SWAN

USER MANUAL

SWAN Cycle III version 41.51

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Contents

Chapter 1

About this manual

The information about the SWAN package is distributed over four different documents. This User Manual describes the specifications for the input of the model. The Implementation Manual explains the installation procedure and the usage of SWAN on a single- or multi-processor machine with shared or distributed memory. The Programming rules is meant for programmers who want to develop SWAN. The Scientific/Technical documentation discusses the physical and mathematical details and the discretizations that have been implemented in the SWAN program.

In Chapter 2 general description of the model and some instructions concerning the usage of SWAN, the treatment of grids, boundary conditions, etc. is given. It is advised to read this chapter before consulting the rest of the manual. Chapter 3 gives some remarks concerning the input and output files of SWAN. Chapter 4 describes the complete set of commands of the program SWAN.

Before start using the SWAN package, it is suggested to first read Chapters 2 and 3.

This Manual also contains some appendices. In Appendix A definitions of several output parameters are given. Appendix B outlines the syntax of the command file (or input file). A complete set of all the commands use in SWAN can be found in Appendix C. Appendix D described the format of the files for spectral input and output by SWAN.

Chapter 2

General description and instructions for use

2.1 Introduction

The purpose of this chapter is to give some general advice in choosing the basic input for SWAN computations.

SWAN is a third-generation wave model for obtaining realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom and current conditions. However, SWAN can be used on any scale relevant for wind-generated surface gravity waves. The model is based on the wave action balance equation with sources and sinks.

An important question addressed is how to choose various grids in SWAN (resolution, orientation, etc.) including nesting. In general, we consider two types of grids: structured and unstructured. Structured grids may be rectilinear and uniform or curvilinear. They always consist of quadrilaterals in which the number of grid cells that meet each other in an internal grid point is 4. In unstructured grids, this number can be arbitrarily (usually between 4 and 10). For this reason, the level of flexibility with respect to the grid point distribution of unstructured grids is far more optimal compared to structured grids. Unstructured grids may contain triangles or a combination of triangles and quadrilaterals (so-called hybrid grids). In the current version of SWAN, however, only triangular meshes can be employed.

Often, the characteristic spatial scales of the wind waves propagating from deep to shallow waters are very diverse and would required to allow local refinement of the mesh near the coast without incurring overhead associated with grid adaptation at some distance offshore. Traditionally, this can be achieved by employing a nesting approach.

The idea of nesting is to first compute the waves on a coarse grid for a larger region and then on a finer grid for a smaller region. The computation on the fine grid uses boundary conditions that are generated by the computation on the coarse grid. Nesting can be

repeated on ever decreasing scales using the same type of coordinates for the coarse computations and the nested computations (Cartesian or spherical). Note that curvilinear grids can be used for nested computations but the boundaries should always be rectangular.

The use of unstructured grids in SWAN offers a good alternative to nested models not only because of the ease of optimal adaption of mesh resolution but also the modest effort needed to generate grids about complicated geometries, e.g. islands and irregular shorelines. This type of flexible meshes is particularly useful in coastal regions where the water depth varies greatly. As a result, this variable spatial meshing gives the highest resolution where it is most needed. The use of unstructured grids facilitates to resolve the model area with a relative high accuracy but with a much fewer grid points than with regular grids.

It must be pointed out that the application of SWAN on ocean scales is not recommended from an efficiency point of view. The WAM model and the WAVEWATCH III model, which have been designed specifically for ocean applications, are probably one order of magnitude more efficient than SWAN. SWAN can be run on large scales (much larger than coastal scales) but this option is mainly intended for the <u>transition</u> from ocean scales to coastal scales (transitions where nonstationarity is an issue and spherical coordinates are convenient for nesting).

A general suggestion is: <u>start simple</u>. SWAN helps in this with default options. Furthermore, suggestions are given that should help the user to choose among the many options conditions and in which mode to run SWAN (first-, second- or third-generation mode, stationary or nonstationary and 1D or 2D).

2.2   Limitations

The DIA approximation for the **quadruplet wave-wave interactions** depends on the width of the directional distribution of the wave spectrum. It seems to work reasonably in many cases but it is a poor approximation for long-crested waves (narrow directional distribution). It also depends on the frequency resolution. It seems to work reasonably in many cases but it is a poor approximation for frequency resolutions with ratios very different from 10% (see command `CGRID`). This is a fundamental problem that SWAN shares with other third-generation wave models such as WAM and WAVEWATCH III.

The LTA approximation for the **triad wave-wave interactions** depends on the width of the directional distribution of the wave spectrum. The present tuning in SWAN (the default settings, see command `TRIAD`) seems to work reasonably in many cases but it has been obtained from observations in a narrow wave flume (long-crested waves).

As an option SWAN computes **wave-induced set-up**. In 1D cases the computations are based on exact equations. In 2D cases, the computations are based on approximate equations. This approximation in SWAN can <u>only</u> be applied to open coast (unlimited supply

of water from outside the domain, e.g. nearshore coasts and estuaries) in contrast to closed basin, e.g. lakes, where this option should not be used. The effects of wave-induced currents are always ignored.

SWAN does not calculate **wave-induced currents**. If relevant, such currents should be provided as input to SWAN, e.g. from a circulation model which can be driven by waves from SWAN in an iteration procedure.

In areas where variations in wave height are large within a horizontal scale of a few wave lengths, **diffraction** should be used. However, the computation of diffraction in arbitrary geophysical conditions is rather complicated and requires considerable computing effort. To avoid this, a phase-decoupled approach is employed in SWAN so that same qualitative behaviour of spatial redistribution and changes in wave direction is obtained. This approach, however, does not properly handle diffraction in harbours or in front of reflecting obstacles.

SWAN can be used on **any scale** relevant for wind generated surface gravity waves. However, SWAN is specifically designed for coastal applications that should actually not require such flexibility in scale. The reasons for providing SWAN with such flexibility are:

- to allow SWAN to be used from laboratory conditions to shelf seas and

- to nest SWAN in the WAM model or the WAVEWATCH III model which are formulated in terms of spherical coordinates.

Nevertheless, these facilities are not meant to support the use of SWAN on oceanic scales because SWAN is less efficient on oceanic scales than WAVEWATCH III and probably also less efficient than WAM.

2.3 Internal scenarios, limiters, shortcomings and coding bugs

Sometimes the user input to SWAN is such that SWAN produces unreliable and sometimes even unrealistic results. This may be the case if the bathymetry or the wave field is not well resolved. Be aware here that the grid on which the computations are performed interpolates from the grids on which the input is provided; different resolutions for these grids (which are allowed) can therefore create unexpected interpolation patterns on the computational grid. In such cases SWAN may invoke some **internal scenarios** or **limiters** instead of terminating the computations. The reasons for this model policy is that

- SWAN needs to be robust, and

- the problem may be only very local, or

- the problem needs to be fully computed before it can be diagnosed.

Examples are:

- The user can request that <u>refraction</u> over one spatial grid step is limited to at most the length of a directional sector associated with one sweep (which in the absence of a current is 90°). See command `NUMERIC`. This may be relevant when the depth varies considerably over one spatial grid step (e.g. at the edge of oceans or near oceanic islands with only one or two grid steps to go from oceanic depths to a shallow coast). This implies inaccurate refraction computations in such grid steps. This may be acceptable when refraction has only local effects that can be ignored but, depending on the topography, the inaccurately computed effects may radiate far into the computational area.

- SWAN cannot handle wave propagation on <u>super-critical current flow</u>. If such flow is encountered during SWAN computations, the current is locally reduced to sub-critical flow.

- If the <u>water depth</u> is less than some user-provided limit, the depth is set at that limit (default is 0.05 m, see command `SET`).

- The <u>user-imposed wave boundary conditions</u> may not be reproduced by SWAN, as SWAN replaces the *imposed* waves at the boundaries that propagate into the computational area with the *computed* waves that move out of the computational area at the boundaries.

- SWAN may have <u>convergence</u> problems. There are three iteration processes in SWAN:

  1. an iteration process for the spatial propagation of the waves,
  2. if ambient currents are present, an iteration process for spectral propagation (current-induced refraction and frequency shift) and
  3. if wave-induced set-up is requested by the user, an iteration process for solving the set-up equation.

  ad 1 For spatial propagation the change of the wave field over one iteration is limited to some realistic value (usually several iterations for stationary conditions or one iteration or upgrade per time step for nonstationary conditions; see command `NUMERIC`). This is a common problem for all third-generation wave models (such as WAM, WAVEWATCH III and also SWAN). It does not seem to affect the result seriously in many cases but sometimes SWAN fails to converge properly.

