.

FORTRAN variable: TETA2L

French translation: DIRECTION PRINCIPALE 2 AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY MAXIMUM PEAK FREQUENCY

Type: Real

Dimension: 1

Default value: 0.2
FORTRAN variable: FPMAXL
French translation: FREQUENCE DE PIC MAXIMALE AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY MEAN FETCH VALUE

Type: Real
Dimension: 1
Default value: 30000.
FORTRAN variable: FETCHL
French translation: VALEUR MOYENNE DU FETCH AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY PEAK FACTOR

Type: Real
Dimension: 1
Default value: 3.3
FORTRAN variable: GAMMAL
French translation: FACTEUR DE PIC AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY PEAK FREQUENCY

Type: Real
Dimension: 1
Default value: 0.067
FORTRAN variable: FPICL
French translation: FREQUENCE DE PIC AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY PHILLIPS CONSTANT

Type: Real
Dimension: 1
Default value: 0.018
FORTRAN variable: APHILL
French translation: CONSTANTE DE PHILLIPS AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY SIGNIFICANT WAVE HEIGHT

Type: Real
Dimension: 1
Default value: 1.
FORTRAN variable: HM0L
French translation: HAUTEUR SIGNIFICATIVE AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY SPECTRUM VALUE OF SIGMA-A

Type: Real
Dimension: 1
Default value: 0.07
FORTRAN variable: SIGMAL
French translation: VALEUR AUX LIMITES DE SIGMA-A POUR SPECTRE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY SPECTRUM VALUE OF SIGMA-B

Type: Real
Dimension: 1
Default value: 0.09
FORTRAN variable: SIGMBL
French translation: VALEUR AUX LIMITES DE SIGMA-B POUR SPECTRE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

BOUNDARY WEIGHTING FACTOR FOR ADF

Type: Real

Dimension: 1

Default value: 1.

FORTRAN variable: XLAMDL

French translation: FACTEUR DE PONDERATION POUR FRA AUX LIMITES

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

CHARNOCK CONSTANT

Type: Real

Dimension: 1

Default value: 0.01

FORTRAN variable: ALPHA

French translation: CONSTANTE DE CHARNOCK

Constant used in the wind source term.

Associated keywords: WIND GENERATION

COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING

Type Real

Dimension: 1

Default value: 1.45

FORTRAN variable: XDTBRK

French translation: COEFFICIENT POUR LES SOUS-PAS DE TEMPS POUR LE DEFERLEMENT

Geometrical ratio of the time sub-increments for the depth-induced breaking

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS

CONSIDERATION OF A STATIONARY CURRENT

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: COUSTA

French translation: PRISE EN COMPTE D'UN COURANT STATIONNAIRE

It indicates whether a stationary current is taken into account, either in a file or in condiw.f.

Associated keywords: CURRENTS FILE FORMAT

CONSIDERATION OF A WIND

Type: LOGICAL

Dimension: 1

Default value: FALSE.

FORTRAN variable: VENT

French translation: PRISE EN COMPTE DU VENT

It indicates whether a wind is taken into account, either in a file or in anaven.f.

Associated keywords: WINDS FILE FORMAT

CONSIDERATION OF PROPAGATION

Type: LOGICAL

Dimension: 1

Default value: .TRUE.

FORTRAN variable: PROP

French translation: PRISE EN COMPTE DE LA PROPAGATION

It indicates whether propagation is taken into account.

CONSIDERATION OF SOURCE TERMS

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: TSOU

French translation: PRISE EN COMPTE DES TERMES SOURCES

It indicates whether the source terms are taken into account or not.

Associated keywords: WIND GENERATION

BOTTOM FRICTION DISSIPATION

WHITE CAPPING DISSIPATION

DEPTH-INDUCED BREAKING DISSIPATION

NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES

TRIAD INTERACTION

CONSIDERATION OF TIDE

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: MAREE

French translation: PRISE EN COMPTE DE LA MAREE

Indicates whether a current is taken into account, either in a file or in maruti.f.

Associated keywords: FORMATTED TIDAL WATER LEVEL FILE
BINARY TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE FORMAT
TIDE REFRESHING PERIOD
TIDAL WATER LEVEL FILE BINARY

CURRENTS FILE BINARY

Type: Character

Dimension: 1

Default value: 'STD'

FORTRAN variable: BINCOU

French translation: BINAIRE DU FICHIER DES COURANTS

Type of the binary used for writing the currents file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords: BINARY CURRENTS FILE
FORMATTED CURRENTS FILE
CURRENTS FILE FORMAT

CURRENTS FILE FORMAT

Type: INTEGER

Dimension: 1

Default value: 1

FORTRAN variable: INDIC

French translation: FORMAT DU FICHIER DES COURANTS

Selection of the type of currents file format:

1 finite differences, WAM cycle 4 format type

2 X Y UX UY, SINUSX format type

3 SERAFIN, TELEMAC type

4 user format (the couuti.f procedure should then be modified)

Associated keywords: CURRENTS BINARY FILE

CURRENTS FORMATTED FILE
CURRENTS FILE BINARY

DATE OF COMPUTATION BEGINNING

Type:	Real
Dimension:	1
Default value:	0
FORTRAN variable:	DDC
French translation:	DATE DE DEBUT DU CALCUL

This gives the start date of the computation. The format is yymmddhhmm, for example 9310241524 means the 24 October 93 at 15h24. This date gives a reference for the reading of the wind file.

Associated keywords:	BINARY WIND FILE
	FORMATTED WIND FILE
	WIND FILE BINARY
	WIND FILE FORMAT

DEFAULT EXECUTABLE

Type:	Character
Dimension:	1
Default value:	TOMAWAC|towa_VVV|PPP|TOMAWACMMMVVV.exe
FORTRAN variable:	EXEDEF
French translation:	EXECUTABLE PAR DEFAUT

Default executable file name for TOMAWAC

DEFAULT PARALLEL EXECUTABLE

Type:	Character
Dimension:	1
Default value:	TOMAWAC|towa_VVV|PPP|TOMAWACMMMVVV_MP.exe
FORTRAN variable:	EXEDEFPARA
French translation:	EXECUTABLE PARALLELE PAR DEFAUT

Default parallel executable file name for TOMAWAC

DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY

Type:	INTEGER
Dimension:	1
Default value:	2
FORTRAN variable:	IFRBJ

French translation: DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE

Selection of the characteristic frequency of the wave spectrum:

1: Frequency Fmoy

2: Frequency F01 (defined by the 0th and 1st moments of the spectrum)

3: Frequency F02 (defined by the 0th and 2nd moments of the spectrum)

4: Frequency Fpic (sampling frequency corresponding to the max)

5: Frequency Fread order 5 (peak frequency, 5th order Read method)

6: Frequency Fread order 8 (peak frequency, 8th order Read method)

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA

Type: Real

Dimension: 1

Default value: 1.

FORTRAN variable: ALFABJ

French translation: DEFERLEMENT 1 (BJ) CONSTANTE ALPHA

ALPHA constant for the Battjes and Janssen model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM
DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA1
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA2

DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1

Type: Real

Dimension: 1

Default value: 0.88

FORTRAN variable: GAMBJ1

French translation: DEFERLEMENT 1 (BJ) CONSTANTE GAMMA1

GAMMA1 constant of the Battjes and Janssen model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION

NUMBER OF BREAKING TIME STEPS
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM
DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE
DEFERLEMENT 1 (BJ) CONSTANTE ALPHA
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA2

DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2

Type: Real
Dimension: 1
Default value: 0.8
FORTRAN variable: GAMBJ2
French translation: DEFERLEMENT 1 (BJ) CONSTANTE GAMMA2

GAMMA1 constant of the Battjes and Janssen model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM
DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE
DEFERLEMENT 1 (BJ) CONSTANTE ALPHA
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA1

DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: IHMBJ
French translation: DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM

Selection of the depth-induced breaking criterium giving the breaking wave height:

1: Hm GAMMA*D ;
2: Hm given the Miche criterium.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD

Type: INTEGER

Dimension: 1

Default value: 2

FORTRAN variable: IQBBJ

French translation: DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB

Selection of the method for the resolution of the implicit equation for QB.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY

Type: INTEGER

Dimension: 1

Default value: 5

FORTRAN variable: IFRTG

French translation: DEFERLEMENT 2 (TG) CHOIX FREQUENCE CARACTERISTIQUE

Selection of the characteristic frequency of the wave spectrum

1: Frequency Fmoy

2: Frequency F01 (defined by the 0th and 1st moments of the spectrum)

3: Frequency F02 (defined by the 0th and 2nd moments of the spectrum)

4: Frequency Fpic (sampling frequency corresponding to the max)

5: Frequency Fread order 5 (peak frequency, 5th order Read method)

6: Frequency Fread order 8 (peak frequency, 8th order Read method)

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA

DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B

Type: Real

Dimension: 1

Default value: 1.0

FORTRAN variable: BORETG

French translation: DEFERLEMENT 2 (TG) CONSTANTE B

Coefficient B of the Thornton and Guza model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA

DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA

Type: Real
Dimension: 1
Default value: 0.42
FORTRAN variable: GAMATG
French translation: DEFERLEMENT 2 (TG) CONSTANTE GAMMA

Coefficient GAMMA of the Thornton and Guza model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B

DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION

Type: INTEGER
Dimension: 1
Default value: 2
FORTRAN variable: IWHTG
French translation: DEFERLEMENT 2 (TG) FONCTION DE PONDERATION

Selection of the expression for the weighting function based on a probability distribution of the wave heights.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA

DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY

Type: INTEGER

Dimension: 1

Default value: 5

FORTRAN variable: IFRRO

French translation: DEFERLEMENT 3 (RO) CHOIX FREQUENCE CARACTERISTIQUE

Selection of the characteristic frequency of the wave spectrum

1: Frequency Fmoy

2: Frequency F01 (defined by the 0th and 1st moments of the spectrum)

3: Frequency F02 (defined by the 0th and 2nd moments of the spectrum)

4: Frequency Fpic (sampling frequency corresponding to the max)

5: Frequency Fread order 5 (peak frequency, 5th order Read method)

6: Frequency Fread order 8 (peak frequency, 8th order Read method)

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA

Type: Real

Dimension: 1

Default value: 1.

FORTRAN variable: ALFARO

French translation: DEFERLEMENT 3 (RO) CONSTANTE ALPHA

Coefficient ALPHA of the Roelvink model (1993).

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA

Type: Real

Dimension: 1
Default value: 0.54
FORTRAN variable: GAMARO
French translation: DEFERLEMENT 3 (RO) CONSTANTE GAMMA

Coefficient GAMMA of the Roelvink model (1993).

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

Type: Real
Dimension: 1
Default value: 0.65
FORTRAN variable: GAM2RO
French translation: DEFERLEMENT 3 (RO) CONSTANTE GAMMA2

Coefficient GAMMA2 of the Roelvink model (1993).

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA

DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION

Type: INTEGER
Dimension: 1
Default value: 10
FORTRAN variable: IEXPRO
French translation: DEFERLEMENT 3 (RO) EXPOSANT FONCTION DE PONDERATION

n exponent of the weighting function used in the Roelvink breaking model.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: IDISRO
French translation: DEFERLEMENT 3 (RO) DISTRIBUTION DES HAUTEURS DE HOULE

Selection of the wave height distribution for the Roelvink breaking model:

1...Weibull,
2...Rayleigh.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2

DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY

Type: INTEGER
Dimension: 1
Default value: 5
FORTRAN variable: IFRIH
French translation: DEFERLEMENT 4 (IH) CHOIX FREQUENCE CARACTERISTIQUE

Selection of the characteristic frequency of the wave spectrum

1: Frequency Fmoy
2: Frequency F01 (defined by the 0th and 1st moments of the spectrum)
3: Frequency F02 (defined by the 0th and 2nd moments of the spectrum)
4: Frequency Fpic (sampling frequency corresponding to the max)

5: Frequency Fread order 5 (peak frequency, 5th order Read method)

6: Frequency Fread order 8 (peak frequency, 8th order Read method)

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR

DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0

Type: Real

Dimension: 1

Default value: 1.8

FORTRAN variable: BETAIH

French translation: DEFERLEMENT 4 (IH) CONSTANTE BETA0

Coefficient BETA0 of the Izumiya and Horikawa model (1984).

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR

DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR

Type: Real

Dimension: 1

Default value: 0.009

FORTRAN variable: EM2SIH

French translation: DEFERLEMENT 4 (IH) CONSTANTE M2STAR

Coefficient M2STAR of the Izumiya and Horikawa model (1984).

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0

DEPTH-INDUCED BREAKING DISSIPATION

Type: INTEGER

Dimension: 1

Default value: 0

FORTRAN variable: SBREK

French translation: DISSIPATION PAR DEFERLEMENT

Selection of the modelling type of the bathymetric-induced breaking dissipation source term:

0: Breaking is ignored.

1: Battjes and Janssen model (1978).

2: Thornton and Guza model (1983)

3: Roelvink model (1993)(

4: Izumiya and Horikawa model (1984).

Associated keywords: NUMBER OF BREAKING TIME STEPS
DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR

DESCRIPTION OF LIBRARIES

Type: Character

Dimension: 5

Default value: 'TOMAWAC|toma_VVV|PPP|TOMAWACMMMVVV.LLL';
'bief|bief_VVV|PPP|biefMMMVVV.LLL';
'damocles|damo_VVV|PPP|damoMMMVVV.LLL';
'paravoid|paravoid_VVV|PPP|paravoidMMMVVV.LLL';
'special|special_VVV|PPP|specialMMMVVV.LLL'

FORTRAN variable: LINKLIBS

French translation: DESCRIPTION DES LIBRAIRIES

TOMAWAC LIBRARIES description

DICTIONARY

Type: Character

Dimension: 1

Default value: 'TOMAWACv6p0.dico'

FORTRAN variable:

French translation: DICTIONNAIRE

Key word dictionary.

FORMATTED CURRENTS FILE

Type: Character

Dimension: 1

Default value: ' '

FORTRAN variable: WAC_FILES(WACCOF)%NAME

French translation: FICHIER DES COURANTS FORMATE

Name of the current data file (if formatted).

Associated keywords: CONSIDERATION OF A STATIONARY CURRENT
CONSIDERATION OF TIDE
BINARY CURRENTS FILE
CURRENTS FILE FORMAT

FORMATTED FILE 1

Type: Character

Dimension: 1

Default value: ' '

FORTRAN variable: WAC_FILES(WACFO1)%NAME

French translation: FICHIER FORMATE 1

Formatted data file made available to the user.