  For curvilinear grids, convergence problems may occur locally where in some points in the grid, the directions separating the 4 sweeping quadrants coincide with the given spectral directions.

  ad 2 For spectral propagation (but only current-induced refraction and frequency shift) SWAN may also not converge.

ad 3 For the wave-induced set-up SWAN may also not converge.

Information on the actual convergence of a particular SWAN run is provided in the `PRINT` file.

Some other problems which the SWAN user may encounter are due to more **fundamental shortcomings** of SWAN (which may or may not be typical for third-generation wave models) and unintentional **coding bugs**.

Because of the issues described above, the results may look realistic, but they may (locally) not be accurate. Any change in these scenarios, limiters or shortcomings, in particular newly discovered coding bugs and their fixes, are published on the SWAN web site and implemented in new releases of SWAN.

2.4 Relation to WAM, WAVEWATCH III and others

The basic scientific philosophy of SWAN is identical to that of WAM (Cycle 3 and 4). SWAN is a third-generation wave model and it uses the same formulations for the source terms (although SWAN uses the adapted code for the DIA technique). On the other hand, SWAN contains some additional formulations primarily for shallow water. Moreover, the numerical techniques are very different. WAVEWATCH III not only uses different numerical techniques but also different formulations for the wind input and the whitecapping.

This close similarity can be exploited in the sense that

- scientific findings with one model can be shared with the others and

- SWAN can be readily nested in WAM and WAVEWATCH III (the formulations of WAVEWATCH III have not yet been implemented in SWAN).

When SWAN is nested in WAM or WAVEWATCH III, it must be noted that the boundary conditions for SWAN provided by WAM or WAVEWATCH III may not be model consistent even if the same physics are used. The potential reasons are manifold such as differences in numerical techniques employed and implementation for the geographic area (spatial and spectral resolutions, coefficients, etc.). Generally, the deep water boundary of the SWAN nest must be located in WAM or WAVEWATCH III where shallow water effects do not dominate (to avoid too large discontinuities between the two models). Also, the spatial and spectral resolutions should not differ more than a factor two or three. If a finer resolution is required, a second or third nesting may be needed.

2.5 Units and coordinate systems

SWAN expects all quantities that are given by the user to be expressed in S.I. units: m, kg, s and composites of these with accepted compounds, such as Newton (N) and Watt

(W). Consequently, the wave height and water depth are in m, wave period in s, etc. For <u>wind and wave direction</u> both the Cartesian and *a* nautical convention can be used (see below). Directions and spherical coordinates are in degrees (^{0}) and not in radians.

For the output of wave energy the user can choose between variance (m^2) or energy (**spatial**) density (Joule/m^2, i.e. energy per unit sea surface) and the equivalents in case of energy transport (m^3/s or W/m, i.e. energy transport per unit length) and spectral energy density (m^2/Hz/Degr or Js/m^2/rad, i.e. energy per unit frequency and direction per unit sea surface area). The wave$-$induced stress components (obtained as spatial derivatives of wave-induced radiation stress) are always expressed in N/m^2 even if the wave energy is in terms of variance. Note that the energy density is also in Joule/m^2 in the case of spherical coordinates.

SWAN operates either in a Cartesian coordinate system or in a spherical coordinate system, i.e. in a flat plane or on a spherical Earth. In the Cartesian system, all geographic locations and orientations in SWAN, e.g. for the bottom grid or for output points, are defined in one common Cartesian coordinate system with origin (0,0) by definition. This <u>geographic origin may be chosen totally arbitrarily by the user</u>. However, be careful, the numbers for the origin should not be chosen too large; the user is advised to translate the coordinates with an offset. In the spherical system, all geographic locations and orientations in SWAN, e.g. for the bottom grid or for output points, are defined in geographic longitude and latitude. Both coordinate systems are designated in this manual as the <u>problem coordinate system</u>.

In the input and output of SWAN the <u>direction of wind and waves</u> are defined according to either

- the <u>Cartesian convention</u>, i.e. the direction to where the vector points, measured counterclockwise from the positive $x-$axis of this system (in degrees) or

- a <u>nautical convention</u> (there are more such conventions), i.e. the direction where the wind or the waves come <u>from</u>, measured clockwise from geographic North.

All <u>other directions</u>, such as orientation of grids, are according to the Cartesian convention!

For regular grids, i.e. uniform and rectangular, Figure 4.1 (in Section 4.5) shows how the locations of the various grids are determined with respect to the problem coordinates. All grid points of curvilinear and unstructured grids are relative to the problem coordinate system.

2.6 Choice of grids, time windows and boundary / initial / first guess conditions

2.6.1 Introduction

Several types of grids and time window(s) need to be defined: (a) spectral grid, (b) spatial (geographic) grids and time window(s) in case of nonstationary computations.

The **spectral** grid that need to be defined by the user is a <u>computational</u> spectral grid on which SWAN performs the computations.

SWAN has the option to make computations that can be nested in (coarse) SWAN, WAM or WAVEWATCH III. In such cases, the spectral grid need not be equal to the spectral grid in the coarse SWAN, WAM or WAVEWATCH III run.

The **spatial** grids that need to be defined by the user are (if required):

- a <u>computational</u> spatial grid on which SWAN performs the computations,

- one (or more) spatial <u>input</u> grid(s) for the bottom, current field, water level, bottom friction, vegetation, mud, sea ice and wind (each input grid may differ from the others) and

- one (or more) spatial <u>output</u> grid(s) on which the user requires output of SWAN.

The wind, bottom friction, vegetation, mud and sea ice do not require a grid if they are uniform over the area of interest.

For one-dimensional situations, i.e. $\partial/\partial y \equiv 0$, SWAN can be run in 1D mode.

If a uniform, rectangular computational spatial grid is chosen in SWAN, then all input and output grids must be uniform and rectangular too, but they may all be different from each other.

If a curvilinear computational spatial grid is chosen in SWAN, then <u>each</u> input grid should be either uniform, rectangular or identical to the used curvilinear grid or staggered with respect to the curvilinear computational grid.

If an unstructured computational spatial grid is chosen in SWAN, then <u>each</u> input grid should be either uniform, rectangular or identical to the used unstructured grid.

SWAN has the option to make computations that are nested in (coarse) SWAN, WAM or WAVEWATCH III. In such runs, SWAN interpolates the spatial boundary of the SWAN, WAM or WAVEWATCH III grid to the (user provided) grid of SWAN (that needs to (nearly) coincide along the grid lines of WAM or WAVEWATCH III or the output nest grid boundaries of SWAN). Since, the computational grids of WAM and WAVEWATCH

III are in spherical coordinates, it is recommended to use spherical coordinates in a nested SWAN when nesting in WAM or WAVEWATCH III.

SWAN using an <u>unstructured mesh</u> may be nested in SWAN employing a <u>regular grid</u> and vice versa. However, SWAN using an unstructured grid cannot be nested in WAM or WAVEWATCH III.

Nesting from a 2D model to a 1D model is possible although is should not be done by using the commands `NGRID` and `NEST`. Instead, define the boundary point of the 1D model as an output point (using command `POINTS`) and write the spectra for that point using the command `SPECout`. In the 1D model, this spectra is used as boundary condition using the `BOUNDSPEC` command.

Similarly, the wind fields may be available in different **time** windows than the current and water level fields and the computations may need to be carried out at other times than these input fields. For these reasons SWAN operates with different time windows with different time steps (each may have a different start and end time and time step):

- one <u>computational time window</u> in which SWAN performs the computations,

- one (or more) <u>input time window(s)</u> in which the bottom, current field, water level, bottom friction, vegetation, mud, sea ice and wind field (if present) are given by the user (each input window may differ form the others) and

- one (or more) <u>output time window(s)</u> in which the user requires output of SWAN.

In case of nesting, SWAN searches the boundary conditions in the relevant output file of the previous SWAN, WAM or WAVEWATCH III runs to take the boundary conditions at the start time of the nested run. It will not take the initial condition (i.e. over the entire computational grid) for the nested run from the previous SWAN, WAM or WAVE-WATCH III run.

During the computation SWAN obtains bottom, current, water level, wind, bottom friction, vegetation, mud and sea ice information by tri-linear **interpolation** from the given input grid(s) and time window(s). The output is in turn obtained in SWAN by bi-linear interpolation in space from the computational grid; there is no interpolation in time, the output time is shifted to the nearest computational time level. Interpolation errors can be reduced by taking the grids and windows as much as equal to one another as possible (preferably identical). It is recommended to choose output times such that they coincide with computational time levels.

2.6.2 Input grid(s) and time window(s)

The bathymetry, current, water level, bottom friction, vegetation, mud, ice and wind (if spatially variable) need to be provided to SWAN on so-called input grids. It is best to

make an input grid so large that it completely covers the computational grid.

In the region outside the input grid SWAN assumes that the bottom level, the water level, bottom friction, vegetation, mud and ice are identical to those at the nearest boundary of the input grid (lateral shift of that boundary). In the regions not covered by this lateral shift (i.e. in the outside quadrants of the corners of the input grid), a constant field equal to the value at the nearest corner point of the input grid is taken. For the current and wind velocity, SWAN takes 0 m/s for points outside the input grid.

In SWAN, the bathymetry, current, water level, wind, bottom friction, vegetation, mud and sea ice may be time varying. In that case they need to be provided to SWAN in so-called input time windows (they need not be identical with the computational, output or other input windows). It is best to make an input window larger than the computational time window. SWAN assumes zero values at times before the earliest begin time of the input parameters (which may be the begin time of any input parameter such as wind). SWAN assumes constant values (the last values) at times after the end time of each input parameter. The input windows should start early enough so that the initial state of SWAN has propagated through the computational area before reliable output of SWAN is expected.

One should choose the spatial resolution for the input grids such that relevant spatial details in the bathymetry, currents, bottom friction, vegetation, mud, ice and wind are properly resolved. Special care is required in cases with sharp and shallow ridges (sand bars, shoals) in the sea bottom and extremely steep bottom slopes. Very inaccurate bathymetry can result in very inaccurate refraction computations the results of which can propagate into areas where refraction as such is not significant (the results may appear to be unstable). For instance, waves skirting an island that is poorly resolved may propagate beyond the island with entirely wrong directions. In such a case it may even be better to deactivate the refraction computations (if refraction is irrelevant for the problem at hand e.g. because the refracted waves will run into the coast anyway and one is not interested in that part of the coast). In such cases the ridges are vitally important to obtain good SWAN results (at sea the waves are 'clipped' by depth-induced breaking over the ridges which <u>must</u> therefore represented in SWAN computation). This requires not only that these ridges should be well represented on the input grid but also after interpolation on the computational grid. This can be achieved by choosing the grid lines of the input grid along the ridges (even if this may require some slight "shifting" of the ridges) <u>and</u> choosing the computational grid to be identical to the input grid (otherwise the ridge may be "lost" in the interpolation from the bottom input grid to the computational grid).

Finally, one should use a time step that is small enough that time variations in the bathymetry, current, water level, wind and bottom friction are well resolved.

2.6.3   Computational grids and boundary / initial / first guess conditions

The **computational spatial grid** must be defined by the user. The orientation (direction) can be chosen arbitrarily.

The boundaries of the computational spatial grid in SWAN are either land or water. In the case of land there is no problem: the land does not generate waves and in SWAN it absorbs all incoming wave energy. But in the case of a water boundary there may be a problem. Often no wave conditions are known along such a boundary and SWAN then assumes that no waves enter the area and that waves can leave the area freely. These assumptions obviously contain errors which propagate into the model. These boundaries must therefore be chosen sufficiently far away from the area where reliable computations are needed so that they do not affect the computational results there. This is best established by varying the location of these boundaries and inspect the effect on the results. Sometimes the waves at these boundaries <u>can</u> be estimated with a certain degree of reliability. This is the case if (a) results of another model run are available (nested computations) or, (b) observations are available. If model results are available along the boundaries of the computational spatial grid, they are usually from a coarser resolution than the computational spatial grid under consideration. This implies that this coarseness of the boundary propagates into the computational grid. The problem is therefore essentially the same as if no waves are assumed along the boundary except that now the error may be more acceptable (or the boundaries are permitted to be closer to the area of interest). If observations are available, they can be used as input at the boundaries. However, this usually covers only part of the boundaries so that the rest of the boundaries suffer from the same error as above.

A special case occurs near the coast. Here it is often possible to identify an up-wave boundary (with proper wave information) and two lateral boundaries (with no or partial wave information). The affected areas with errors are typically regions with the apex at the corners of the water boundary with wave information, spreading towards shore at an angle of 30º to 45º for wind sea conditions to either side of the imposed mean wave direction (less for swell conditions; the angle is essentially the one-sided width of the directional distribution of wave energy). For propagation of short crested waves (wind sea condtions) an example is given in Figure 2.1. For this reason the lateral boundaries should be sufficiently far away from the area of interest to avoid the propagation of this error into this area. Such problems do not occur if the lateral boundaries contain proper wave information over their entire length e.g. obtained from a previous SWAN computation or if the lateral boundaries are coast.

When <u>output</u> is requested along a <u>boundary of the computational grid</u>, it may occur that this output differs from the boundary conditions that are imposed by the user. The reason is that SWAN accepts only the user-imposed <u>incoming</u> wave components and that it re-places the user-imposed <u>outgoing</u> wave components with computed outgoing components (propagating to the boundary from the interior region). The user is informed by means of
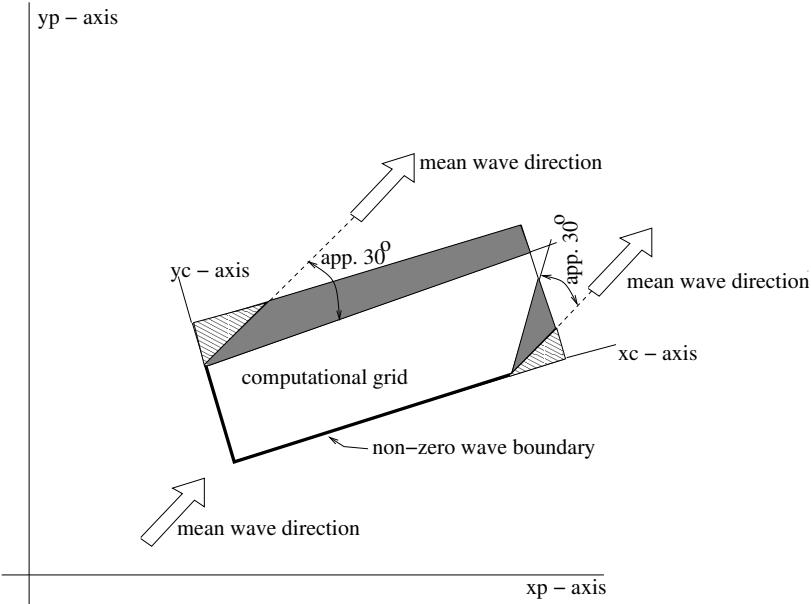
Figure 2.1: Disturbed regions in the computational grid due to erroneous boundary conditions are indicated with shaded areas.

a warning in the output when the computed significant wave height differs more than 10%, say (10% is default), from the user-imposed significant wave height (command `BOUND...`). The actual value of this difference can be set by the user (see the `SET` command). Note that this warning will not apply in the case of unstructured grids.

If the computational grid extends outside the input grid, the reader is referred to Section 2.6.2 to find the assumptions of SWAN on depth, current, water level, wind, bottom friction, vegetation, mud, and ice in the non-overlapping area.

The spatial resolution of the computational grid should be sufficient to resolve relevant details of the wave field. Usually a good choice is to take the resolution of the computational grid approximately equal to that of the bottom or current grid. If necessary, an unstructured grid may be used.

SWAN may not use the entire user-provided computational grid if the user defines exception values on the depth grid (see command `INPGRID BOTTOM`) or on the curvilinear computational grid (see command `CGRID`). A computational grid point is either

- <u>wet</u>, i.e. the grid point is included in the computations since it represents water; this may vary with time-dependent or wave-induced water levels or

- <u>dry</u>, i.e. the grid point is excluded from the computations since it represents land which may vary with time-dependent or wave-induced water levels or

- <u>exceptional</u>, i.e. the grid point is permanently excluded from the computations since

it is so defined by the user.

If exceptional grid points occur in the computational grid, then SWAN filters the entire computational grid as follows:

- each grid line between two adjacent wet computational grid points (a wet link) <u>without</u> an adjacent, parallel wet link, is removed,

- each wet computational grid point that is linked to only one other wet computational grid point, is removed and

- each wet computational grid point that has no wet links is removed.

The effect of this filter is that if exception values are used for the depth grid or the curvilinear computational grid, one-dimensional water features are ignored in the SWAN computations (results at these locations with a width of about one grid step may be unrealistic). If no exception values are used, the above described filter will not be applied. As a consequence, one-dimensional features may appear or disappear due to changing water levels (flooding may create them, drying may reduce two-dimensional features to one-dimensional features).

It must be noted that for parallel runs using MPI the user must indicate an exception value when reading the bottom levels (by means of command `INPGRID BOTTOM EXCEPTION`), if appropriate, in order to obtain good load balancing.

The **computational time window** must be defined by the user in case of nonstationary runs. The computational window in time must start at a time that is early enough that the initial state of SWAN has propagated through the computational area before reliable output of SWAN is expected. Before this time the output may not be reliable since usually the initial state is not known and only either no waves or some very young sea state is assumed for the initial state. This is very often erroneous and this erroneous initial state is propagated into the computational area.