FORMATTED TIDAL WATER LEVEL FILE

Type: Character

Dimension: 1

Default value: ' '

FORTRAN variable: WAC_FILES(WACMAF)%NAME

French translation: FICHIER DU NIVEAU DE LA MAREE FORMATE

Name of the current data file (if formatted).

Associated keywords: CONSIDERATION OF TIDE
BINARY TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE FORMAT
TIDE REFRESHING PERIOD
TIDAL WATER LEVEL FILE BINARY

FORMATTED WINDS FILE

Type: Character
Dimension: 1
Default value: ‘ ‘
FORTRAN variable: WAC_FILES(WACVEF)%NAME
French translation: FICHIER DES VENTS FORMATE

Name of wind data file (if formatted).

Associated keywords: CONSIDERATION OF WIND
BINARY WINDS FILE
WINDS FILE FORMAT

FORTRAN FILE

Type: Character
Dimension: 1
Default value: 'DEFAUT1'
FORTRAN variable: NOMFOR
French translation: FICHIER FORTRAN

Name of FORTRAN file to be submitted.

FREQUENTIAL RATIO

Type: Real
Dimension: 1
Default value: 1.1
FORTRAN variable: RAISF
French translation: RAISON FREQUENTIELLE

It defines the ratio between 2 successive discretised frequencies

Associated keywords: MINIMAL FREQUENCY
NUMBER OF FREQUENCIES
SPECTRUM TAIL FACTOR

GEOMETRY FILE

Type: Character

Dimension: 1

Default value: geo

FORTRAN variable: WAC_FILES(WACGEO)%NAME

French translation: FICHIER DE GEOMETRIE

Name of the file containing the grid of the computation to be made.

Associated keywords: GEOMETRY FILE BINARY

GEOMETRY FILE BINARY

Type: Character

Dimension: 1

Default value: ‘STD’

FORTRAN variable: BINGEO

French translation: BINAIRE DU FICHIER DE GEOMETRIE

Type of the binary used for writing the geometry file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords: GEOMETRY FILE

GEOMETRY FILE FORMAT

Type: Character

Dimension: 1

Default value: ‘SERAFIN’

FORTRAN variable: WAC_FILES(WACGEO)%FMT

French translation: FORMAT DU FICHIER DE GEOMETRIE

Geometry file format. Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5'

GLOBAL OUTPUT AT THE END

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: GLOB

French translation: SORTIE GLOBALE A LA FIN

It indicates whether a global output is made at the end of this computation (for a next computation).

Associated keywords: GLOBAL RESULTS FILE

GLOBAL RESULT FILE

Type: Character

Dimension: 1

Default value: ‘ ‘

FORTRAN variable: WAC_FILES(WACRBI)%NAME

French translation: FICHIER DES RESULTATS GLOBAUX

Name of the file in which the table F (density spectrum) is written at the end of the computation to be used in a subsequent computation

Associated keywords: BINARY OF THE GLOBAL RESULT FILE

GLOBAL RESULT FILE BINARY

Type: Character

Dimension: 1

Default value: ‘STD’

FORTRAN variable: BINRBI

French translation: BINAIRE DU FICHIER DES RESULTATS GLOBAUX

Type of the binary used for writing the global result file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords: GLOBAL RESULT FILE

IMPLICITATION COEFFICIENT FOR SOURCE TERMS

Type: Real

Dimension: 1

Default value: 0.5’

FORTRAN variable: CIMPLI

French translation: COEFFICIENT IMPLICITATION POUR TERMES SOURCES

Implicitation coefficient for the source terms integration, included between 0 et 1.

CIMPLI=0.: explicit

CIMPLI=0.5: semi-implicit

CIMPLI=1.: implicit

Associated keywords: CONSIDERATION OF SOURCE TERMS

INFINITE DEPTH

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: PROINF

French translation: PROFONDEUR INFINIE

Indicates whether an infinite depth is assumed. If so, bottom friction is inhibited.

Associated keywords: GLOBAL RESULT FILE

INITIAL ANGULAR DISTRIBUTION FUNCTION

Type: SPECTRE DIRECTIONNEL INITIAL

Dimension: 1

Default value: 1

FORTRAN variable: FRABI

French translation: FONCTION DE REPARTITION ANGULAIRE INITIALE

This is one of the constants used for computing the boundary directional spectrum. The following angular distribution functions are allowed:

1: cos^2s(T-T0) ; T in range [T0-pi/2;T0+pi/2]

2: exp(-0.5((T-T0)/s)^2) ; T in range [T0-pi/2;T0+pi/2]

3: cos^2s((T-T0)/2) (Mitsuyasu type)

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL DIRECTIONAL SPREAD 1

Type: Real

Dimension: 1

Default value: 2.

FORTRAN variable: SPRED1

French translation: ETALEMENT DIRECTIONNEL 1 INITIAL

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL DIRECTIONAL SPREAD 2

Type: Real

Dimension: 1

Default value: 2.

FORTRAN variable: SPRED2

French translation: ETALEMENT DIRECTIONNEL 2 INITIAL

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL MAIN DIRECTION 1

Type: Real

Dimension: 1

Default value: 0.

FORTRAN variable: TETA1

French translation: DIRECTION PRINCIPALE 1 INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL MAIN DIRECTION 2

Type: Real

Dimension: 1

Default value: 0.

FORTRAN variable: TETA2

French translation: DIRECTION PRINCIPALE 2 INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL MAXIMUM PEAK FREQUENCY

Type: Real

Dimension: 1

Default value: 0.2

FORTRAN variable: FREMAX

French translation: FREQUENCE DE PIC MAXIMALE INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL MEAN FETCH VALUE

Type: Real
Dimension: 1
Default value: 30000.
FORTRAN variable: FETCH
French translation: VALEUR MOYENNE DU FETCH INITIAL

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL PEAK FACTOR

Type: Real
Dimension: 1
Default value: 3.3
FORTRAN variable: GAMMA
French translation: FACTEUR DE PIC INITIAL

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL PEAK FREQUENCY

Type: Real
Dimension: 1
Default value: 0.067
FORTRAN variable: FPIC
French translation: FREQUENCE DE PIC INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL PHILLIPS CONSTANT

Type: Real
Dimension: 1
Default value: 0.018
FORTRAN variable: ALPHIL
French translation: CONSTANTE DE PHILLIPS INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL SIGNIFICANT WAVE HEIGHT

Type:	Real
Dimension:	1
Default value:	1.
FORTRAN variable:	HM0
French translation:	HAUTEUR SIGNIFICATIVE INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL STILL WATER LEVEL

Type:	Real
Dimension:	1
Default value:	0.
FORTRAN variable:	ZREPOS
French translation:	COTE INITIALE DU PLAN DEAU AU REPOS

Parameter used in the computation of the initial water DEPTH: DEPTH=ZREPOS-ZF.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL VALUE OF SIGMA-A FOR SPECTRUM

Type:	Real
Dimension:	1
Default value:	0.07
FORTRAN variable:	SIGMAA
French translation:	VALEUR INITIALE DE SIGMA-A POUR SPECTRE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL VALUE OF SIGMA-B FOR SPECTRUM

Type:	Real
Dimension:	1
Default value:	0.09
FORTRAN variable:	SIGMAB
French translation:	VALEUR INITIALE DE SIGMA-B POUR SPECTRE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

INITIAL WEIGHTING FACTOR FOR ADF

Type: Real
Dimension: 1
Default value: 1.
FORTRAN variable: XLAMDA
French translation: FACTEUR DE PONDERATION POUR FRA INITIALE

This is one of the constants used for computing the boundary directional spectrum as a function of the wind field.

Associated keywords: TYPE OF INITIAL DIRECTIONAL SPECTRUM

LIMIT SPECTRUM MODIFIED BY USER

Type: LOGICAL
Dimension: 1
Default value: .FALSE.
FORTRAN variable: SPEULI
French translation: SPECTRE AUX LIMITES MODIFIE PAR LUTILISATEUR

It indicates whether the user wants to modify the boundary spectrum. It should then retrieve the limwac.f subroutine.

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

LIST OF FILES

Type: Character
Dimension: 20
Default value: DEFAUT1 ='STEERING FILE';
'DICTIONARY';
'FORTRAN FILE';
'GEOMETRY FILE';
'BOUNDARY CONDITIONS FILE';
'BOTTOM TOPOGRAPHY FILE';
'2D RESULTS FILE';
'PUNCTUAL RESULTS FILE';
'PREVIOUS COMPUTATION FILE';
'GLOBAL RESULT FILE';
'BINARY CURRENTS FILE';
'FORMATTED CURRENTS FILE';

'BINARY FILE 1';
'FORMATTED FILE 1';
'BINARY WINDS FILE';
'FORMATTED WINDS FILE';
'VALIDATION FILE';
'BINARY TIDAL WATER LEVEL FILE';
'FORMATTED TIDAL WATER LEVEL FILE'

FORTRAN variable:
French translation: LISTE DES FICHIERS

Names of the files used by the software

Associated keywords: TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

MAXIMUM VALUE OF THE RATIO HM0 ON D

Type: Real
Dimension: 1
Default value: 1.
FORTRAN variable: COEFHS
French translation: VALEUR MAXIMALE DU RAPPORT HM0 SUR D

At the beginning of the integration of the source terms, the wave height is limited in order to satisfy the specified criterion.

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION

MINIMAL FREQUENCY

Type: Real
Dimension: 1
Default value: 1
FORTRAN variable: F1
French translation: FREQUENCE MINIMALE

It defines the minimal frequency in Hz. The discretised frequencies are computed from the FREQUENTIAL RATIO r and the NUMBER OF FREQUENCIES NF by the relation

f=f0*r^(k-1) k=1,NF.

Associated keywords: FREQUENTIAL RATIO
NUMBER OF FREQUENCIES
SPECTRUM TAIL FACTOR

MINIMUM WATER DEPTH

Type: Real

Dimension: 1

Default value: 0.1

FORTRAN variable: PROMIN

French translation: PROFONDEUR DEAU MINIMALE

It defines the minimum water depth below which bottom elevations are regarded as dry.

Associated keywords: FREQUENTIAL RATIO
NUMBER OF FREQUENCIES
SPECTRUM TAIL FACTOR

NEXT COMPUTATION

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: SUIT

French translation: SUITE DE CALCUL

It indicates whether a subsequent computation is to be done.

Associated keywords: PREVIOUS RESULTS FILE

NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES

Type: INTEGER

Dimension: 1

Default value: 0

FORTRAN variable: STRIF

French translation: TRANSFERTS NON LINEAIRES INTER-FREQUENCES

Selection of the modelling type of the non-linear transfer (quadrulplets) source term. If its value is 0, the non-linear transfers are ignored; if its value is 1, they are integrated in accordance with the formula of WAM cycle 4.

NUMBER OF BREAKING TIME STEPS

Type: INTEGER

Dimension: 1

Default value: 1

FORTRAN variable: NDTBRK

French translation: NOMBRE DE SOUS-PAS DE TEMPS POUR LE DEFERLEMENT

Number of time steps for the breaking source term. These time steps are in a geometric progression

Associated keywords: DEPTH-INDUCED BREAKING DISSIPATION
COEFFICIENT FOR THE BREAKING TIME STEPS

NUMBER OF DIRECTIONS

Type:	INTEGER
Dimension:	1
Default value:	12
FORTRAN variable:	NPLAN
French translation:	NOMBRE DE DIRECTIONS

It defines the number of wave propagation directions. The propagation directions are evenly distributed from 0 to 360 degrees.

NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS

Type:	INTEGER
Dimension:	1
Default value:	0
FORTRAN variable:	GRADEB
French translation:	NUMERO DE LA PREMIERE ITERATION POUR LES SORTIES GRAPHIQUES

It determines the number of iterations over the mean angular frequency from which the results are written into the 2D RESULTS FILE and the PUNCTUAL RESULTS FILE.

Associated keywords:	PERIOD FOR GRAPHIC PRINTOUTS
	VARIABLES FOR 2D GRAPHIC PRINTOUTS
	ABSCISSAE OF SPECTRUM PRINTOUT POINTS
	ORDINATES OF SPECTRUM PRINTOUT POINTS
	2D RESULTS FILE
	PUNCTUAL RESULTS FILE

NUMBER OF FREQUENCIES

Type:	INTEGER
Dimension:	1
Default value:	15
FORTRAN variable:	NF
French translation:	NOMBRE DE FREQUENCES

It defines the number of wave propagation frequencies. The propagation frequencies are geometrically distributed as a function of the MINIMAL FREQUENCY OF THE COMPUTATION and the FREQUENTIAL RATIO

Associated keywords:	FREQUENTIAL RATIO
	SPECTRUM TAIL FACTOR

NUMBER OF ITERATIONS FOR THE SOURCE TERMS

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: NSITS
French translation: NOMBRE DE SOUS-ITERATIONS POUR LES TERMES SOURCES

Number of sub-iterations for the computation of the source terms. The time step considered in the integration of the source terms is the ratio between the TIME STEP and the NUMBER OF SUB-ITERATIONS.

Associated keywords: TIME STEP

NUMBER OF PRIVATE ARRAYS

Type: INTEGER
Dimension: 1
Default value: 0
FORTRAN variable: NPRIV
French translation: NOMBRE DE TABLEAUX PRIVES

Number of private arrays used by the user

NUMBER OF TIME STEP

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: NIT
French translation: NOMBRE DE PAS DE TEMPS

It defines the number of time step.

Associated keywords: TIME STEP

ORDINATES OF SPECTRUM PRINTOUT POINTS

Type: Real
Dimension: Variable
Default value: 0.;0.;0.;0.;0.;0.;0.;0.;0.
FORTRAN variable: YLEO
French translation: ORDONNEES DES POINTS DE SORTIE DU SPECTRE

Array providing the ordinates of the SERAFIN spectrum printout points with a maximum dimension of 10. The spectrum printout points are the closest 2D points to the specified co-ordinates

Associated keywords: ABSCISSAE OF SPECTRUM PRINTOUT POINTS

PUNCTUAL RESULT FILE

ORIGIN COORDINATES

Type:	Integer
Dimension:	2
Default value:	0.;0
FORTRAN variable:	I_ORIG,J_ORIG
French translation:	COORDONNEES DE L''ORIGINE

Value in metres, used to avoid large real numbers, added in SERAFIN format, but so far no other treatment

PARALLEL PROCESSORS

Type:	Integer
Dimension:	1
Default value:	0
FORTRAN variable:	NCSIZE
French translation:	PROCESSEURS PARALLELES

Number of processors for parallel processing

0: 1 machine, compiling without parallel library

1: 1 machine, compiling with a parallel library

2: 2 processors or machines in parallel

etc....'