The computational time step must be given by the user in case of nonstationary runs. Since, SWAN is based on implicit numerical schemes, it is not limited by the Courant stability criterion (which couples time and space steps). In this sense, the time step in SWAN is not restricted. However, the accuracy of the results of SWAN are obviously affected by the time step. Generally, the time step in SWAN should be small enough to resolve the time variations of computed wave field itself. Usually, it is enough to consider the time variations of the driving fields (wind, currents, water depth, wave boundary conditions). But be careful: relatively(!) small time variations in depth (e.g. by tide) can result in relatively(!) large variations in the wave field.

As default, the first guess conditions of a <u>stationary</u> run of SWAN are determined with the 2nd generation mode of SWAN. The initial condition of a <u>nonstationary</u> run of SWAN is by default a JONSWAP spectrum with a $\cos^2(\theta)$ directional distribution centred around

the local wind direction.

A quasi-stationary approach can be employed with stationary SWAN computations in a time-varying sequence of stationary conditions.

The **computational spectral grid** needs to be provided by the user. In frequency space, it is simply defined by a minimum and a maximum frequency and the frequency resolution which is proportional to the frequency itself (i.e. logarithmic, e.g., $\Delta f = 0.1 f$). The frequency domain may be specified as follows (see command `CGRID`):

- The lowest frequency, the highest frequency and the number of frequencies can be chosen.

- Only the lowest frequency and the number of frequencies can be chosen. The highest frequency will be computed by SWAN such that $\Delta f = 0.1 f$. This resolution is required by the DIA method for the approximation of nonlinear 4-wave interactions (the so-called quadruplets).

- Only the highest frequency and the number of frequencies can be chosen. The lowest frequency will be computed by SWAN such that $\Delta f = 0.1 f$. This resolution is required by the DIA method for the approximation of nonlinear 4-wave interactions.

- Only the lowest frequency and the highest frequency can be chosen. The number of frequencies will be computed by SWAN such that $\Delta f = 0.1 f$. This resolution is required by the DIA method for the approximation of nonlinear 4-wave interactions.

The value of lowest frequency must be somewhat smaller than 0.7 times the value of the lowest peak frequency expected. The value of highest frequency must be at least 2.5 to 3 times the highest peak frequency expected. For the XNL approach, however, this should be 6 times the highest peak frequency. Usually, it is chosen less than or equal to 1 Hz.

SWAN has the option to make computations that can be nested in WAM or WAVE-WATCH III. In such runs SWAN interpolates the spectral grid of WAM or WAVEWATCH III to the (user provided) spectral grid of SWAN. The WAM Cycle 4 source term in SWAN has been retuned for a highest prognostic frequency (that is explicitly computed by SWAN) of 1 Hz. It is therefore recommended that for cases where wind generation is important and WAM Cycle 4 formulations are chosen, the highest prognostic frequency is about 1 Hz.

In directional space, the directional range is the full 360º unless the user specifies a limited directional range. This may be convenient (less computer time and/or memory space), for example, when waves travel towards a coast within a limited sector of 180º. The directional resolution is determined by the number of discrete directions that is provided by the user. For wind seas with a directional spreading of typically 30º on either side of the mean wave direction, a resolution of 10º seems enough whereas for swell with a directional spreading of less than 10º, a resolution of 2º or less may be required. If the user is confident that no energy will occur outside a certain directional sector (or is willing to ignore this amount

of energy), then the computations by SWAN can be limited to the directional sector that does contain energy. This may often be the case of waves propagating to shore within a sector of 180º around some mean wave direction.

It is recommended to use the following discretization in SWAN for applications in coastal areas:

direction resolution for wind sea	$\Delta\theta = 15^o - 10^o$
direction resolution for swell	$\Delta\theta = 5^o - 2^o$
frequency range	$0.04 \leq f \leq 1.00$ Hz
spatial resolution	$\Delta x, \Delta y = 50 - 1000$ m

The numerical schemes in the SWAN model require a minimum number of discrete grid points in each spatial directions of 2. The minimum number of directional bins is 3 per directional quadrant and the minimum number of frequencies should be 4.

A final remark on the choice of spatial and spectral resolution. SWAN should not shift energy more than one spectral bin (Δf and/or $\Delta\theta$) when propagating over one spatial grid cell (Δx and/or Δy). This is for reasons for accuracy and not stability. See for details Section 3.8 of the Scientific/Technical documentation. This implies that although SWAN will be stable, whatever resolution you choose, you need to balance spectral and spatial resolution. This could mean, i.e. not necessarily, that you have to refine your spatial resolution when you refine your spectral resolution.

In a situation with currents this is particularly important at the highest frequencies where the Doppler shifts are largest. However, it may well be that inaccuracies thus generated will be removed by the source terms. In other words, accurate Doppler shifts at high frequencies require high spectral and spatial resolution, but the effects may be dominated by white capping. Hence, at the high frequencies, the problem is perhaps masked by white capping. The inaccuracies may only appear at the lowest frequencies, where usually the source terms are relatively weak at these frequencies.

Another issue concerns the excessive wave turning of relatively long waves at shallow water, or cases with depth varies considerably over one spatial grid step, e.g. at the edge of shelf break or seamount at deep ocean. As the refraction becomes excessive in a region with steep bottom gradients, it is possible that the wave energy focus toward a single grid point, creating unrealistically large wave heights and long periods; see Dietrich et al. (2013).

SWAN can optionally uses a Courant-type limiter (see command `NUMERIC`). This limiter is locally in geographic space for cosmetic reasons, but it avoids propagating a large error to the rest of the geographic domain and thus improve the solution there. However, if the limiter is activated, the computation is still inaccurate, but less so as you are farther from the location with poor resolution. The common mistake people often make is that the limiter may affect the model results negatively, which is, however, not entirely true. As

the resolution is too coarse, the model results are inaccurate anyway. Hence, the proper solution to this problem is to choose a suitable resolution, both spectral and spatial, and one can thus avoid the use of the limiter.

2.6.4 Output grids

SWAN can provide output on uniform, rectilinear spatial grids that are independent from the input grids and from the computational grid. In the computation with a curvilinear computational grid, curvilinear output grids are available in SWAN. This also holds for triangular meshes. An output grid has to be specified by the user with an arbitrary resolution, but it is of course wise to choose a resolution that is fine enough to show relevant spatial details. It must be pointed out that the information on an output grid is obtained from the computational grid by bi-linear interpolation (output always at computational time level). This implies that some inaccuracies are introduced by this interpolation. It also implies that bottom or current information on an output plot has been obtained by interpolating twice: once from the input grid to the computational grid and once from the computational grid to the output grid. If the input-, computational- and output grids are identical, then no interpolation errors occur.

In the regions where the output grid does not cover the computational grid, SWAN assumes output values equal to the corresponding exception value. For example, the default exception value for the significant wave height is -9. The exception values of output quantities can be changed by means of the `QUANTITY` command.

In nonstationary computations, output can be requested at regular intervals starting at a given time always at computational times.

2.7   Activation of physical processes

SWAN contains a number of physical processes (see Scientific/Technical documentation) that add or withdraw wave energy to or from the wave field. The processes included are: wind input, whitecapping, bottom friction, depth-induced wave breaking, dissipation due to vegetation, mud, sea ice or turbulence, obstacle transmission, nonlinear wave-wave interactions (quadruplets and triads) and wave-induced set-up. In version 41.41, another source term is introduced called the Bragg scattering, taking into account the scattering of waves by small-scale bottom features.

SWAN can run in several modes, indicating the level of parameterization. SWAN can operate in first-, second- and third-generation mode. The first- and second-generation modes are essentially those of Holthuijsen and De Boer (1988); first-generation with a constant Phillips "constant" of 0.0081 and second-generation with a variable Phillips "constant". An overview of the options is given in Table below. The processes are activated as follows:

- *Wind input* is activated by commands `GEN1`, `GEN2` or `GEN3`[1].

- *Whitecapping* is activated by commands `GEN1`, `GEN2` or `GEN3`[2].

- *Quadruplets* is activated by command `GEN3`[3].

- *Triads* is activated by command `TRIAD`.

- *Depth-induced breaking* is activated by default[4].

- *Bottom friction* is activated by command `FRICTION`.

- *Obstacle transmission* is activated by command `OBSTACLE`.

- *Wave-induced set-up* is activated by command `SETUP`.

- *Vegetation dissipation* is activated by command `VEGETATION`.

- *Mud dissipation* is activated by command `MUD`.

- *Sea ice dissipation* is activated by command `SICE`.

- *Turbulence dissipation* is activated by command `TURBULENCE`.

- *Bragg scattering* is activated by command `BRAGG`.

For the preliminary SWAN runs, it is strongly advised to use the default values of the model coefficients. First, it should be determined whether or not a certain physical process is relevant to the result. If this cannot be decided by means of a simple hand computation, one can perform a SWAN computation without and with the physical process included in the computations, in the latter case using the standard values chosen in SWAN.

After it has been established that a certain physical process is important, it may be worthwhile to modify coefficients. In the case of wind input one may at first try to vary the wind velocity. Concerning the bottom friction, the best coefficients to vary are the friction coefficients. Switching off the depth-induced breaking term is usually not wise, since this may lead to unacceptably high wave heights near beaches (the computed wave heights 'explode' due to shoaling effects).

_____

[1]active by default, can be deactivated with command `OFF`.
[2]active by default, can be deactivated with command `OFF`.
[3]active by default, can be deactivated with command `OFF`.
[4]can be deactivated with command `OFF`.

2.8 Time and date notation

SWAN can run for dates (i.e. nonstationary mode)

- between the years 0 and 9999, if ISO-notation is used in the input (recommended) or

- between the years 1931 and 2030 if two-digit code for years is used (formats 2-6 in every command that contains moments in time).

Be careful when nesting SWAN in WAM, since WAM does not use ISO-notation.

Table 2.1: Overview of physical processes and generation mode in SWAN.

process	authors	generation mode		
		1st	2nd	3rd
Linear wind growth	Cavaleri and Malanotte-Rizzoli (1981) (modified)	×	×	
	Cavaleri and Malanotte-Rizzoli (1981)			×
Exponential wind growth	Snyder *et al.* (1981) (modified)	×	×	
	Snyder *et al.* (1981)			×
	Janssen (1989, 1991)			×
	Yan (1987) (modified)			×
Whitecapping	Holthuijsen and De Boer (1988)	×	×	
	Komen *et al.* (1984)			×
	Janssen (1991)			×
	Alves and Banner (2003)			×
Quadruplets	Hasselmann *et al.* (1985)			×
Triads	Eldeberky (1996)	×	×	×
	Booij *et al.* (2009)	×	×	×
Depth-induced breaking	Battjes and Janssen (1978)	×	×	×
Bottom friction	JONSWAP (1973)	×	×	×
	Collins (1972)	×	×	×
	Madsen *et al.* (1988)	×	×	×
Obstacle transmission	Seelig (1979), d'Angremond (1996)	×	×	×
Wave-induced set-up		×	×	×
Vegetation dissipation	Dalrymple (1984), Jacobsen et al (2019)	×	×	×
Mud dissipation	Ng (2000)	×	×	×
Sea ice dissipation	Collins and Rogers (2017), Rogers (2019)	×	×	×
Turbulence dissipation		×	×	×
Bragg scattering	Ardhuin and Herbers (2002)	×	×	×

Chapter 3

Input and output files

3.1 General

SWAN is one single computer program. The names of the files provided by the user should comply with the rules of file identification of the computer system on which SWAN is run. In addition: SWAN does not permit file names longer than 36 characters. Moreover, the maximum length of the lines in the input files for SWAN is 180 positions.

The user should provide SWAN with a number of files (input files) with the following information:

- a file containing the instructions of the user to SWAN (the command file),

- file(s) containing: grid, bottom, current, friction, and wind (if relevant) and

- file(s) containing the wave field at the model boundaries (if relevant).

3.2 Input / output facilities

To assist in making the command file, an edit file is available to the user (see Appendix C). In its original form this file consists only of comments; all lines begin with exclamation mark. In the file, all commands as given in this User Manual (Chapter 4) are reproduced as mnemonics for making the final command file. Hence, the user does not need to consult the User Manual every time to check the correct spelling of keywords, order of data, etc. The user is advised to first copy the edit file (the copy file should have a different name) and then start typing commands between the comment lines of the edit file.

SWAN is fairly flexible with respect to output processing. Output is available for many different wave parameters and wave related parameters (e.g., wave-induced stresses and bottom orbital motion). However, the general rule is that output is produced by SWAN only at the user's request. The instructions of the user to control output are separated into three categories:

- Definitions of the geographic location(s) of the output. The output locations may be either on a geographic grid, or along user specified lines (e.g., a given depth contour line) or at individual output locations.

- Times for which the output is requested (only in nonstationary runs).

- Type of output quantities (wave parameters, currents or related quantities).

3.3   Print file and error messages

SWAN always creates a print file. Usually the name of this file is identical to the name of the command file of the computations with the extension (.SWN) replaced with (.PRT). Otherwise, it depends on the batch file that is used by the user. Consult the Implementation Manual for more information.

The print file contains an echo of the command file, an overview of the actual physical and numerical parameters to be used in the simulation run, and possibly warning and error messages. These messages are usually self-explanatory. The print file also contains computational results if the user so requests (with command `BLOCK` or `TABLE`).

In any case, always check the PRINT file!

Chapter 4

Description of commands

4.1 List of available commands

The following commands are available to users of SWAN (to look for the commands quickly, see table of contents and index).

Start-up commands

(a) Start-up commands:

`PROJECT`	title of the problem to be computed
`SET`	sets values of certain general parameters
`MODE`	requests a stationary / nonstationary or 1D-mode / 2D-mode of SWAN
`COORD`	to choose between Cartesian and spherical coordinates

Commands for model description

(b) Commands for computational grid:

`CGRID`	defines dimensions of computational grid
`READGRID`	reads a <u>curvilinear</u> or <u>unstructured</u> computational grid

(c) Commands for input fields:

`INPGRID`	defines dimensions of bottom, water level, current and friction grids
`READINP`	reads input fields
`WIND`	activates constant wind option
`ICE`	activates constant ice field option

(d) Commands for boundary and initial conditions:

BOUND	defines the shape of the spectra at the boundary of geographic grid
BOUNDSPEC	defines (parametric) spectra at the boundary of geographic grid
BOUNDNEST1	defines boundary conditions obtained from (coarse) SWAN run
BOUNDNEST2	defines boundary conditions obtained from WAM run
BOUNDNEST3	defines boundary conditions obtained from WAVEWATCH III run
INITIAL	specifies an initial wave field

(e) Commands for physics:

GEN1	SWAN runs in first generation mode
GEN2	SWAN runs in second generation mode
GEN3	SWAN runs in third generation mode
WCAP	controls whitecapping
QUAD	controls the computation of quadruplets
BREAKING	activates dissipation by depth-induced wave breaking
FRICTION	activates dissipation by bottom friction
TRIAD	activates three wave-wave interactions
VEGETAT	activates dissipation due to vegetation
MUD	activates dissipation due to mud
SICE	activates dissipation due to sea ice
TURBULE	activates dissipation due to turbulence
BRAGG	activates Bragg scattering
LIMITER	de-actives quadruplets if a certain Ursell number exceeds
OBSTACLE	defines characteristics of sub-grid obstacles
SETUP	activates the computation of the wave-induced set-up
DIFFRAC	activates diffraction
SURFBEAT	activates the Infragravity Energy Module (IEM)
OFF	de-activates certain physical processes

(f) Commands for numerics:

PROP	to choose the numerical propagation scheme
NUMERIC	sets some of the numerical properties of SWAN

Output commands

(g) Commands for output locations:

`FRAME`	defines an output frame (a regular grid)
`GROUP`	defines an output group (for regular and curvilinear grids)
`CURVE`	defines an output curve
`RAY`	defines a set of straight output lines (rays)
`ISOLINE`	defines a depth- or bottom contour (for output along that contour)
`POINTS`	defines a set of individual output points
`NGRID`	defines a nested grid

(h) Commands to write or plot output quantities:

`QUANTITY`	defines properties of output quantities
`OUTPUT`	influence format of block, table and/or spectral output
`BLOCK`	requests a block output (geographic distribution)
`TABLE`	requests a table output (set of locations)
`SPECOUT`	requests a spectral output
`NESTOUT`	requests a spectral output for subsequent nested computations

(i) Commands to write or plot intermediate results:

`TEST`	requests an output of intermediate results for testing purposes

Lock-up commands

(j) Commands to lock-up the input file:

`COMPUTE`	starts a computation
`HOTFILE`	stores results for subsequent SWAN run
`STOP`	end of user's input

4.2 Sequence of commands

SWAN executes the above command blocks (a,...,j) in the above sequence except (f), (i) and (j). The commands of the blocks (f) and (i) may appear anywhere before block (j), except that `TEST POINTS` must come after `READINP BOTTOM`. The commands of block (j) may appear anywhere in the command file (all commands after `COMPUTE` are ignored by SWAN, except `HOTFILE` and `STOP`). A sequence of commands of block (g) is permitted (all commands will be executed without overriding). Also a sequence of commands of block (h) is permitted (all commands will be executed without overriding).