PERIOD FOR GRAPHIC PRINTOUTS

Type:	INTEGER
Dimension:	1
Default value:	1
FORTRAN variable:	GRAPRD
French translation:	PERIODE POUR LES SORTIES GRAPHIQUES

It determines the printing period of graphical output.

Associated keywords:	VARIABLES FOR 2D GRAPHIC PRINTOUTS
	ABSCISSAE OF SPECTRUM PRINTOUT POINTS
	ORDINATES OF SPECTRUM PRINTOUT POINTS
	2D RESULTS FILE
	PUNCTUAL RESULTS FILE
	NUMBER OF FIRST ITERATION FOR GRAPHIC PRINTOUTS

PERIOD FOR LISTING PRINTOUTS

Type: INTEGER

Dimension: 1

Default value: 1

FORTRAN variable: LISPRD

French translation: PERIODE POUR LES SORTIES LISTING

It determines the printing period of output to the list file.

Associated keywords: VARIABLES FOR 2D GRAPHIC PRINTOUTS
ABSCISSAE OF SPECTRUM PRINTOUT POINTS
ORDINATES OF SPECTRUM PRINTOUT POINTS
2D RESULTS FILE
PUNCTUAL RESULTS FILE
NUMBER OF FIRST ITERATION FOR GRAPHIC PRINTOUTS

PREVIOUS COMPUTATION FILE

Type: Character

Dimension: 1

Default value: ‘ ‘

FORTRAN variable: WAC_FILES(WACPRE)%NAME

French translation: FICHIER DU CALCUL PRECEDENT

Name of the file containing the global results of a previous computation carried out with the same mesh. This file gives the initial conditions for a next computation.

Associated keywords: BINARY OF THE PREVIOUS COMPUTATION FILE

PREVIOUS COMPUTATION FILE BINARY

Type: Character

Dimension: 1

Default value: ‘STD’

FORTRAN variable: BINPRE

French translation: BINAIRE DU FICHIER DU CALCUL PRECEDENT

Type of the binary used for reading the previous computation file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords: PREVIOUS COMPUTATION FILE

PREVIOUS COMPUTATION FILE FORMAT

Type:	Character
Dimension:	1
Default value:	'SERAFIN'
FORTRAN variable:	WAC_FILES(WACPRE)%FMT
French translation:	FORMAT DU FICHIER DU CALCUL PRECEDENT

Previous computation results file format. Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5'

PUNCTUAL RESULTS FILE

Type:	Character
Dimension:	1
Default value:	‘spect’
FORTRAN variable:	WAC_FILES(WACLEO)%NAME
French translation:	FICHIER DES RESULTATS PONCTUELS

Name of the file to which the spectra will be written.

Associated keywords:	PUNCTUAL RESULTS FILE BINARY
	ABSCISSAE OF SPECTRUM PRINTOUT POINTS
	ORDINATES OF SPECTRUM PRINTOUT POINTS
	PERIOD FOR GRAPHIC PRINTOUTS
	NUMBER OF FIRST ITERATION FOR GRAPHIC PRINTOUTS

PUNCTUAL RESULTS FILE BINARY

Type:	Character
Dimension:	1
Default value:	‘STD’
FORTRAN variable:	BINLEO
French translation:	BINAIRE DU FICHIER DES RESULTATS PONCTUELS

Type of the binary used for writing the spectral results file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;
- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords:	PUNCTUAL RESULTS FILE

RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED

Type: INTEGER
Dimension: 1
Default value: 0
FORTRAN variable: IDTEL
French translation: RANG DE LA DONNEE TELEMAC A RECUPERER

It indicates the rank of the TELEMAC data to be recovered in the currents file.

Associated keywords: TIME INCREMENT NUMBER IN TELEMAC FILE
RECOVERY OF TELEMAC DATA ITEM

RANK OF THE WATER LEVEL DATA IN THE TELEMAC FILE

Type: INTEGER
Dimension: 1
Default value: 4
FORTRAN variable: IDHMA
French translation: RANG DU NIVEAU DE LA MAREE DANS LE FICHIER TELEMAC

The rank of the water level data in the TELEMAC file

Associated keywords: CONSIDERATION OF TIDE
BINARY TIDAL WATER LEVEL FILE
FORMATTED TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE BINARY
TIDE REFRESHING PERIOD

RECOVERY OF TELEMAC DATA ITEM

Type: LOGICAL
Dimension: 1
Default value: .FALSE.
FORTRAN variable: DONTEL
French translation: RECUPERATION DE DONNEE TELEMAC

It indicates whether TELEMAC data are recovered in lecdon.f. If so, a proper-formatted CURRENTS FILE should be used and the rank of the respective variable should be entered into the TELEMAC file.

Associated keywords: BINARY CURRENTS FILE
FORMATTED CURRENTS FILE
CURRENTS FILE FORMAT
RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED
TIME INCREMENT NUMBER IN TELEMAC FILE

REFERENCE FILE FORMAT

Type: Character

Dimension: 1

Default value: 'SERAFIN'

FORTRAN variable: WAC_FILES(WACREF)%FMT

French translation: FORMAT DU FICHIER DE REFERENCE

Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5'

RELEASE

Type: Character

Dimension: 1

Default value: V6P0

FORTRAN variable: VERS

French translation: NUMERO DE VERSION

Release number

RESULTS FILE FORMAT

Type: Character

Dimension: 1

Default value: 'SERAFIN'

FORTRAN variable: WAC_FILES(WACRES)%FMT

French translation: FORMAT DU FICHIER DE RESULTATS

Results file format. Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5'

SHIFT GROWING CURVE DUE TO WIND

Type: Real

Dimension: 1

Default value: 0.011

FORTRAN variable: DECAL

French translation: DECALAGE COURBE DE CROISSANCE DUE AU VENT

Constant used in the wind source term.

Associated keywords: WIND GENERATION

SPECTRUM FILE FORMAT

Type: Character

Dimension: 1

Default value: 'SERAFIN'

FORTRAN variable: WAC_FILES(WACLEO)%FMT

French translation: FORMAT DU FICHIER DE SPECTRE

Possible values are:

- SERAFIN: classical single precision format in Telemac;
- SERAFIND: classical double precision format in Telemac;
- MED : MED format based on HDF5'

SPECTRUM ENERGY THRESHOLD

Type: Real

Dimension: 1

Default value: 1.D-30

FORTRAN variable: E2FMIN

French translation: SEUIL DENERGIE CONSIDERE POUR LE SPECTRE

For initial conditions, the energy, for all frequency-direction components, lower to this threshold are set to 0. Useful for comparisons with WAM cycle 4.

Associated keywords: WIND GENERATION

SPECTRUM TAIL FACTOR

Type: Real

Dimension: 1

Default value: 5.

FORTRAN variable: TAILF

French translation: FACTEUR DE QUEUE DU SPECTRE

Used to consider the contribution of the non discretised high frequencies in the computations.

Associated keywords: NUMBER OF FREQUENCIES
FREQUENTIAL RATIO

SPHERICAL COORDINATES

Type: LOGICAL

Dimension: 1

Default value: .FALSE.

FORTRAN variable: SPHE

French translation: COORDONNEES SPHERIQUES

It indicates whether the coordinates are spherical (unit= degree) or Cartesian (unit metre).

ATTENTION, in Cartesian co-ordinates, the co-ordinates are expressed in metres whereas they are expressed in degrees in spherical co-ordinates

STANDARD CONFIGURATION PARAMETER

Type:	Real
Dimension:	1
Default value:	0.25
FORTRAN variable:	XLAMD
French translation:	PARAMETRE DE LA CONFIGURATION STANDARD

Parameter defining the standard configuration for the quadruplet interactions in the DIA method.

Associated keywords:	NON-LINEAR TRANSFERTS

STATIONNARY WIND

Type:	Logical
Dimension:	1
Default value:	TRUE
FORTRAN variable:	VENSTA
French translation:	VENT STATIONNAIRE

It indicates whether the wind evolves temporally and requires to be updated

Associated keywords:	CONSIDERATION OF A WIND

STEERING FILE

Type:	Character
Dimension:	1
Default value:	‘cas’
FORTRAN variable:	WACCAS
French translation:	FICHIER DES PARAMETRES

Name of the file containing the parameters of the computation to be made.

TIDAL WATER LEVEL FILE BINARY

Type:	Character
Dimension:	1
Default value:	‘STD’
FORTRAN variable:	BINMAR
French translation:	BINAIRE DU FICHIER DU NIVEAU DE LA MAREE

Type of the binary used for writing the currents file. This type depends on the machine in which the file was generated. The possible values are as follows:

- IBM; for a file created in an IBM machine;

- I3E; for a file created in a HP machine;
- STD; normal READ and WRITE instructions are then generated.

Associated keywords: CONSIDERATION OF TIDE
BINARY TIDAL WATER LEVEL FILE
FORMATTED TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE FORMAT
TIDE REFRESHING PERIOD

TIDAL WATER LEVEL FILE FORMAT

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: INDIM
French translation: FORMAT DU FICHIER DU NIVEAU DE LA MAREE

Selection of the type of currents file format:

1 finite differences, WAM cycle 4 format type
2 X Y UX UY, SINUSX format type
3 SERAFIN, TELEMAC type
4 user format (the maruti.f procedure should then be modified)

Associated keywords: CONSIDERATION OF TIDE
BINARY TIDAL WATER LEVEL FILE
FORMATTED TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE BINARY
TIDE REFRESHING PERIOD

TIDE REFRESHING PERIOD

Type: INTEGER
Dimension: 1
Default value: 1
FORTRAN variable: LAM
French translation: PERIODE DACTUALISATION DE LA MAREE

It determines the period in number of iterations to update the tidal currents and the water depth.

Associated keywords: CONSIDERATION OF TIDE
BINARY TIDAL WATER LEVEL FILE
FORMATTED TIDAL WATER LEVEL FILE
TIDAL WATER LEVEL FILE BINARY
FORMAT DU FICHIER DU NIVEAU DE LA MAREE

TIME INCREMENT NUMBER IN TELEMAC FILE

Type:	INTEGER
Dimension:	1
Default value:	1
FORTRAN variable:	NPTT
French translation:	NUMERO DU PAS DE TEMPS DU FICHIER TELEMAC

It indicates the number of the time step in the TELEMAC results (currents) file corresponding to the desired time for data recovery.

Associated keywords:	RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED
	RECOVERY OF TELEMAC DATA ITEM

TIME STEP

Type:	Real
Dimension:	1
Default value:	1.
FORTRAN variable:	DT
French translation:	PAS DE TEMPS

It defines the time step in seconds.

Associated keywords: NUMBER OF TIME STEPS

TITLE

Type:	Character
Dimension:	1
Default value:	‘SET A TITLE !!!’
FORTRAN variable:	TITCAS
French translation:	TITRE

Title of the case being studied.

TRIAD INTERACTIONS

Type:	INTEGER
Dimension:	1
Default value:	0
FORTRAN variable:	STRIA
French translation:	TRANSFERTS ENTRE TRIPLETS DE FREQUENCES

Selection of the triad interaction model:

0: no triad interactions

1: LTA model (Eldeberky, 1996)

2: SPB model (Becq, 1998)

Associated keywords: TRIADS 1 (LTA) COEFFICIENT ALPHA
TRIADS 1 (LTA) COEFFICIENT RFMLTA
TRIADS 2 (SPB) COEFFICIENT K
TRIADS 2 (SPB) LOWER DIRECTIONAL BOUND
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUND

TRIADS 1 (LTA) COEFFICIENT ALPHA

Type: Real
Dimension: 1
Default value: 0.5
FORTRAN variable: ALFLTA
French translation: TRIADS 1 (LTA) CONSTANTE ALPHA

Coefficient alpha of the LTA model proposed by Eldeberky (1996). If alpha=0, no energy transfers will occur. The energy transfers increases with alpha.

Associated keywords: TRIAD INTERACTIONS
TRIADS 1 (LTA) COEFFICIENT RFMLTA

TRIADS 1 (LTA) COEFFICIENT RFMLTA

Type: Real
Dimension: 1
Default value: 2.5
FORTRAN variable: RFMLTA
French translation: TRIADS 1 (LTA) CONSTANTE RFMLTA

This determines the upper frequency on which the energy transfers may occur. The maximal frequency is calculated as the product of the constant RFMLTA and the peak frequency of the spectrum.

Associated keywords: TRIAD INTERACTIONS
TRIADS 1 (LTA) COEFFICIENT ALPHA

TRIADS 2 (SPB) COEFFICIENT K

Type: Real
Dimension: 1
Default value: 0.34
FORTRAN variable: KSPB
French translation: TRIADS 2 (SPB) CONSTANTE K

Coefficient K of the SPB model

Associated keywords: TRIAD INTERACTIONS

TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY

TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY

Type: Real
Dimension: 1
Default value: 0.
FORTRAN variable: BDISPB
French translation: TRIADS 2 (SPB) BORNE DIRECTIONNELLE INFERIEURE

Lower directional boundary of the SPB model

Associated keywords: TRIAD INTERACTIONS
TRIADS 2 (SPB) COEFFICIENT K
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY
NOM = 'TRIADS 2 (SPB) BORNE DIRECTIONNELLE INFERIEURE'

TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY

Type: Real
Dimension: 1
Default value: 360.
FORTRAN variable: DBSSPB
French translation: TRIADS 2 (SPB) BORNE DIRECTIONNELLE SUPERIEURE

Upper directional boundary of the SPB model

Associated keywords: TRIAD INTERACTIONS
TRIADS 2 (SPB) COEFFICIENT K
TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY

TRIGONOMETRICAL CONVENTION

Type: LOGICAL
Dimension: 1
Default value: .FALSE.
FORTRAN variable: TRIGO
French translation: CONVENTION TRIGONOMETRIQUE

True if the wave directions are measured counterclockwise from the positive x-axis, false if they are measured clockwise from geographic North

TYPE OF BOUNDARY DIRECTIONAL SPECTRUM

Type: INTEGER

Dimension: 1

Default value: 0

FORTRAN variable: LIMSPE

French translation: TYPE DE SPECTRE DIRECTIONNEL AUX LIMITES

If this keyword is set to 0, a zero valued spectrum is specified at the inlet boundaries of the domain. If it ranges from 1 to 7, a JONSWAP (or TMA) -typed spectrum is specified at these points as a function of the initial wind field and/or of the values of the following keywords

Associated keywords: BOUNDARY SIGNIFICANT HEIGHT
BOUNDARY PEAK FREQUENCY
BOUNDARY PEAK FACTOR
BOUNDARY VALUE OF SIGMA-A FOR SPECTRUM
BOUNDARY VALUE OF SIGMA-B FOR SPECTRUM
BOUNDARY PHILLIPS CONSTANT
BOUNDARY MEAN FETCH VALUE
BOUNDARY MAXIMUM PEAK FREQUENCY
BOUNDARY MAIN DIRECTION 1
BOUNDARY DIRECTIONAL SPREAD 1
BOUNDARY MAIN DIRECTION 2
BOUNDARY DIRECTIONAL SPREAD 2
BOUNDARY WEIGHTING FACTOR FOR ADF

TYPE OF INITIAL DIRECTIONAL SPECTRUM

Type: INTEGER

Dimension: 1

Default value: 0

FORTRAN variable: INISPE

French translation: TYPE DE SPECTRE DIRECTIONNEL INITIAL

If this keyword is set to 0, a zero valued spectrum is specified at the inlet boundaries of the domain. If it ranges from 1 to 7, a JONSWAP (or TMA)-typed spectrum is specified at these very points as a function of the initial wind field and/or of the values of the following keywords

Associated keywords: INITIAL SIGNIFICANT WAVE HEIGHT
INITIAL PEAK FREQUENCY
INITIAL PEAK FACTOR
INITIAL VALUE OF SIGMA-A FOR SPECTRUM
INITIAL VALUE OF SIGMA-B FOR SPECTRUM
INITIAL PHILLIPS CONSTANT
INITIAL MEAN FETCH VALUE
INITIAL MAXIMUM PEAK FREQUENCY

INITIAL MAIN DIRECTION 1
INITIAL DIRECTIONAL SPREAD 1
INITIAL MAIN DIRECTION 2
INITIAL DIRECTIONAL SPREAD 2
INITIAL WEIGHTING FACTOR FOR ADF

VALIDATION

Type: LOGICAL
Dimension: 1
Default value: .FALSE.
FORTRAN variable: VALID
French translation: VALIDATION

True if the computation is a validation, in which case a validation file is expected.

Associated keywords: VALIDATION FILE

VALIDATION FILE

Type: Character
Dimension: 1
Default value: ' '
FORTRAN variable: WAC_FILES(WACREF)%NAME
French translation: FICHIER DE REFERENCE

Name of validation data file

Associated keywords: VALIDATION

VARIABLES FOR 2D GRAPHIC PRINTOUTS

Type: Character
Dimension: 1
Default value: HM0,DMOY
FORTRAN variable: SORT2D
French translation: VARIABLES POUR LES SORTIES GRAPHIQUES 2D

Codes of the variables the user wants to write into the 2D RESULTS FILE. The available variables are as follows:

M0: Total variance
HM0: Spectral significant wave height
DMOY: Mean wave direction
SPD: Mean directional spreading
ZF: Sea bottom level

WD: Water depth

UX: Current along X

UY: Current along Y

VX: Wind along X

VY: Wind along Y

FX: Driving force along X

FY: Driving force along Y

SXX: Radiation stress along xx

SYY: Radiation stress along yy

SXY: Radiation stress along xy

UWB: Bottom celerity

POW: Wave power (per meter along wave crest)

FMOY: Mean frequency FMOY

FM01: Mean frequency FM01

FM02: Mean frequency FM02

FPD: Discrete peak frequency

FPR5: Peak frequency by Read method of order 5

FPR8: Peak frequency by Read method of order 8

US: Surface friction velocity u*

CD: Surface drag coefficient CD

Z0: Surface roughness length Z0

WS: Surface wave stress

TMOY: Mean period Tmoy

TM01: Mean period Tm01

TM02: Mean period Tm02

TPD: Discrete peak period

TPR5: Peak period by Read method of order 5

TPR8: Peak period by Read method of order 8

PRI: Private table

BETA: Breaking waves coefficient

Associated keywords: 2D RESULTS FILE
NUMBER OF FIRST ITERATION FOR GRAPHIC PRINTOUTS
PERIOD FOR GRAPHIC PRINTOUTS

VECTOR LENGTH

Type: INTEGER

Dimension: 1

Default value: 1

FORTRAN variable: LVMAC

French translation: LONGUEUR DU VECTEUR

It indicates the vector length of the vector machine being used.

VON KARMAN CONSTANT

Type: Real

Dimension: 1

Default value: 0.41

FORTRAN variable: XKAPPA

French translation: CONSTANTE DE VON KARMAN

Constant used in the wind source term.

Associated keywords: WIND GENERATION

WATER DENSITY

Type: Real

Dimension: 1

Default value: 1000.

FORTRAN variable: ROEAU

French translation: DENSITE DE LEAU

The ratio ROAIR/ROEAU is used in the wind generation source term.

Associated keywords: WIND GENERATION
AIR DENSITY

WAVE GROWTH LIMITER

Type: INTEGER

Dimension: 1

Default value: 1

FORTRAN variable: LIMIT

French translation: LIMITEUR DE CROISSANCE

Choice of the wave growth limiter.

If LIMIT=0, no wave growth limiter.

If LIMIT=1, WAM 4 original limiter.

If LIMIT=2, Hersbach et Janssen (1999) limiter.

Associated keywords: CONSIDERATION OF SOURCE TERMS

WHITE CAPPING DISSIPATION

Type: INTEGER

Dimension: 1

Default value: 0

FORTRAN variable: SMOUT

French translation: DISSIPATION PAR MOUTONNEMENT

Selection of the modelling type of the white capping source term. If its value is 0, the white capping dissipation is ignored; if its value is 1, it is integrated in accordance with a formula that is similar to that of WAM cycle 4.

Associated keywords: WHITE CAPPING DISSIPATION COEFFICIENT
WHITE CAPPING WEIGHTING COEFFICIENT

WHITE CAPPING DISSIPATION COEFFICIENT

Type: Real

Dimension: 1

Default value: 4.5

FORTRAN variable: CMOUT1

French translation: COEFFICIENT DE DISSIPATION PAR MOUTONNEMENT

White capping dissipation coefficient.

Associated keywords: WHITE CAPPING DISSIPATION
WHITE CAPPING WEIGHTING COEFFICIENT

WHITE CAPPING WEIGHTING COEFFICIENT

Type: Real

Dimension: 1

Default value: 0.5

FORTRAN variable: CMOUT2

French translation: COEFFICIENT DE PONDERATION POUR LE MOUTONNEMENT

White capping weighting coefficient.

Associated keywords: WHITE CAPPING DISSIPATION
WHITE CAPPING DISSIPATION COEFFICIENT

WIND DRAG COEFFICIENT

Type: Real

Dimension: 1

Default value: 1.2875E-3

FORTRAN variable: CDRAG

French translation: COEFFICIENT DE TRAINEE DE VENT

Constant used in the wind source term.

Associated keywords: WIND GENERATION

WIND GENERATION

Type:	INTEGER
Dimension:	1
Default value:	0
FORTRAN variable:	SVENT
French translation:	APPORTS DUS AU VENT

Selection of the type of modelling of the wind generation source term. If its value is 0, the wind generation is ignored; if its value is 1, it is integrated in accordance with the WAM cycle 4 formula.

Associated keywords:	CONSIDERATION OF A WIND
	WINDS FILE FORMAT
	AIR DENSITY
	WATER DENSITY
	WIND GENERATION COEFFICIENT
	VON KARMAN CONSTANT
	CHARNOCK CONSTANT
	SHIFT GROWING CURVE DUE TO WIND
	WIND MEASUREMENTS LEVEL
	WIND DRAG COEFFICIENT

WIND GENERATION COEFFICIENT

Type	Real
Dimension:	1
Default value:	1.2
FORTRAN variable:	BETAM
French translation:	COEFFICIENT DE GENERATION PAR LE VENT

Constant used in the wind source term.

Associated keywords:	WIND GENERATION

WIND MEASUREMENTS LEVEL

Type:	Real
Dimension:	1
Default value:	10.
FORTRAN variable:	ZVENT
French translation:	COTE DE MESURE DES VENTS

Constant used in the wind source term.

Associated keywords:	WIND GENERATION

WIND VELOCITY ALONG X

Type:	Real
Dimension:	1
Default value:	0.
FORTRAN variable:	VX_CTE
French translation:	VITESSE DU VENT SUIVANT X

Wind velocity along X axis, constant and homogeneous (m/s)

Associated keywords: CONSIDERATION OF A WIND

WIND VELOCITY ALONG Y

Type:	Real
Dimension:	1
Default value:	0.
FORTRAN variable:	VY_CTE
French translation:	VITESSE DU VENT SUIVANT Y

Wind velocity along Y axis, constant and homogeneous (m/s)

Associated keywords: CONSIDERATION OF A WIND

WINDS FILE BINARY

Type:	Character
Dimension:	1
Default value:	‘STD’
FORTRAN variable:	BINVEN
French translation:	BINAIRE DU FICHIER DES VENTS

Type of the binary used for writing the winds file. This type depends on the machine in which the file was generated. The possible values are the same as for the geometry file.

WARNING! This file is a binary file so the keyword WINDS FILE FORMAT must be set higher than 2.

Associated keywords: BINARY WINDS FILE
WINDS FILE FORMAT

WINDS FILE FORMAT

Type:	INTEGER
Dimension:	1
Default value:	1
FORTRAN variable:	INDIV
French translation:	FORMAT DU FICHIER DES VENTS

Selection of winds file format Type:

1 finite differences, WAM cycle 4 format type

2 X Y UX UY, SINUSX format type

3 SERAFIN, TELEMAC type

4 user format (the venuti.f procedure should then be modified)

Associated keywords: WINDS FILE BINARY

APPENDIX 4: List of keywords classified by subject

INPUT-OUTPUT FILES

RANK OF THE WATER LEVEL DATA IN THE TELEMAC FILE

BINARY SPECIFICATION

BINARY FILE 1 BINARY
GEOMETRY FILE BINARY
CURRENTS FILE BINARY
2D RESULTS FILE BINARY
GLOBAL RESULT FILE BINARY
PUNCTUAL RESULTS FILE BINARY
WINDS FILE BINARY
PREVIOUS COMPUTATION FILE BINARY
TIDAL WATER LEVEL FILE BINARY

FILE NAMES

BINARY FILE 1
GEOMETRY FILE
VALIDATION FILE
BOUNDARY CONDITIONS FILE
BINARY CURRENTS FILE
FORMATTED CURRENTS FILE
BOTTOM TOPOGRAPHY FILE
STEERING FILE
2D RESULTS FILE
GLOBAL RESULT FILE
PUNCTUAL RESULTS FILE
BINARY WINDS FILE
FORMATTED WINDS FILE
PREVIOUS COMPUTATION FILE
BINARY TIDAL WATER LEVEL FILE
FORMATTED TIDAL WATER LEVEL FILE
FORMATTED FILE 1
FORTRAN FILE

FORMATS

BINARY DATA FILE 1 FORMAT
CURRENTS FILE FORMAT
GEOMETRY FILE FORMAT
PREVIOUS COMPUTATION FILE FORMAT
REFERENCE FILE FORMAT
RESULTS FILE FORMAT
SPECTRUM FILE FORMAT
WINDS FILE FORMAT
TIDAL WATER LEVEL FILE FORMAT

TELEMAC

TIME INCREMENT NUMBER IN TELEMAC FILE

RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED

INPUT-OUTPUT, GRAPHICS AND LISTING

SPECTRA

ABSCISSAE OF SPECTRUM PRINTOUT POINTS
ORDINATES OF SPECTRUM PRINTOUT POINTS

GENERAL

PERIOD FOR GRAPHIC PRINTOUTS
PERIOD FOR LISTING PRINTOUTS
NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS

GRID

VARIABLES FOR 2D GRAPHIC PRINTOUTS

SOURCE TERMS

WIND GENERATION

WIND GENERATION
WIND GENERATION COEFFICIENT
WIND DRAG COEFFICIENT
WIND GENERATION COEFFICIENT
CHARNOCK CONSTANT
VON KARMAN CONSTANT
WIND MEASUREMENTS LEVEL
SHIFT GROWING CURVE DUE TO WIND
STATIONARY WIND
WIND VELOCITY ALONG X
WIND VELOCITY ALONG Y
AIR DENSITY
WATER DENSITY

WHITE-CAPPING

WHITE CAPPING DISSIPATION COEFFICIENT
WHITE CAPPING WEIGHTING COEFFICIENT
WHITE CAPPING DISSIPATION

SEABED FRICTION

BOTTOM FRICTION COEFFICIENT
BOTTOM FRICTION DISSIPATION

DEPTH LIMITED WAVE BREAKING

COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD
DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B

DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR
DEPTH-INDUCED BREAKING DISSIPATION
NUMBER OF BREAKING TIME STEPS
MAXIMUM VALUE OF THE RATIO HM0 ON D

NON-LINEAR TRANSFER

STANDARD CONFIGURATION PARAMETER
NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES

GENERAL

CONSIDERATION OF SOURCE TERMS
IMPLICITATION COEFFICIENT FOR SOURCE TERMS

TRIAD INTERACTIONS

TRIAD INTERACTIONS
TRIADS 1 (LTA) COEFFICIENT ALPHA
TRIADS 1 (LTA) COEFFICIENT RFMLTA
TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY
TRIADS 2 (SPB) COEFFICIENT K

COMPUTATION OPTIONS

TRIGONOMETRICAL CONVENTION

TIDE

CONSIDERATION OF TIDE

CURRENTS

CONSIDERATION OF A STATIONARY CURRENT
TIDE REFRESHING PERIOD

SPHERICAL COORDINATES

SPHERICAL COORDINATES

SMOOTHING

BOTTOM SMOOTHINGS

PROPAGATION

CONSIDERATION OF PROPAGATION

WIND

CONSIDERATION OF A WIND

DEPTH

INFINITE DEPTH
MINIMUM WATER DEPTH

TELEMAC

RECOVERY OF TELEMAC DATA ITEM

CALCULATION CONTINUATION

GLOBAL OUTPUT AT THE END
NEXT COMPUTATION

VALIDATION

VALIDATION

BOUNDARY CONDITIONS

BOUNDARY PHILLIPS CONSTANT
BOUNDARY MAIN DIRECTION 1
BOUNDARY MAIN DIRECTION 2
BOUNDARY DIRECTIONAL SPREAD 1
BOUNDARY DIRECTIONAL SPREAD 2
BOUNDARY PEAK FACTOR
BOUNDARY WEIGHTING FACTOR FOR ADF
BOUNDARY PEAK FREQUENCY
BOUNDARY MAXIMUM PEAK FREQUENCY
BOUNDARY SIGNIFICANT WAVE HEIGHT
TYPE OF BOUNDARY DIRECTIONAL SPECTRUM
BOUNDARY SPECTRUM VALUE OF SIGMA-A
BOUNDARY SPECTRUM VALUE OF SIGMA-B
BOUNDARY MEAN FETCH VALUE
BOUNDARY ANGULAR DISTRIBUTION FUNCTION