Within the blocks the following sequence is to be used:

In block (a)   : no prescribed sequence in block
In block (b)   : `READGRID` after `CGRID`
In block (c)   : `READINP` after `INPGRID` (repeat both in this sequence for each quantity)
In block (d)   : `BOUND SHAPE` before `BOUNDSPEC`, otherwise no prescribed sequence in block
In block (e)   : use only one `GEN` command; use command `OFF` only after a `GEN` command
                 (note that `GEN3` is the default)
In block (f)   : no prescribed sequence in block
In block (g)   : `ISOLINE` after `RAY` (`ISOLINE` and `RAY` can be repeated independently)
In block (h)   : no prescribed sequence in block
In block (i)   : no prescribed sequence in block
In block (j)   : `HOTFILE` immediately after `COMPUTE`, `STOP` after `COMPUTE`

It must be noted that a repetition of a command may override an earlier occurrence of that command.

Many commands provide the user with the opportunity to assign values to coefficients of SWAN (e.g. the bottom friction coefficient). If the user does not use such option SWAN will use a default value.

Some commands cannot be used in 1D-mode (see individual command descriptions below).

4.3   Command syntax and input / output limitations

The command syntax is given in Appendix B.

Limitations:

- The maximum length of the input lines is 180 characters. A line may be continued on the next line while it is terminated with a continuation mark &. See also Section B.4.

- The maximum length of the file names is 36 characters.

- The maximum number of file names is 99. This can be extended (edit the file `swaninit` to change highest unit number of 99 to a higher number).

4.4   Start-up

```
PROJect 'name' 'nr'

        'title1'
```

```
        'title2'


        'title3'
```

With this required command the user defines a number of strings to identify the SWAN run (project name e.g., an engineering project) in the print and plot file.

`'name'`   is the name of the project, at most 16 characters long.
             Default: blanks.
`'nr'`   is the run identification (to be provided as a character string; e.g. the run
             number) to distinguish this run among other runs for the same project; it is at
             most 4 characters long. It is the only required information in this command.
`'title1'`   is a string of at most 72 characters provided by the user to appear in the
             output of the program for the user's convenience.
             Default: blanks.
`'title2'`   same as `'title1'`.
`'title3'`   same as `'title1'`.

```
SET  [level] [nor] [depmin] [maxmes] [maxerr] [grav] [rho] [cdcap] [inrhog] &


              |     NAUTical  |
     [hsrerr] <                 > [pwtail] [froudmax] [icewind] [excmark]
              | -> CARTesian |
```

With this optional command the user assigns values to various general parameters.

`[level]`   increase in water level that is constant in space and time can be given with
             this option, `[level]` is the value of this increase (in m). For a variable water
             level reference is made to the commands `INPGRID` and `READINP`.
             Default: `[level]`=0.
`[nor]`   direction of North with respect to the $x-$axis (measured counterclockwise);
             default `[nor]`= 90º, i.e. $x-$axis of the problem coordinate system
             points East.
             When spherical coordinates are used (see command `COORD`) the value
             of `[nor]` may not be modified.
`[depmin]`   threshold depth (in m). In the computation any positive depth smaller than
             `[depmin]` is made equal to `[depmin]`.
             Default: `[depmin]` = 0.05.
`[maxmes]`   maximum number of error messages (not necessarily the number of errors!)
             during the computation at which the computation is terminated. During the

	computational process messages are written to the print file.
	Default: `[maxmes]` = 200.
`[maxerr]`	during pre-processing SWAN checks input data. Depending on the severity of the errors encountered during this pre-processing, SWAN does not start computations. The user can influence the error level above which SWAN will not start computations (at the level indicated the computations will continue). The error level `[maxerr]` is coded as follows:
	1 : warnings,
	2 : errors (possibly automatically repaired or repairable by SWAN),
	3 : severe errors.
	Default: `[maxerr]` = 1.
`[grav]`	is the gravitational acceleration (in m/s^2).
	Default: `[grav]` = 9.81.
`[rho]`	is the water density ρ (in kg/m^3).
	Default: `[rho]` = 1025.
`[cdcap]`	is the maximum value for the wind drag coefficient. A value of `[cdcap]` = 99999 means no cutting off the drag coefficient. A suggestion for this parameter is `[cdcap]` = 2.5× 10^{-3}.
	Default: `[cdcap]` = 99999.
`[inrhog]`	to indicate whether the user requires output based on variance or based on true energy (see Section 2.5).
	`[inrhog]` = 0 : output based on variance
	`[inrhog]` = 1 : output based on true energy
	Default: `[inrhog]` = 0.
`[hsrerr]`	the relative difference between the user imposed significant wave height and the significant wave height computed by SWAN (anywhere along the computational grid boundary) above which a warning will be given. This relative difference is the difference normalized with the user provided significant wave height. This warning will be given for each boundary grid point where the problem occurs (with its $x-$ and $y-$index number of the computational grid). The cause of the difference is explained in Section 2.6.3. To supress these warnings (in particular for nonstationary computations), set `[hsrerr]` at a very high value or use command `OFF BNDCHK`.
	Default: `[hsrerr]` = 0.10.
	ONLY MEANT FOR STRUCTURED GRIDS.
NAUTICAL	indicates that the Nautical convention for wind and wave direction (SWAN input and output) will be used instead of the default Cartesian convention. For definition, see Section 2.5 or Appendix A.
CARTESIAN	indicates that the Cartesian convention for wind and wave direction (SWAN input and output) will be used. For definition, see Section 2.5 or Appendix A.
`[pwtail]`	power of high frequency tail; defines the shape of the spectral tail above the highest prognostic frequency `[fhigh]` (see command `CGRID`). The energy density is assumed to be proportional to frequency to the power `[pwtail]`.

Default values depend on formulations of physics:

command `GEN1`   : $[\mathtt{pwtail}] = 5$
command `GEN2`   : $[\mathtt{pwtail}] = 5$
command `GEN3 KOMEN`   : $[\mathtt{pwtail}] = 4$
command `GEN3 WESTH`   : $[\mathtt{pwtail}] = 4$
command `GEN3 JANSSEN`: $[\mathtt{pwtail}] = 5$

If the user wishes to use another value, then this `SET` command should be located in the command file after the `GEN1`, `GEN 2` or `GEN3` command (these will override the `SET` command with respect to [`pwtail`]).

[`froudmax`]   is the maximum Froude number ($U/\sqrt{gd}$ with U the current and d the water depth). The currents taken from a circulation model may mismatch with given water depth d in the sense that the Froude number becomes larger than 1. For this, the current velocities will be maximized by Froude number times $\sqrt{gd}$. Default: [`froudmax`] $= 0.8$.

[`icewind`]   controls the scaling of wind input by open water fraction. Default value of zero corresponds to the case where wind input is scaled by the open water fraction. If [`icewind`] $= 1$ then sea ice does not affect wind input directly. (Though there is still indirect effect via the sea ice sink term; see command `SICE`.) Default: [`icewind`] $= 0$.

[`excmark`]   this option excludes boundary vertices with marker greater than or equal to [`excmark`] during the processing of the boundary conditions (see command `BOUN`). Examples are the boundaries of the islands within the computational domain. The intended markers are given in the file(s) produced by a grid generator (such as in the last column of the Triangle `.node` file). Default: [`excmark`] $= 999$. ONLY MEANT FOR UNSTRUCTURED GRIDS.

```
        |-> STATionary    |      |-> TWODimensional |
MODE <                    > <                        >
        |   NONSTationary |      |   ONEDimensional |
```

With this optional command the user indicates that the run will be either stationary or nonstationary and one-dimensional (1D-mode) or two-dimensional (2D-mode). Non-stationary means either (see command `COMPUTE`):

(a) one nonstationary computations or

(b) a sequence of stationary computations or

(c) a mix of (a) and (b).

The default option is `STATIONARY TWODIMENSIONAL`.

```
             | -> CARTesian              |
COORDINATES <                     | -> CCM |    > REPeating
             |      SPHErical   <         > |
                                  | QC     |
```

Command to choose between Cartesian and spherical coordinates (see Section 2.5).

A nested SWAN run must use the same coordinate system as the coarse grid SWAN run.