INITIALISATION OF SPECTRA

LIMIT SPECTRUM MODIFIED BY USER
SPECTRUM ENERGY THRESHOLD
INITIAL PHILLIPS CONSTANT
INITIAL MAIN DIRECTION 1
INITIAL MAIN DIRECTION 2
INITIAL DIRECTIONAL SPREAD 1
INITIAL DIRECTIONAL SPREAD 2
INITIAL PEAK FACTOR
INITIAL WEIGHTING FACTOR FOR ADF
INITIAL ANGULAR DISTRIBUTION FUNCTION
INITIAL PEAK FREQUENCY
INITIAL MAXIMUM PEAK FREQUENCY
INITIAL SIGNIFICANT WAVE HEIGHT
TYPE OF INITIAL DIRECTIONAL SPECTRUM
INITIAL VALUE OF SIGMA-A FOR SPECTRUM
INITIAL VALUE OF SIGMA-B FOR SPECTRUM
INITIAL MEAN FETCH VALUE

GENERAL

DURATION OF CALCULATION

DATE OF COMPUTATION BEGINNING
NUMBER OF TIME STEP

- NUMBER OF ITERATIONS FOR THE SOURCE TERMS
- TIME STEP

DISCRETISATION OF SPECTRA

- SPECTRUM TAIL FACTOR
- MINIMAL FREQUENCY
- NUMBER OF DIRECTIONS
- NUMBER OF FREQUENCIES
- FREQUENTIAL RATIO

OTHERS

- NUMBER OF PRIVATE ARRAYS
- INITIAL STILL WATER LEVEL
- DESCRIPTION OF LIBRARIES
- DICTIONARY
- DEFAULT EXECUTABLE
- DEFAULT PARALLEL EXECUTABLE
- PARALLEL PROCESSORS
- LIST OF FILES
- VECTOR LENGTH

VERSION

- RELEASE

TITLE

- TITLE

APPENDIX 5: French/English keyword dictionary

ABSCISSES DES POINTS DE SORTIE DU SPECTRE	*ABSCISSAE OF SPECTRUM PRINTOUT POINTS*
APPORTS DUS AU VENT	*WIND GENERATION*
BINAIRE DU FICHIER BINAIRE 1	*BINARY FILE 1 BINARY*
BINAIRE DU FICHIER DE GEOMETRIE	*GEOMETRY FILE BINARY*
BINAIRE DU FICHIER DES COURANTS	*CURRENTS FILE BINARY*
BINAIRE DU FICHIER DES RESULTATS 2D	*2D RESULTS FILE BINARY*
BINAIRE DU FICHIER DES RESULTATS GLOBAUX	*GLOBAL RESULT FILE BINARY*
BINAIRE DU FICHIER DES RESULTATS PONCTUELS	*PUNCTUAL RESULTS FILE BINARY*
BINAIRE DU FICHIER DES VENTS	*WINDS FILE BINARY*
BINAIRE DU FICHIER DU CALCUL PRECEDENT	*PREVIOUS COMPUTATION FILE BINARY*
BINAIRE DU FICHIER DU NIVEAU DE LA MAREE	*TIDAL WATER LEVEL FILE BINARY*
COEFFICIENT DE DISSIPATION PAR MOUTONNEMENT	*WHITE CAPPING DISSIPATION COEFFICIENT*
COEFFICIENT DE FROTTEMENT SUR LE FOND	*BOTTOM FRICTION COEFFICIENT*
COEFFICIENT DE GENERATION PAR LE VENT	*WIND GENERATION COEFFICIENT*
COEFFICIENT DE PONDERATION POUR LE MOUTONNEMENT	*WHITE CAPPING WEIGHTING COEFFICIENT*
COEFFICIENT DE TRAINEE DE VENT	*WIND DRAG COEFFICIENT*
COEFFICIENT IMPLICITATION POUR TERMES SOURCES	*IMPLICITATION COEFFICIENT FOR SOURCE TERMS*
COEFFICIENT POUR LES SOUS-PAS DE TEMPS POUR LE DEFERLEMENT	*COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING*
CONSTANTE DE CHARNOCK	*CHARNOCK CONSTANT*
CONSTANTE DE PHILLIPS AUX LIMITES	*BOUNDARY PHILLIPS CONSTANT*
CONSTANTE DE PHILLIPS INITIALE	*INITIAL PHILLIPS CONSTANT*
CONSTANTE DE VON KARMAN	*VON KARMAN CONSTANT*
CONVENTION TRIGONOMETRIQUE	*TRIGONOMETRICAL CONVENTION*
COORDONNEES SPHERIQUES	*SPHERICAL COORDINATES*
COTE DE MESURE DES VENTS	*WIND MEASUREMENTS LEVEL*
COTE INITIALE DU PLAN DEAU AU REPOS	*INITIAL STILL WATER LEVEL*
DATE DE DEBUT DU CALCUL	*DATE OF COMPUTATION BEGINNING*
DECALAGE COURBE DE CROISSANCE DUE AU VENT	*SHIFT GROWING CURVE DUE TO WIND*
DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE	*DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY*
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM	*DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD*
DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB	*DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD*
DEFERLEMENT 1 (BJ) CONSTANTE ALPHA	*DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA*
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA1	*DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1*
DEFERLEMENT 1 (BJ) CONSTANTE GAMMA2	*DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2*
DEFERLEMENT 2 (TG) CHOIX FREQUENCE CARACTERISTIQUE	*DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY*
DEFERLEMENT 2 (TG) FONCTION DE PONDERATION	*DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION*
DEFERLEMENT 2 (TG) CONSTANTE B	*DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B*

DEFERLEMENT 2 (TG) CONSTANTE GAMMA	*DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA*
DEFERLEMENT 3 (RO) CHOIX FREQUENCE CARACTERISTIQUE	*DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY*
DEFERLEMENT 3 (RO) DISTRIBUTION DES HAUTEURS DE HOULE	*DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION*
DEFERLEMENT 3 (RO) EXPOSANT FONCTION DE PONDERATION	*DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION*
DEFERLEMENT 3 (RO) CONSTANTE ALPHA	*DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA*
DEFERLEMENT 3 (RO) CONSTANTE GAMMA	*DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA*
DEFERLEMENT 3 (RO) CONSTANTE GAMMA2	*DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2*
DEFERLEMENT 4 (IH) CHOIX FREQUENCE CARACTERISTIQUE	*DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY*
DEFERLEMENT 4 (IH) CONSTANTE BETA0	*DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0*
DEFERLEMENT 4 (IH) CONSTANTE M2STAR	*DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR*
DESCRIPTION DES LIBRAIRIES	*DESCRIPTION OF LIBRARIES*
DICTIONNAIRE	*DICTIONARY*
DIRECTION PRINCIPALE 1 AUX LIMITES	*BOUNDARY MAIN DIRECTION 1*
DIRECTION PRINCIPALE 1 INITIALE	*INITIAL MAIN DIRECTION 1*
DIRECTION PRINCIPALE 2 AUX LIMITES	*BOUNDARY MAIN DIRECTION 2*
DIRECTION PRINCIPALE 2 INITIALE	*INITIAL MAIN DIRECTION 2*
DISSIPATION PAR DEFERLEMENT	*DEPTH-INDUCED BREAKING DISSIPATION*
DISSIPATION PAR FROTTEMENT SUR LE FOND	*BOTTOM FRICTION DISSIPATION*
DISSIPATION PAR MOUTONNEMENT	*WHITE CAPPING DISSIPATION*
ETALEMENT DIRECTIONNEL 1 AUX LIMITES	*BOUNDARY DIRECTIONAL SPREAD 1*
ETALEMENT DIRECTIONNEL 1 INITIAL	*INITIAL DIRECTIONAL SPREAD 1*
ETALEMENT DIRECTIONNEL 2 AUX LIMITES	*BOUNDARY DIRECTIONAL SPREAD 2*
ETALEMENT DIRECTIONNEL 2 INITIAL	*INITIAL DIRECTIONAL SPREAD 2*
EXECUTABLE PAR DEFAUT	*DEFAULT EXECUTABLE*
EXECUTABLE PARALLELE PAR DEFAUT	*DEFAULT PARALLEL EXECUTABLE*
FACTEUR DE PIC AUX LIMITES	*BOUNDARY PEAK FACTOR*
FACTEUR DE PIC INITIAL	*INITIAL PEAK FACTOR*
FACTEUR DE PONDERATION POUR FRA AUX LIMITES	*BOUNDARY WEIGHTING FACTOR FOR ADF*
FACTEUR DE PONDERATION POUR FRA INITIALE	*INITIAL WEIGHTING FACTOR FOR ADF*
FACTEUR DE QUEUE DU SPECTRE	*SPECTRUM TAIL FACTOR*
FICHIER BINAIRE 1	*BINARY FILE 1*
FICHIER DE GEOMETRIE	*GEOMETRY FILE*
FICHIER DE REFERENCE	*VALIDATION FILE*
FICHIER DES CONDITIONS AUX LIMITES	*BOUNDARY CONDITIONS FILE*
FICHIER DES COURANTS BINAIRE	*BINARY CURRENTS FILE*
FICHIER DES COURANTS FORMATE	*FORMATTED CURRENTS FILE*
FICHIER DES FONDS	*BOTTOM TOPOGRAPHY FILE*
FICHIER DES PARAMETRES	*STEERING FILE*
FICHIER DES RESULTATS 2D	*2D RESULTS FILE*
FICHIER DES RESULTATS GLOBAUX	*GLOBAL RESULT FILE*
FICHIER DES RESULTATS PONCTUELS	*PUNCTUAL RESULTS FILE*
FICHIER DES VENTS BINAIRE	*BINARY WINDS FILE*
FICHIER DES VENTS FORMATE	*FORMATTED WINDS FILE*
FICHIER DU CALCUL PRECEDENT	*PREVIOUS COMPUTATION FILE*

FICHIER DU NIVEAU DE LA MAREE BINAIRE	*BINARY TIDAL WATER LEVEL FILE*
FICHIER DU NIVEAU DE LA MAREE FORMATE	*FORMATTED TIDAL WATER LEVEL FILE*
FICHIER FORMATE 1	*FORMATTED FILE 1*
FICHIER FORTRAN	*FORTRAN FILE*
FONCTION DE REPARTITION ANGULAIRE AUX LIMITES	*BOUNDARY ANGULAR DISTRIBUTION FUNCTION*
FONCTION DE REPARTITION ANGULAIRE INITIALE	*INITIAL ANGULAR DISTRIBUTION FUNCTION*
FORMAT DU FICHIER DE GEOMETRIE	*GEOMETRY FILE FORMAT*
FORMAT DU FICHIER DE DONNEES BINAIRE 1	*BINARY DATA FILE 1 FORMAT*
FORMAT DU FICHIER DE REFERENCE	*REFERENCE FILE FORMAT*
FORMAT DU FICHIER DE RESULTATS	*RESULTS FILE FORMAT*
FORMAT DU FICHIER DE SPECTRE	*SPECTRUM FILE FORMAT*
FORMAT DU FICHIER DES COURANTS	*CURRENTS FILE FORMAT*
FORMAT DU FICHIER DES VENTS	*WINDS FILE FORMAT*
FORMAT DU FICHIER DU CALCUL PRECEDENT	*PREVIOUS COMPUTATION FILE FORMAT*
FORMAT DU FICHIER DU NIVEAU DE LA MAREE	*TIDAL WATER LEVEL FILE FORMAT*
FREQUENCE DE PIC AUX LIMITES	*BOUNDARY PEAK FREQUENCY*
FREQUENCE DE PIC INITIALE	*INITIAL PEAK FREQUENCY*
FREQUENCE DE PIC MAXIMALE AUX LIMITES	*BOUNDARY MAXIMUM PEAK FREQUENCY*
FREQUENCE DE PIC MAXIMALE INITIALE	*INITIAL MAXIMUM PEAK FREQUENCY*
FREQUENCE MINIMALE	*MINIMAL FREQUENCY*
HAUTEUR SIGNIFICATIVE AUX LIMITES	*BOUNDARY SIGNIFICANT WAVE HEIGHT*
HAUTEUR SIGNIFICATIVE INITIALE	*INITIAL SIGNIFICANT WAVE HEIGHT*
LIMITEUR DE CROISSANCE	*WAVE GROWTH LIMITER*
LISSAGES DU FOND	*BOTTOM SMOOTHINGS*
LISTE DES FICHIERS	*LIST OF FILES*
LONGUEUR DU VECTEUR	*VECTOR LENGTH*
DENSITE DE LAIR	*AIR DENSITY*
DENSITE DE LEAU	*WATER DENSITY*
NOMBRE DE DIRECTIONS	*NUMBER OF DIRECTIONS*
NOMBRE DE FREQUENCES	*NUMBER OF FREQUENCIES*
NOMBRE DE PAS DE TEMPS	*NUMBER OF TIME STEP*
NOMBRE DE SOUS-ITERATIONS POUR LES TERMES SOURCES	*NUMBER OF ITERATIONS FOR THE SOURCE TERMS*
NOMBRE DE SOUS-PAS DE TEMPS POUR LE DEFERLEMENT	*NUMBER OF BREAKING TIME STEPS*
NOMBRE DE TABLEAUX PRIVES	*NUMBER OF PRIVATE ARRAYS*
NUMERO DE LA PREMIERE ITERATION POUR LES SORTIES GRAPHIQUES	*NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS*
NUMERO DE VERSION	*RELEASE*
NUMERO DU PAS DE TEMPS DU FICHIER TELEMAC	*TIME INCREMENT NUMBER IN TELEMAC FILE*
ORDONNEES DES POINTS DE SORTIE DU SPECTRE	*ORDINATES OF SPECTRUM PRINTOUT POINTS*
PARAMETRE DE LA CONFIGURATION STANDARD	*STANDARD CONFIGURATION PARAMETER*
PAS DE TEMPS	*TIME STEP*
PERIODE DACTUALISATION DE LA MAREE	*TIDE REFRESHING PERIOD*
PERIODE POUR LES SORTIES GRAPHIQUES	*PERIOD FOR GRAPHIC PRINTOUTS*
PERIODE POUR LES SORTIES LISTING	*PERIOD FOR LISTING PRINTOUTS*
PRISE EN COMPTE DE LA MAREE	*CONSIDERATION OF TIDE*
PRISE EN COMPTE DE LA PROPAGATION	*CONSIDERATION OF PROPAGATION*
PRISE EN COMPTE DES TERMES SOURCES	*CONSIDERATION OF SOURCE TERMS*

PRISE EN COMPTE DU VENT	*CONSIDERATION OF A WIND*
PRISE EN COMPTE DUN COURANT STATIONNAIRE	*CONSIDERATION OF A STATIONARY CURRENT*
PROCESSEURS PARALLELES	*PARALLEL PROCESSORS*
PROFONDEUR DEAU MINIMALE	*MINIMUM WATER DEPTH*
PROFONDEUR INFINIE	*INFINITE DEPTH*
RAISON FREQUENTIELLE	*FREQUENTIAL RATIO*
RANG DE LA DONNEE TELEMAC A RECUPERER	*RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED*
RANG DU NIVEAU DE LA MAREE DANS LE FICHIER TELEMAC	*RANK OF THE WATER LEVEL DATA IN THE TELEMAC FILE*
RECUPERATION DE DONNEE TELEMAC	*RECOVERY OF TELEMAC DATA ITEM*
SEUIL DENERGIE CONSIDERE POUR LE SPECTRE	*SPECTRUM ENERGY THRESHOLD*
SORTIE GLOBALE A LA FIN	*GLOBAL OUTPUT AT THE END*
SPECTRE AUX LIMITES MODIFIE PAR LUTILISATEUR	*LIMIT SPECTRUM MODIFIED BY USER*
SUITE DE CALCUL	*NEXT COMPUTATION*
TITRE	*TITLE*
TRANSFERTS ENTRE TRIPLETS DE FREQUENCES	*TRIAD INTERACTIONS*
TRANSFERTS NON LINEAIRES INTER-FREQUENCES	*NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES*
TRIADS 1 (LTA) CONSTANTE ALPHA	*TRIADS 1 (LTA) COEFFICIENT ALPHA*
TRIADS 1 (LTA) CONSTANTE RFMLTA	*TRIADS 1 (LTA) COEFFICIENT RFMLTA*
TRIADS 2 (SPB) BORNE DIRECTIONNELLE INFERIEURE	*TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY*
TRIADS 2 (SPB) BORNE DIRECTIONNELLE SUPERIEURE	*TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY*
TRIADS 2 (SPB) CONSTANTE K	*TRIADS 2 (SPB) COEFFICIENT K*
TYPE DE SPECTRE DIRECTIONNEL AUX LIMITES	*TYPE OF BOUNDARY DIRECTIONAL SPECTRUM*
TYPE DE SPECTRE DIRECTIONNEL INITIAL	*TYPE OF INITIAL DIRECTIONAL SPECTRUM*
VALEUR AUX LIMITES DE SIGMA-A POUR SPECTRE	*BOUNDARY SPECTRUM VALUE OF SIGMA-A*
VALEUR AUX LIMITES DE SIGMA-B POUR SPECTRE	*BOUNDARY SPECTRUM VALUE OF SIGMA-B*
VALEUR INITIALE DE SIGMA-A POUR SPECTRE	*INITIAL VALUE OF SIGMA-A FOR SPECTRUM*
VALEUR INITIALE DE SIGMA-B POUR SPECTRE	*INITIAL VALUE OF SIGMA-B FOR SPECTRUM*
VALEUR MAXIMALE DU RAPPORT HM0 SUR D	*MAXIMUM VALUE OF THE RATIO HM0 ON D*
VALEUR MOYENNE DU FETCH AUX LIMITES	*BOUNDARY MEAN FETCH VALUE*
VALEUR MOYENNE DU FETCH INITIAL	*INITIAL MEAN FETCH VALUE*
VALIDATION	*VALIDATION*
VARIABLES POUR LES SORTIES GRAPHIQUES 2D	*VARIABLES FOR 2D GRAPHIC PRINTOUTS*
VENT STATIONNAIRE	*STATIONARY WIND*
VITESSE DU VENT SUIVANT X	*WIND VELOCITY ALONG X*
VITESSE DU VENT SUIVANT Y	*WIND VELOCITY ALONG Y*

APPENDIX 6: English/French keyword dictionary

2D RESULTS FILE	*FICHIER DES RESULTATS 2D*
2D RESULTS FILE BINARY	*BINAIRE DU FICHIER DES RESULTATS 2D*
ABSCISSAE OF SPECTRUM PRINTOUT POINTS	*ABSCISSES DES POINTS DE SORTIE DU SPECTRE*
AIR DENSITY	*DENSITE DE LAIR*
BINARY CURRENTS FILE	*FICHIER DES COURANTS BINAIRE*
BINARY DATA FILE 1 FORMAT	*FORMAT DU FICHIER DE DONNEES BINAIRE 1*
BINARY FILE 1	*FICHIER BINAIRE 1*
BINARY FILE 1 BINARY	*BINAIRE DU FICHIER BINAIRE 1*
BINARY TIDAL WATER LEVEL FILE	*FICHIER DU NIVEAU DE LA MAREE BINAIRE*
BINARY WINDS FILE	*FICHIER DES VENTS BINAIRE*
BOTTOM FRICTION COEFFICIENT	*COEFFICIENT DE FROTTEMENT SUR LE FOND*
BOTTOM FRICTION DISSIPATION	*DISSIPATION PAR FROTTEMENT SUR LE FOND*
BOTTOM SMOOTHINGS	*LISSAGES DU FOND*
BOTTOM TOPOGRAPHY FILE	*FICHIER DES FONDS*
BOUNDARY ANGULAR DISTRIBUTION FUNCTION	*FONCTION DE REPARTITION ANGULAIRE AUX LIMITES*
BOUNDARY CONDITIONS FILE	*FICHIER DES CONDITIONS AUX LIMITES*
BOUNDARY DIRECTIONAL SPREAD 1	*ETALEMENT DIRECTIONNEL 1 AUX LIMITES*
BOUNDARY DIRECTIONAL SPREAD 2	*ETALEMENT DIRECTIONNEL 2 AUX LIMITES*
BOUNDARY MAIN DIRECTION 1	*DIRECTION PRINCIPALE 1 AUX LIMITES*
BOUNDARY MAIN DIRECTION 2	*DIRECTION PRINCIPALE 2 AUX LIMITES*
BOUNDARY MAXIMUM PEAK FREQUENCY	*FREQUENCE DE PIC MAXIMALE AUX LIMITES*
BOUNDARY MEAN FETCH VALUE	*VALEUR MOYENNE DU FETCH AUX LIMITES*
BOUNDARY PEAK FACTOR	*FACTEUR DE PIC AUX LIMITES*
BOUNDARY PEAK FREQUENCY	*FREQUENCE DE PIC AUX LIMITES*
BOUNDARY PHILLIPS CONSTANT	*CONSTANTE DE PHILLIPS AUX LIMITES*
BOUNDARY SIGNIFICANT WAVE HEIGHT	*HAUTEUR SIGNIFICATIVE AUX LIMITES*
BOUNDARY SPECTRUM VALUE OF SIGMA-A	*VALEUR AUX LIMITES DE SIGMA-A POUR SPECTRE*
BOUNDARY SPECTRUM VALUE OF SIGMA-B	*VALEUR AUX LIMITES DE SIGMA-B POUR SPECTRE*
BOUNDARY WEIGHTING FACTOR FOR ADF	*FACTEUR DE PONDERATION POUR FRA AUX LIMITES*
CHARNOCK CONSTANT	*CONSTANTE DE CHARNOCK*
COEFFICIENT OF THE TIME SUB-INCREMENTS FOR BREAKING	*COEFFICIENT POUR LES SOUS-PAS DE TEMPS POUR LE DEFERLEMENT*
CONSIDERATION OF A STATIONARY CURRENT	*PRISE EN COMPTE DUN COURANT STATIONNAIRE*
CONSIDERATION OF A WIND	*PRISE EN COMPTE DU VENT*
CONSIDERATION OF PROPAGATION	*PRISE EN COMPTE DE LA PROPAGATION*
CONSIDERATION OF SOURCE TERMS	*PRISE EN COMPTE DES TERMES SOURCES*
CONSIDERATION OF TIDE	*PRISE EN COMPTE DE LA MAREE*
CURRENTS FILE BINARY	*BINAIRE DU FICHIER DES COURANTS*
CURRENTS FILE FORMAT	*FORMAT DU FICHIER DES COURANTS*
DATE OF COMPUTATION BEGINNING	*DATE DE DEBUT DU CALCUL*
DEFAULT EXECUTABLE	*EXECUTABLE PAR DEFAUT*
DEFAULT PARALLEL EXECUTABLE	*EXECUTABLE PARALLELE PAR DEFAUT*
DEPTH-INDUCED BREAKING 1 (BJ) CHARACTERISTIC FREQUENCY	*DEFERLEMENT 1 (BJ) CHOIX FREQUENCE CARACTERISTIQUE*
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT ALPHA	*DEFERLEMENT 1 (BJ) CONSTANTE ALPHA*

DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA1	*DEFERLEMENT 1 (BJ) CONSTANTE GAMMA1*
DEPTH-INDUCED BREAKING 1 (BJ) COEFFICIENT GAMMA2	*DEFERLEMENT 1 (BJ) CONSTANTE GAMMA2*
DEPTH-INDUCED BREAKING 1 (BJ) HM COMPUTATION METHOD	*DEFERLEMENT 1 (BJ) MODE DE CALCUL DE HM*
DEPTH-INDUCED BREAKING 1 (BJ) QB COMPUTATION METHOD	*DEFERLEMENT 1 (BJ) MODE DE CALCUL DE QB*
DEPTH-INDUCED BREAKING 2 (TG) CHARACTERISTIC FREQUENCY	*DEFERLEMENT 2 (TG) CHOIX FREQUENCE CARACTERISTIQUE*
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT B	*DEFERLEMENT 2 (TG) CONSTANTE B*
DEPTH-INDUCED BREAKING 2 (TG) COEFFICIENT GAMMA	*DEFERLEMENT 2 (TG) CONSTANTE GAMMA*
DEPTH-INDUCED BREAKING 2 (TG) WEIGHTING FUNCTION	*DEFERLEMENT 2 (TG) FONCTION DE PONDERATION*
DEPTH-INDUCED BREAKING 3 (RO) CHARACTERISTIC FREQUENCY	*DEFERLEMENT 3 (RO) CHOIX FREQUENCE CARACTERISTIQUE*
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT ALPHA	*DEFERLEMENT 3 (RO) CONSTANTE ALPHA*
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA	*DEFERLEMENT 3 (RO) CONSTANTE GAMMA*
DEPTH-INDUCED BREAKING 3 (RO) COEFFICIENT GAMMA2	*DEFERLEMENT 3 (RO) CONSTANTE GAMMA2*
DEPTH-INDUCED BREAKING 3 (RO) EXPONENT WEIGHTING FUNCTION	*DEFERLEMENT 3 (RO) EXPOSANT FONCTION DE PONDERATION*
DEPTH-INDUCED BREAKING 3 (RO) WAVE HEIGHT DISTRIBUTION	*DEFERLEMENT 3 (RO) DISTRIBUTION DES HAUTEURS DE HOULE*
DEPTH-INDUCED BREAKING 4 (IH) CHARACTERISTIC FREQUENCY	*DEFERLEMENT 4 (IH) CHOIX FREQUENCE CARACTERISTIQUE*
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT BETA0	*DEFERLEMENT 4 (IH) CONSTANTE BETA0*
DEPTH-INDUCED BREAKING 4 (IH) COEFFICIENT M2STAR	*DEFERLEMENT 4 (IH) CONSTANTE M2STAR*
DEPTH-INDUCED BREAKING DISSIPATION	*DISSIPATION PAR DEFERLEMENT*
DESCRIPTION OF LIBRARIES	*DESCRIPTION DES LIBRAIRIES*
DICTIONARY	*DICTIONNAIRE*
FORMATTED CURRENTS FILE	*FICHIER DES COURANTS FORMATE*
FORMATTED FILE 1	*FICHIER FORMATE 1*
FORMATTED TIDAL WATER LEVEL FILE	*FICHIER DU NIVEAU DE LA MAREE FORMATE*
FORMATTED WINDS FILE	*FICHIER DES VENTS FORMATE*
FORTRAN FILE	*FICHIER FORTRAN*
FREQUENTIAL RATIO	*RAISON FREQUENTIELLE*
GEOMETRY FILE	*FICHIER DE GEOMETRIE*
GEOMETRY FILE BINARY	*BINAIRE DU FICHIER DE GEOMETRIE*
GEOMETRY FILE FORMAT	*FORMAT DU FICHIER DE GEOMETRIE*
GLOBAL OUTPUT AT THE END	*SORTIE GLOBALE A LA FIN*
GLOBAL RESULT FILE	*FICHIER DES RESULTATS GLOBAUX*
GLOBAL RESULT FILE BINARY	*BINAIRE DU FICHIER DES RESULTATS GLOBAUX*
IMPLICITATION COEFFICIENT FOR SOURCE TERMS	*COEFFICIENT IMPLICITATION POUR TERMES SOURCES*
INFINITE DEPTH	*PROFONDEUR INFINIE*
INITIAL ANGULAR DISTRIBUTION FUNCTION	*FONCTION DE REPARTITION ANGULAIRE INITIALE*
INITIAL DIRECTIONAL SPREAD 1	*ETALEMENT DIRECTIONNEL 1 INITIAL*
INITIAL DIRECTIONAL SPREAD 2	*ETALEMENT DIRECTIONNEL 2 INITIAL*
INITIAL MAIN DIRECTION 1	*DIRECTION PRINCIPALE 1 INITIALE*
INITIAL MAIN DIRECTION 2	*DIRECTION PRINCIPALE 2 INITIALE*
INITIAL MAXIMUM PEAK FREQUENCY	*FREQUENCE DE PIC MAXIMALE INITIALE*