CARTESIAN	all locations and distances are in m. Coordinates are given with respect to $x-$ and $y-$axes chosen by the user in the various commands.
SPHERICAL	all coordinates of locations and geographical grid sizes are given in degrees; x is longitude with $x = 0$ being the Greenwich meridian and $x > 0$ is East of this meridian; y is latitude with $y > 0$ being the Northern hemisphere. Input and output grids have to be oriented with their $x-$axis to the East; mesh sizes are in degrees. All other distances are in meters.
CCM	defines the projection method in case of spherical coordinates. CCM means central conformal Mercator. The horizontal and vertical scales are uniform in terms of cm/degree over the area shown. In the centre of the scale is identical to that of the conventional Mercator projection (but only at that centre). The area in the projection centre is therefore exactly conformal.
QC	the projection method is quasi-cartesian, i.e. the horizontal and vertical scales are equal to one another in terms of cm/degree.
REPEATING	this option is only for academic cases. It means that wave energy leaving at one end of the domain (in computational $x-$direction) enter at the other side; it is as if the wave field repeats itself in $x-$direction with the length of the domain in $x-$direction. This option cannot be used in combination with computation of set-up (see command `SETUP`). This option is available only with <u>regular grids</u>.

Note that spherical coordinates can also be used for relatively small areas, say 10 or 20 km horizontal dimension. This may be useful if one obtains the boundary conditions by nesting in an oceanic model which is naturally formulated in spherical coordinates.

Note that in case of spherical coordinates regular grids must always be oriented E-W, N-S, i.e. [alpc]=0, [alpinp]=0, [alpfr]=0 (see commands `CGRID`, `INPUT GRID` and `FRAME`, respectively).

4.5   Model description

4.5.1   Computational grid

```
        | -> REGular [xpc] [ypc] [alpc] [xlenc] [ylenc] [mxc] [myc] |
        |                                                           |
CGRID <      CURVilinear [mxc] [myc]  (EXCeption  [xexc]  [yexc])   >  &
        |                                                           |
        |    UNSTRUCtured                                           |

          | -> CIRcle                |
          <                          > [mdc] [flow] [fhigh] [msc]
          |     SECtor [dir1] [dir2] |
```

With this required command the user defines the geographic location, size, resolution and orientation of the computational grid in the problem coordinate system (see Section 2.6.3) in case of a uniform, rectilinear computational grid, a curvilinear grid or unstructured mesh. The origin of the regular grid and the direction of the positive $x-$axis of this grid can be chosen arbitrary by the user. Must be used for nested runs. Note that in a nested case, the geographic and spectral range (directional sector inclusive) and resolution may differ from the previous run (outside these ranges zero's are used).

REGULAR	this option indicates that the computational grid is to be taken as uniform and rectangular.
CURVILINEAR	this option indicates that the computational grid is to be taken as curvilinear. The user must provide the coordinates of the grid points with command `READGRID COOR`.
UNSTRUCTURE	this option indicates that the computational grid is to be taken as unstructured. The user must provide the coordinates of the vertices and the numbering of triangles with the associated connectivity table with vertices with command `READGRID UNSTRUC`.
[xpc]	geographic location of the origin of the computational grid in the problem coordinate system ($x-$coordinate, in m). See command `COORD`. Default: `[xpc]` = 0.0 (Cartesian coordinates). In case of spherical coordinates there is no default, the user must give a value.
[ypc]	geographic location of the origin of the computational grid in the problem coordinate system ($y-$coordinate, in m). See command `COORD`. Default: `[ypc]` = 0.0 (Cartesian coordinates). In case of spherical coordinates there is no default, the user must give a value.
[alpc]	direction of the positive $x-$axis of the computational grid (in degrees, Cartesian convention). In 1D-mode, `[alpc]` should be equal to the direction `[alpinp]`

	(see command INPGRID).
	Default: [alpc] = 0.0.
[xlenc]	length of the computational grid in $x-$direction (in m). In case of spherical coordinates [xlenc] is in degrees.
[ylenc]	length of the computational grid in $y-$direction (in m). In 1D-mode, [ylenc] should be 0. In case of spherical coordinates [ylenc] is in degrees.
[mxc]	number of meshes in computational grid in $x-$direction for a uniform, rectilinear grid or $\xi-$direction for a curvilinear grid (this number is <u>one less</u> than the number of grid points in this domain!).
[myc]	number of meshes in computational grid in $y-$direction for a uniform, rectilinear grid or $\eta-$direction for a curvilinear grid (this number is <u>one less</u> than the number of grid points in this domain!). In 1D-mode, [myc] should be 0.
EXCEPTION	only available in the case of a <u>curvilinear grid</u>. If certain grid points are to be ignored during the computation (e.g. land points that remain dry i.e. no flooding; saving computer time and memory), then this can be indicated by identifying these grid points in the file containing the grid point coordinates (see command READGRID). For an alternative, see command INPGRID BOTTOM.
[xexc]	the value which the user uses to indicate that a grid point is to be ignored in the computations (this value is provided by the user at the location of the $x-$coordinate considered in the file of the $x-$coordinates, see command READGRID COOR). Required if the option EXCEPTION is used.
	Default: [xexc] = 0.0.
[yexc]	the value which the user uses to indicate that a grid point is to be ignored in the computations (this value is provided by the user at the location of the $y-$coordinate considered in the file of the $y-$coordinates, see command READGRID COOR). Required if the option EXCEPTION is used.
	Default: [yexc] = [xexc].
CIRCLE	this option indicates that the spectral directions cover the full circle.
	This option is the default.
SECTOR	this option means that only spectral wave directions in a limited directional sector are considered; the range of this sector is given by [dir1] and [dir2].
	It must be noted that if the quadruplet interactions are to be computed (see command GEN3), then the SECTOR should be 30° wider on each side than the directional sector occupied by the spectrum (everywhere in the computational grid). If not, then these computations are inaccurate. If the directional distribution of the spectrum is symmetric around the centre of the SECTOR, then the computed quadruplet wave-wave interactions are effectively zero in the 30° range on either end of the SECTOR. The problem can be avoided by not activating the quadruplet wave-wave interactions (use command GEN1 or GEN2) or, if activated (with command GEN3), by subsequently de-activating them with command OFF QUAD.
[dir1]	the direction of the right-hand boundary of the sector when looking outward from the sector (required for option SECTOR) in degrees.

[dir2]	the direction of the left-hand boundary of the sector when looking outward from the sector (required for option SECTOR) in degrees.
[mdc]	number of meshes in θ−space. In the case of CIRCLE, this is the number of subdivisions of the 360 degrees of a circle, so $\Delta\theta = [360^o]/$[mdc] is the spectral directional resolution. In the case of SECTOR, $\Delta\theta = ($[dir2] - [dir1]$)/$[mdc]. The minimum number of directional bins is 3 per directional quadrant.
[flow]	lowest discrete frequency that is used in the calculation (in Hz).
[fhigh]	highest discrete frequency that is used in the calculation (in Hz).
[msc]	<u>one less</u> than the number of frequencies. This defines the grid resolution in frequency-space between the lowest discrete frequency [flow] and the highest discrete frequency [fhigh]. This resolution is not constant, since the frequencies are distributed logarithmical: $f_{i+1} = \gamma f_i$ with γ is a constant. The minimum number of frequencies is 4.

The value of [msc] depends on the frequency resolution Δf that the user requires. Since, the frequency distribution on the frequency axis is logarithmic, the relationship is:

$$\Delta f = \left(-1 + \left[\frac{[\texttt{fhigh}]}{[\texttt{flow}]} \right]^{1/[\texttt{msc}]} \right) f$$

Vice versa, if the user chooses the value of $\Delta f/f$ $(= \gamma - 1.)$, then the value of [msc] is given by:

$$[\texttt{msc}] = \log([\texttt{fhigh}]/[\texttt{flow}])/\log(1 + \Delta f/f)$$

In this respect, it must be observed that the DIA approximation of the quadruplet interactions (see command GEN3) is based on a frequency resolution of $\Delta f/f = 0.1$ and hence, $\gamma = 1.1$. The actual resolution in the computations should therefore not deviate too much from this. Alternatively, the user may only specifies one of the following possibilities:

- [flow] and [msc]; SWAN will compute [fhigh], such that $\gamma = 1.1$, and write it to the PRINT file.
- [fhigh] and [msc]; SWAN will compute [flow], such that $\gamma = 1.1$, and write it to the PRINT file.
- [flow] and [fhigh]; SWAN will compute [msc], such that $\gamma = 1.1$, and write it to the PRINT file.

Note that [fhigh] = 1 Hz is usually fine. But more importantly, the first frequency bin should be empty, i.e. it should not contain energy. For instance, a value of [flow] = 0.03 Hz is recommended (especially when simulating a strong hurricane).