INITIAL MEAN FETCH VALUE	*VALEUR MOYENNE DU FETCH INITIAL*
INITIAL PEAK FACTOR	*FACTEUR DE PIC INITIAL*
INITIAL PEAK FREQUENCY	*FREQUENCE DE PIC INITIALE*
INITIAL PHILLIPS CONSTANT	*CONSTANTE DE PHILLIPS INITIALE*
INITIAL SIGNIFICANT WAVE HEIGHT	*HAUTEUR SIGNIFICATIVE INITIALE*
INITIAL STILL WATER LEVEL	*COTE INITIALE DU PLAN DEAU AU REPOS*
INITIAL VALUE OF SIGMA-A FOR SPECTRUM	*VALEUR INITIALE DE SIGMA-A POUR SPECTRE*
INITIAL VALUE OF SIGMA-B FOR SPECTRUM	*VALEUR INITIALE DE SIGMA-B POUR SPECTRE*
INITIAL WEIGHTING FACTOR FOR ADF	*FACTEUR DE PONDERATION POUR FRA INITIALE*
LIMIT SPECTRUM MODIFIED BY USER	*SPECTRE AUX LIMITES MODIFIE PAR LUTILISATEUR*
LIST OF FILES	*LISTE DES FICHIERS*
MAXIMUM VALUE OF THE RATIO HM0 ON D	*VALEUR MAXIMALE DU RAPPORT HM0 SUR D*
MINIMAL FREQUENCY	*FREQUENCE MINIMALE*
MINIMUM WATER DEPTH	*PROFONDEUR DEAU MINIMALE*
NEXT COMPUTATION	*SUITE DE CALCUL*
NON-LINEAR TRANSFERTS BETWEEN FREQUENCIES	*TRANSFERTS NON LINEAIRES INTER-FREQUENCES*
NUMBER OF BREAKING TIME STEPS	*NOMBRE DE SOUS-PAS DE TEMPS POUR LE DEFERLEMENT*
NUMBER OF DIRECTIONS	*NOMBRE DE DIRECTIONS*
NUMBER OF FIRST ITERATION FOR GRAPHICS PRINTOUTS	*NUMERO DE LA PREMIERE ITERATION POUR LES SORTIES GRAPHIQUES*
NUMBER OF FREQUENCIES	*NOMBRE DE FREQUENCES*
NUMBER OF ITERATIONS FOR THE SOURCE TERMS	*NOMBRE DE SOUS-ITERATIONS POUR LES TERMES SOURCES*
NUMBER OF PRIVATE ARRAYS	*NOMBRE DE TABLEAUX PRIVES*
NUMBER OF TIME STEP	*NOMBRE DE PAS DE TEMPS*
ORDINATES OF SPECTRUM PRINTOUT POINTS	*ORDONNEES DES POINTS DE SORTIE DU SPECTRE*
PARALLEL PROCESSORS	*PROCESSEURS PARALLELES*
PERIOD FOR GRAPHIC PRINTOUTS	*PERIODE POUR LES SORTIES GRAPHIQUES*
PERIOD FOR LISTING PRINTOUTS	*PERIODE POUR LES SORTIES LISTING*
PREVIOUS COMPUTATION FILE	*FICHIER DU CALCUL PRECEDENT*
PREVIOUS COMPUTATION FILE BINARY	*BINAIRE DU FICHIER DU CALCUL PRECEDENT*
PUNCTUAL RESULTS FILE	*FICHIER DES RESULTATS PONCTUELS*
PUNCTUAL RESULTS FILE BINARY	*BINAIRE DU FICHIER DES RESULTATS PONCTUELS*
RANK OF THE TELEMAC DATA ITEM TO BE RECOVERED	*RANG DE LA DONNEE TELEMAC A RECUPERER*
RANK OF THE WATER LEVEL DATA IN THE TELEMAC FILE	*RANG DU NIVEAU DE LA MAREE DANS LE FICHIER TELEMAC*
RECOVERY OF TELEMAC DATA ITEM	*RECUPERATION DE DONNEE TELEMAC*
REFERENCE FILE FORMAT	*FORMAT DU FICHIER DE REFERENCE*
RELEASE	*NUMERO DE VERSION*
SHIFT GROWING CURVE DUE TO WIND	*DECALAGE COURBE DE CROISSANCE DUE AU VENT*
SPECTRUM FILE FORMAT	*FORMAT DU FICHIER DE SPECTRE*
SPECTRUM ENERGY THRESHOLD	*SEUIL DENERGIE CONSIDERE POUR LE SPECTRE*
SPECTRUM TAIL FACTOR	*FACTEUR DE QUEUE DU SPECTRE*
SPHERICAL COORDINATES	*COORDONNEES SPHERIQUES*
STANDARD CONFIGURATION PARAMETER	*PARAMETRE DE LA CONFIGURATION STANDARD*
STATIONARY WIND	*VENT STATIONNAIRE*
STEERING FILE	*FICHIER DES PARAMETRES*
TIDAL WATER LEVEL FILE BINARY	*BINAIRE DU FICHIER DU NIVEAU DE LA MAREE*

TIDAL WATER LEVEL FILE FORMAT	*FORMAT DU FICHIER DU NIVEAU DE LA MAREE*
TIDE REFRESHING PERIOD	*PERIODE DACTUALISATION DE LA MAREE*
TIME INCREMENT NUMBER IN TELEMAC FILE	*NUMERO DU PAS DE TEMPS DU FICHIER TELEMAC*
TIME STEP	*PAS DE TEMPS*
TITLE	*TITRE*
TRIAD INTERACTIONS	*TRANSFERTS ENTRE TRIPLETS DE FREQUENCES*
TRIADS 1 (LTA) COEFFICIENT ALPHA	*TRIADS 1 (LTA) CONSTANTE ALPHA*
TRIADS 1 (LTA) COEFFICIENT RFMLTA	*TRIADS 1 (LTA) CONSTANTE RFMLTA*
TRIADS 2 (SPB) COEFFICIENT K	*TRIADS 2 (SPB) CONSTANTE K*
TRIADS 2 (SPB) LOWER DIRECTIONAL BOUNDARY	*TRIADS 2 (SPB) BORNE DIRECTIONNELLE INFERIEURE*
TRIADS 2 (SPB) UPPER DIRECTIONAL BOUNDARY	*TRIADS 2 (SPB) BORNE DIRECTIONNELLE SUPERIEURE*
TRIGONOMETRICAL CONVENTION	*CONVENTION TRIGONOMETRIQUE*
TYPE OF BOUNDARY DIRECTIONAL SPECTRUM	*TYPE DE SPECTRE DIRECTIONNEL AUX LIMITES*
TYPE OF INITIAL DIRECTIONAL SPECTRUM	*TYPE DE SPECTRE DIRECTIONNEL INITIAL*
VALIDATION	*VALIDATION*
VALIDATION FILE	*FICHIER DE REFERENCE*
VARIABLES FOR 2D GRAPHIC PRINTOUTS	*VARIABLES POUR LES SORTIES GRAPHIQUES 2D*
VECTOR LENGTH	*LONGUEUR DU VECTEUR*
VON KARMAN CONSTANT	*CONSTANTE DE VON KARMAN*
WATER DENSITY	*DENSITE DE LEAU*
WAVE GROWTH LIMITER	*LIMITEUR DE CROISSANCE*
WHITE CAPPING DISSIPATION	*DISSIPATION PAR MOUTONNEMENT*
WHITE CAPPING DISSIPATION COEFFICIENT	*COEFFICIENT DE DISSIPATION PAR MOUTONNEMENT*
WHITE CAPPING WEIGHTING COEFFICIENT	*COEFFICIENT DE PONDERATION POUR LE MOUTONNEMENT*
WIND DRAG COEFFICIENT	*COEFFICIENT DE TRAINEE DE VENT*
WIND GENERATION	*APPORTS DUS AU VENT*
WIND GENERATION COEFFICIENT	*COEFFICIENT DE GENERATION PAR LE VENT*
WIND MEASUREMENTS LEVEL	*COTE DE MESURE DES VENTS*
WIND VELOCITY ALONG X	*VITESSE DU VENT SUIVANT X*
WIND VELOCITY ALONG Y	*VITESSE DU VENT SUIVANT Y*
WINDS FILE BINARY	*BINAIRE DU FICHIER DES VENTS*
WINDS FILE FORMAT	*FORMAT DU FICHIER DES VENTS*

APPENDIX 7: Output variables of TOMAWAC V6P0

N°	Symbol	Description of the variable	Unit	Output name
1	**M0**	Variance of the sea state m_o (moment of order 0 of the wave spectrum). $m_0 = \int_0^\infty \int_0^{2\pi} F(f,\theta)\, df\, d\theta = \int_0^\infty S(f)\, df$	m^2	VARIANCE M0
2	**HM0**	Spectral significant wave height H_{mo} $H_{mo} = 4\sqrt{m_0}$	m	WAVE HEIGHT HM0
3	**DMOY**	Mean wave direction θ_m with respect to the North or to the X axis depending on the adopted choice. $\theta_m = \mathrm{Arc\,tan}(\frac{b}{a}) * (180/\pi)$ $a = \frac{\int_0^\infty \int_0^{2\pi} \cos(\theta)\, F(f,\theta)\, df\, d\theta}{m_o}$ $b = \frac{\int_0^\infty \int_0^{2\pi} \sin(\theta)\, F(f,\theta)\, df\, d\theta}{m_o}$	deg.	MEAN DIRECTION
4	**SPD**	Mean angular spreading σ of the directional wave spectrum. $\sigma = \sqrt{2\left(1-\sqrt{a^2+b^2}\right)} * (180/\pi)$	deg.	WAVE SPREAD
5	**ZF**	Sea bottom elevation.	m	BOTTOM
6	**WD**	Water depth.	m	WATER DEPTH
7	**UX**	Component along X axis of the marine flow velocity vector (input data)	m/s	VELOCITY U
8	**UY**	Component along Y axis of the marine flow velocity vector (input data)	m/s	VELOCITY V
9	**VX**	Component along X axis of the wind velocity vector (input data)	m/s	WIND ALONG X
10	**VY**	Component along Y axis of the wind velocity vector (input data)	m/s	WIND ALONG Y
11	**FX**	Component along X axis of the radiation force due to waves.	m/s^2	FORCE FX
12	**FY**	Component along Y axis of the radiation force due to waves.	m/s^2	FORCE FY
13	**SXX**	Component Sxx of the radiation stress tensor.	m^3/s^2	STRESS SXX
14	**SXY**	Component Sxy of the radiation stress tensor.	m^3/s^2	STRESS SXY
15	**SYY**	Component Syy of the radiation stress tensor.	m^3/s^2	STRESS SYY
16	**UWB**	Mean orbital wave velocity at the bottom.	m/s	BOTTOM VELOCITY
17	**PRI**	« Private » variable as chosen by the user.	(user)	PRIVATE 1

N°	Symbol	Description of the variable	Unit	Output name
18	**FMOY**	Mean wave frequency, computed from the moments of order -1 and 0 of the wave spectrum. $$f_{moy} = f_{-10} = \left(\frac{m_{-1}}{m_0}\right)^{-1} = \left(\frac{\int_0^\infty \frac{S(f)}{f}\,df}{\int_0^\infty S(f)\,df}\right)^{-1}$$	Hz	MEAN FREQ FMOY
19	**FM01**	Mean wave frequency, computed from the moments of order 0 and 1 of the wave spectrum. $$f_{01} = \frac{m_1}{m_0} = \frac{\int_0^\infty f.S(f)\,df}{\int_0^\infty S(f)\,df}$$	Hz	MEAN FREQ FM01
20	**FM02**	Mean wave frequency, computed from the moments of order 0 and 2 of the wave spectrum. $$f_{02} = \sqrt{\frac{m_2}{m_0}} = \sqrt{\frac{\int_0^\infty f^2.S(f)\,df}{\int_0^\infty S(f)\,df}}$$	Hz	MEAN FREQ FM02
21	**FPD**	Discrete peak frequency (among the frequencies used to discretise the spectrum).	Hz	PEAK FREQ FPD
22	**FPR5**	Peak frequency computed by the Read method of order 5. $$f_{pR5} = \frac{\int_0^\infty f.S^5(f)\,df}{\int_0^\infty S^5(f)\,df}$$	Hz	PEAK FREQ FPR5
23	**FPR8**	Peak frequency computed by the Read method of order 8. $$f_{pR8} = \frac{\int_0^\infty f.S^8(f)\,df}{\int_0^\infty S^5(f)\,df}$$	Hz	PEAK FREQ FPR8
24	**US**	Surface friction velocity u*.	m/s	USTAR
25	**CD**	Surface drag coefficient C_D.	-	CD
26	**Z0**	Surface roughness length z_o.	m	Z0
27	**WS**	Surface stress due to waves.	$kg/(m.s^2)$	WAVE STRESS

N°	Symbol	Description of the variable	Unit	Output name
28	**TMOY**	Mean wave period, computed from the moments of order -1 and 0 of the wave spectrum. $T_{moy} = T_{-10} = \frac{m_{-1}}{m_0} = \frac{\int_0^\infty T.S(f)\,df}{\int_0^\infty S(f)\,df}$	s	MEAN PERIOD TMOY
29	**TM01**	Mean wave period, computed from the moments of order 0 and 1 of the wave spectrum. $T_{01} = \frac{1}{f_{01}}$	s	MEAN PERIOD TM01
30	**TM02**	Mean wave period, computed from the moments of order 0 and 2 of the wave spectrum. $T_{02} = \frac{1}{f_{02}}$	s	MEAN PERIOD TM02
31	**TPD**	Discrete peak period. $T_{pD} = \frac{1}{f_{pD}}$	s	PEAK PERIOD TPD
32	**TPR5**	Peak period computed by the Read method of order 5. $T_{pR5} = \frac{1}{f_{pR5}}$	s	PEAK PERIOD TPR5
33	**TPR8**	Peak period computed by the Read method of order 8. $T_{pR8} = \frac{1}{f_{pR8}}$	s	PEAK PERIOD TPR8
34	**POW**	Unit wave power rate (per meter of crest length).	kW/m	WAVE POWER
	BETA	Breaking wave coefficient	-	BETA

APPENDIX 8: Description of the formats being used

SERAFIN-formatted file

It is a binary file. This format is used for the *2D RESULTS FILE*, the *CURRENTS FILE FORMAT* (format 3) and the *WINDS FILE FORMAT* (format 3).
The list of records is as follows:

- a record including the study title (80 digits),
- a record including the pair of integers `NBV(1)` and `NBV(2)` (number of variables of linear and quadratic discretisations, `NBV(2)` being 0),
- `NBV(1) + NBV(2)` records including (in 32 digits) each variable's name and unit,
- a record including the integers 1,0,0,0,0,0,0,0,0,0 (10 integers, only the first and the last one of which are presently used). If the last integer is equal to one, the record is followed by another record made of 6 integers indicating the date of computation beginning (year, month, day, hour, minute and second),
- a record including the integers `NELEM,NPOIN,NDP`,1 (number of elements, number of points, number of points per element and the value 1),
- a record including the integer array `IKLE` ((`NDP,NELEM`)-dimensioned array), the connectivity table. WARNING: the dimensions of this array are (`NELEM,NDP`) in TOMAWAC),
- a record including the integer array `IPOBO` (`NPOIN`-dimensioned array). An item value is 0 for an inner point, and provides the edge point numbers for the others),
- a record including the `X` real array (`NPOIN`-dimensioned array of point abscissae),
- a record including the `Y` real array (`NPOIN` -dimensioned array of point ordinates),

The following can then be found for each time step:

- a record including time `T` (real),
- `NBV(1)+NBV(2)` records including the results arrays for each variable at time `T`.

TOMAWAC-formatted file

It is a binary file. That format is used for the *PREVIOUS COMPUTATION FILE* and the *GLOBAL RESULT FILE*
The list of records is as follows:

- a record including the study title (80 digits).
- a record including the pair of integers NPLAN and NF corresponding respectively to the number of propagation directions and the number of frequencies.
- a record including the pair of integers NELEM2 and NPOIN2 corresponding respectively to the numbers of elements and 2D points.
- a record including end-of-computation time t (real).
- a record including the NPLAN-dimensioned real array TETA (directions of propagation, as expressed in radians).
- a record including the NF-dimensioned real array FREQ (propagation frequencies, as expressed in Hz).
- a record including the NPOIN*NPLAN*NF –dimensioned real area F (directional spectrum of wave action) at time t.

When a current is taken into account, then one can find:

- a record including the NPOIN–dimensioned real array UC (component of current along X) upon time t.
- a record including the NPOIN–dimensioned real array VC (component of current along Y) at time t.

When a wind is taken into account, then one can find:

- a record including the NPOIN–dimensioned real array UV (component of wind along X) at time t.
- a record including the NPOIN–dimensioned real array VV (component of wind along Y) at time t.

When the tide is taken into account, then one can find:

- a record including the NPOIN–dimensioned real array DEPTH at time t.

VENTS-WAM-Cycle 4-formatted file

It is a formatted file. This format is used for the *WINDS FILE* when *WINDS FILE FORMAT* is set to 1.
The list of records is as follows:

- 1- Winds grid input dimensions:

`KCOL, KROW, RLATS, RLATN, RLONL, RLONR, ICOORD, IWPER`

Read with the format `(2I4,4F9.3,2I2)`
`KCOL:` Number of longitudes in the winds grid
`KROW:` Number of latitudes in the winds grid
`RLATS:` Latitude of southern grid boundary (degrees)
`RLATN:` Latitude of northern grid boundary (degrees)
`RLONL:` Longitude of western grid boundary (degrees)
`RLONR:` Longitude of eastern grid boundary (degrees)
`ICOORD:` Code of coordinates (`ICOORD=1` **mandatory**)
`IWPER:` Code of periodicity (`IWPER=0` **mandatory**)

The latitude and longitude increments are respectively computed by:

```
DPHI = (RLATN-RLATS)/(KROW-1)
DLAM = (RLONR-RLONL)/(KCOL-1)
```

Subsequently, for each wind field date:

- 2- Wind field date:

`IDTWIR` read with format `(I10)`
WAM-formatted wind field date WAM (`yymmddhhmm`)

3- Horizontal (W-E) wind components at the grid points:

`ICODE` read with format `(I2)`
Input field type flag
1: friction velocities
2: surface stresses
3: wind velocities at 10 m

`(UWND(ILON,ILAT), (ILON=1,KCOL), ILAT=1,KROW)`
read with format `(10F6.2)`
Horizontal (W-E) component value

- 4- Vertical (S-N) wind components at the grid points:

`KCODE` read with format `(I2)`
Input field type flag
`KCODE` should be equal to ICODE.

`(VWND(ILON,ILAT), (ILON=1,KCOL), ILAT=1,KROW)`
read with format `(10F6.2)`
Vertical (S-N) component value

The longitudes are scanned from the West eastwards and the latitudes from the South northwards

"finite differences" type- formatted file

It is a formatted file. That file is possibly used for the *FORMATTED CURRENTS FILE*, the *FORMATTED WINDS FILE* or the *FORMATTED TIDAL WATER LEVEL FILE* when the option 1 is chosen for the format.
The list of records is as follows:

- a record including eight integers `NCOL, NLIG, YMIN, YMAX, XMIN, XMAX, BID1` and `BID`. These variables respectively correspond to the number of columns, the lines of the mesh, the minimum and maximum ordinates, the minimum and maximum abscissae of the mesh, followed by 2 variables that are left unused by TOMAWAC.
- an empty record
- a record including the first component of the variable to be retrieved (for example Ux)
- a record including, if any, the second component of the variable to be retrieved (for example Uy)

SINUSX -formatted file

This format is used for the *BOTTOM TOPOGRAPHY FILE* and possibly for the *CURRENTS FILE* when *CURRENTS FILE FORMAT* is set to 2.
It is a quite simple format, consisting in successive records of the `X, Y, ZF` type for the bottom topography file and of the `X, Y, UC, VC` type for the currents file.

APPENDIX 9: File structure and processing

All files in the Serafin format may now be built in 3 different formats (given in 8 characters):

'SERAFIN ': old format, understood by Rubens
'SERAFIND': the same in double precision, not understood by Rubens
'MED ': understood by the Salomé Platform.

Consequently, for every previous Serafin file called "NAME-OF-FILE", a key-word "NAME-OF-FILE FORMAT" has been added. In French "FORMAT DU FICHIER DE …".

For simplifying the implementation of this new possibility, as well as simplifying the coupling between programmes, a new file structure has been added to library BIEF. The goal is to store all the information related to a file in a single structure. The previous names of logical units and file names, such as NGEO, NRES,… and NOMGEO, NOMRES,… have been replaced by this new structure. It concerns ALL the files, not only the Serafin format. As a consequence, all the subroutines reading or writing to files have been modified.

More details are given here below.

<u>Structure of files</u>
The new Fortran 90 structure for files is as follows:

```
C
C==============================================================
==========
C
C STRUCTURE OF FILE
C
C==============================================================
==========
C
  TYPE BIEF_FILE
C
C   LU: LOGICAL UNIT TO OPEN THE FILE
   INTEGER LU
C
C   NAME: NAME OF FILE
   CHARACTER(LEN=144) NAME
C
C   TELNAME: NAME OF FILE IN TEMPORARY DIRECTORY
   CHARACTER(LEN=6) TELNAME
C
C   FMT: FORMAT (SERAFIN, MED, ETC.)
   CHARACTER(LEN=8) FMT
C
C   ACTION: READ, WRITE OR READWRITE
   CHARACTER(LEN=9) ACTION
```

```
C
C    BINASC: ASC FOR ASCII OR BIN FOR BINARY
   CHARACTER(LEN=3) BINASC
C
C    TYPE: KIND OF FILE
   CHARACTER(LEN=12) TYPE
C
  END TYPE BIEF_FILE
```

Inputs and outputs: opening and closing files

The various data and results files of TOMAWAC are described in its dictionary. The information relevant to files will be read with the subroutine READ_SUBMIT, which is called in subroutine LECDON_TOMAWAC, and stored in an array of file structures (called, WAC_FILES). Hereafter is given an excerpt of TOMAWAC dictionary regarding the results file:

```
NOM = 'FICHIER DES RESULTATS 2D'
NOM1 = '2D RESULTS FILE'
TYPE = CARACTERE
INDEX = 08
MNEMO = ‘WAC_FILES(WACRES)%NAME'
SUBMIT = 'WACRES-READWRITE-08;WACRES;OBLIG;BIN;ECR;SELAFIN'
DEFAUT = ' '
DEFAUT1 = ' '
```

The character string called SUBMIT is used both by the perl scripts and, through Damocles, by the Fortran programme. It is composed of 6 character strings.
The first string, here WACRES-READWRITE-08, is made of:

1) the fortran integer for storing the file number: WACRES (which is declared in declarations_telemac2d.f)
2) the argument ACTION in the Fortran Open statement that will be used to open the file. ACTION may be READ, WRITE, or READWRITE. Here it is READWRITE because the results file is written, and in case of validation it is read at the end of the computation. It will be stored into WAC_FILES(WACRES) %ACTION
3) the logical unit to open the file. This a priori value may be changed in case of code coupling. It is stored into WAC_FILES(WACRES) %LU

The **second** string, here WACRES, is the name of the file as it will appear in the temporary file where the computation is done.

The **third** string may be OBLIG (the name of the file must always be given), or FACUL (this file is not mandatory).

The **fourth** string (here BIN) says if it is a binary (BIN) or ASCII (ASC) file.

The **fifth** string is just like the READWRITE statement and is used by the perl scripts.

The **sixth** string is also used by the perl scripts and gives information on how the file must be treated. ‘SELAFIN’ means that the file is a Selafin format, it will have to be decomposed if parallelism is used. Other possibilities are:

SELAFIN-GEOM: this is the geometry file
FORTRAN: this is the Fortran file for user subroutines
CAS: this is the parameter file
CONLIM: this is the boundary conditions file
PARAL: this file will have an extension added to its name, for distinguishing between processors
DICO: this is the dictionary
SCAL: this file will be the same for all processors

The following sequence of subroutines is used for opening, using and closing files:
Note: subroutine INIT_FILES2 in BIEF version 5.9 has been renamed BIEF_INIT in version 6.0 and has from now on nothing to see with files.

1) opening files

```
IFLOT=0
CALL
BIEF_OPEN_FILES(CODE,WAC_FILES,44,PATH,NCAR,COUPLAGE,IFLOT,ICO
DE)
```

CODE: name of calling program in 24 characters
WAC_FILES: the array of BIEF_FILE structures
44: the size of the previous array
PATH: full name of the path leading to the directory the case is
NCAR: number of characters of the string PATH
COUPLAGE: logical stating if there is a coupling between several programs.
IFLOT: in case of coupling, will be the last logical unit taken by a file
ICODE: code number in a coupling. For example in a coupling between Telemac-2D and Sisyphe, Telemac-2D will be code 1 and Sisyphe will be code 2.

2) using files:

Most operations on files consist on reading and writing, which always uses the logical unit. Every file has a name in the temporary folder where the program is executed, e.g. WACRES. The associated file number is an integer with the same name. The logical unit of this file will be equal to WACRES if there is no coupling, but more generally it is stored into WAC_FILES(WACRES)%LU. The logical unit of the geometry file in Sisyphe will be SIS_FILES(SISGEO)%LU.
Sometimes the real name of files in the original is also used, for example to know if it exists (= has been given in the parameter file). This name is retrieved in the component NAME. For example the name of the geometry file in Sisyphe will be SIS_FILES(SISGEO)%NAME.

3) closing files:

```
CALL BIEF_CLOSE_FILES(CODE,WAC_FILES,44,PEXIT)
```

CODE: name of calling program in 24 characters
WAC_FILES: the array of BIEF_FILE structures

44: the size of the previous array
PEXIT: logical, if yes will stop parallelism (in a coupling the last program calling BIEF_CLOSE_FILES will also stop parallelism).

APPENDIX 10: parallel computing in TOMAWAC

This document presents some basic concepts about the parallelism in TOMAWAC. It does not describe the parallel algorithm.

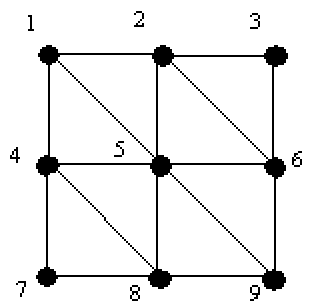
The parallelism in TOMAWAC is based on the message passing paradigm in order to run on a distributed memory architecture. The MPI library is used to manage the communication between parallel processors. Each MPI processor performs operations on its local memory independently from the other ones. The synchronisation and the data transfer between MPI processors are realized by sending or receiving messages.

Suppose that the parallel computing is performed on *n* MPI processus. The user has to add the following statement in the steering file:

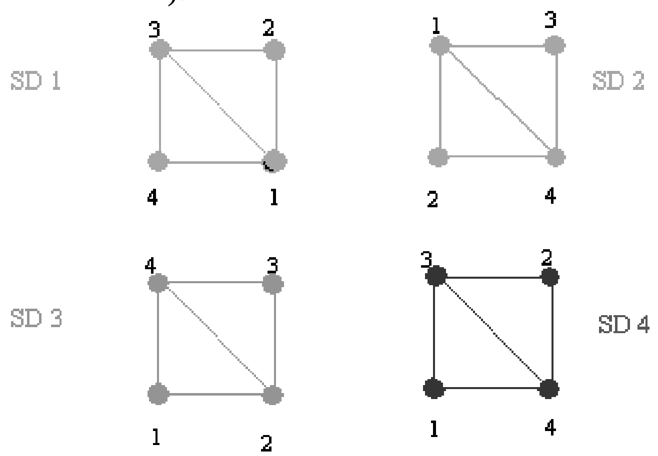
`PARALLEL PROCESSORS = n`

The domain (the finite element mesh) is split into *n* nonoverlapping subdomains. Each subdomain is assigned to a single MPI processor; in other words there is only one subdomain per MPI processor. The mesh partitioning is ensured by the PARTEL program included in the TELEMAC system. It generates the *n* local geometries and the boundary condition files required by the *n* MPI processus.

Let's consider a finite element mesh having 8 finite elements and 9 nodes



and suppose that the PARTEL program produces this following mesh partitionning (partition into 4 subdomains SD1 to SD4):



One could remark that a node does not have necessarily the same number in the global finite element mesh and in each subdomain. The node number in the global mesh is called global number whereas the node number in a subdomain is called local number.

Two arrays (`knogl` and `knolg`) are used to link the global numbering and the local numbering:

`knogl(k)=j` indicates that the local number of the node having global number k is j ("gl" means global numbering to local numbering, `knogl(k)=0` indicates that the node having global number k does not belong to the subdomain);
`knolg(j)=k` indicates that the global number of the node having local number j is k in the global mesh ("lg" means global numbering to local numbering) .

Note that these arrays are different among subdomains. For example, these arrays contain for subdomain SD 1:

j	**1**	**2**	**3**	**4**
knolg(j)	5	2	1	4

k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
knogl(k)	3	2	0	4	1	0	0	0	0

and for subdomain SD 2 :

j	**1**	**2**	**3**	**4**
knolg(j)	2	5	3	6

k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
knogl(k)	0	1	3	0	2	4	0	0	0

It is important to understand that the global numbering does not exist in parallel: the user files **need to be modified** if global node numbering is used. Suppose that in the user file there is the following instruction:

```
c The D-value  is set to 0.0 for  the node number 200
D(200)=0.0
```

This instruction needs to be rewritten as follows to be used both in sequential or in parallel:

```
IF (NCSIZE.GE.1) THEN
c NCSIZE is the number of MPI processus, so if NCSIZE > 1, the
c code runs in parallel
     IF (KNOGL(100) .NE. 0) THEN
c the node having global number 100 belongs to the subdomain
          D(KNOGL(100))=0.0
     END IF
ELSE
c here the code runs in sequential
     D(100)=0.0
END IF
```

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