For illustration of a regular grid with its dimensions, see Figure 4.1.
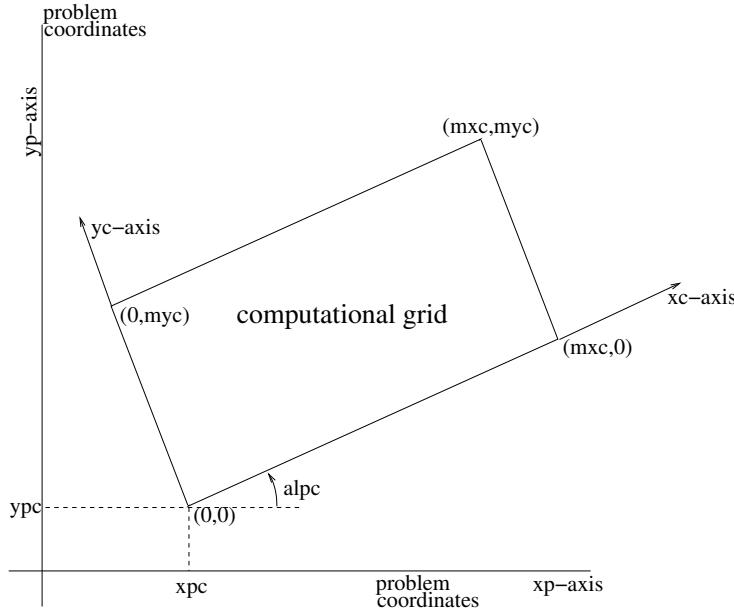
Figure 4.1: Coordinates of the origin [xpc] and [ypc], the orientation [alpc] and the grid point numbering of the computational grid with respect to the problem coordinate system. Note that in case of spherical coordinates the $xc-$ and $xp-$axes both point East.

```
READgrid COORdinates [fac] 'fname' [idla] [nhedf] [nhedvec] &


                        | -> FREe                 |
                        |                         |
                        |                | 'form' |  |
                        <      FORmat  <           > >
                        |                | [idfm] |  |
                        |                         |
                        |      UNFormatted        |
```

CANNOT BE USED IN 1D-MODE.

This command READGRID COOR must follow a command CGRID CURV. With this command (required if the computational grid is curvilinear; not allowed in case of a regular grid) the user controls the reading of the co-ordinates of the computational grid points. These co-ordinates must be read from a file as a vector ($x-$coordinate, $y-$coordinate of each single grid point). See command READINP for the description of the options in this command READGRID. SWAN will check whether all angles in the grid are > 0 and < 180 degrees. If not, it will print an error message giving the coordinates of the grid points involved. It is recommended to use grids with angles between 45 and 135 degrees.

```
                         | -> ADCirc
                         |
READgrid UNSTRUCtured  <      TRIAngle |
                         |                > 'fname'
                         |      EASYmesh |
```

CANNOT BE USED IN <u>1D-MODE</u>.

<u>This command</u> `READGRID UNSTRUC` <u>must follow a command</u> `CGRID UNSTRUC`. With this command (required if the computational grid is <u>unstructured</u>; not allowed in case of a regular or curvilinear grid) the user controls the reading of the (x, y) co-ordinates of the vertices including boundary markers and a connectivity table for triangles (or elements). This table contains three corner vertices around each triangle in counterclockwise order. This information should be provided by a number of files generated by one of the following grid generators currently supported by SWAN:

- ADCIRC (*http://www.adcirc.org*)

- Triangle (*http://www.cs.cmu.edu/afs/cs/project/quake/public/www/triangle.html*)

- Easymesh (*http://www-dinma.univ.trieste.it/nirftc/research/easymesh/easymesh.html*)

After setting up the vertices and the connectivity tables for cells and faces (automatically done in SWAN), SWAN will print some information concerning the used mesh, among others, number of vertices, cells and faces and minimum and maximum gridsizes. Furthermore, SWAN will check at two levels for a possible occurence of badly shaped triangles. Firstly, the number of triangles that meet at each vertex inside the mesh should not be smaller than 4 or larger than 10. Secondly, the angles inside each triangle should not be higher than 143°. If, at least, one of these two situations occur, SWAN will print an error message.

ADCIRC	the necessary grid information is read from file `fort.14` as used by ADCIRC. This file also contains the depth information that is read as well.
TRIANGLE	the necessary grid information is read from two files as produced by Triangle. The `.node` and `.ele` files are required. The basename of these files must be indicated with parameter `'fname'`.
EASYMESH	the necessary grid information is read from two files as produced by Easymesh. The `.n` and `.e` files are required. The basename of these files must be indicated with parameter `'fname'`.
`'fname'`	basename of the required files, i.e. without extension. Only meant for Triangle and Easymesh.

4.5.2   Input grids and data

```
                    | BOTtom       |
                    |              |
                    | WLEVel       |
                    |              |
                    |  | CURrent   |
                    | <            |
                    |  | VX        |
                    |  | VY        |
                    |              |
                    | FRiction     |
                    |              |
                    |  | WInd      |
                    | <            |
                    |  | WX        |
                    |  | WY        |
INPgrid       (<                   >)                                           &
                    | NPLAnts      |
                    |              |
                    | TURBvisc     |
                    |              |
                    | MUDLayer     |
                    |              |
                    | AICE         |
                    |              |
                    | HICE         |
                    |              |
                    | HSS          |
                    |              |
                    | TSS          |
                    |              |
                    | DSS          |


        | -> REGular [xpinp] [ypinp] [alpinp] [mxinp] [myinp] [dxinp] [dyinp] |
        |                                                                     |
        <      CURVilinear  [stagrx] [stagry] [mxinp] [myinp]                 > &
        |                                                                     |
        |      UNSTRUCtured                                                    |

      (EXCeption  [excval])                                                     &
```

```
                               | -> Sec  |
      (NONSTATionary [tbeginp] [deltinp] <    MIn   >  [tendinp])
                               |    HR   |
                               |    DAy  |
```

OPTIONS <u>CURVILINEAR</u> AND <u>UNSTRUCTURED</u> NOT FOR <u>1D-MODE</u>.

With this required command the user defines the geographic location, size and orientation of an input grid and also the time characteristics of the variable if it is not stationary. If this is the case (the variable is not stationary), the variable should be given in a sequence of fields, one for each time step [deltinp]. The actual reading of values of bottom levels, currents, etc. from file is controlled by the command READINP. <u>This command INPGRID must precede the following command READINP.</u>

There can be different grids for bottom level (BOTTOM), flow current (CURRENT), bottom friction coefficient (FRICTION), wind velocity (WIND), vegetation density (NPLANTS), turbulent viscosity (TURB), mud layer thickness (MUDLAY), sea ice fraction (AICE), sea ice thickness (HICE), sea-swell significant wave height (HSS), sea-swell mean wave period (TSS) and sea-swell mean wave direction (DSS). If the current velocity components are available on different grids, then option VX, VY can define these different grids for the $x-$ and $y-$component of the current, respectively (but the grids must have identical orientation). Different grids for VX and VY may be useful if the data are generated by a circulation model using a staggered grid. The same holds for the wind velocity components, i.e. WX and WY.

In case of a regular grid (option REGULAR in the INPGRID command) the current and wind velocity vectors are defined with the $x-$ and $y-$component of the current or wind vector with respect to the <u>$x-$axis of the input grid</u>. So, these velocity components are grid oriented.

In case of a curvilinear grid (option CURVILINEAR in the INPGRID command) the current and wind velocity vectors are defined with the $x-$ and $y-$component of the current or wind vector with respect to the <u>$x-$axis of the problem coordinate system</u>.

In case of an unstructured grid (option UNSTRUC in the INPGRID command) the current and wind velocity vectors are defined with the $x-$ and $y-$component of the current or wind vector with respect to the <u>$x-$axis of the problem coordinate system</u>.

For wind velocity, friction coefficient, vegetation density, mud layer, sea ice fraction (between 0 and 1) and sea-swell height and period it is also possible to use a constant value over the computational field (see commands WIND, VEGE, FRICTION, MUD, ICE, and OBSTACLE FIG, respectively). No grid definition for wind, friction, vegetation density, mud layer, sea ice concentration, or sea-swell height/period is then required.

Note that in case of option `BOTTOM` only stationary input field is allowed.

Note that in 1D mode, both $x-$ and $y-$components of the current and/or wind must be specified. Also, `VX` and `WX` must always be followed by `VY` and `WY`, respectively.

If the computational grid is unstructured, the input grids can be either regular or identical to the used computational grid.

Do not use the command `INP BOTTOM` when the unstructured grid of ADCIRC is employed! The file `fort.14` contains the bottom levels and will be read by SWAN through the command `READ UNSTRUC ADCIRC`.

If land points remain dry during the computation (no flooding!), then these points can be ignored. In this way, turn-around time and internal memory can be saved. This can be done by indicating bottom level in these points as exception value. See command `INPGRID BOTTOM EXCEPTION`. For parallel runs using MPI, an exception value for bottom levels should be prescribed in order to have a good load-balancing!

See Section 2.6 for more information on grids.

`BOTTOM`	defines the input grid of the bottom level. (For the definition of the bottom level, see command `READINP`).
`WLEV`	defines the input grid of the water level. (For the definition of the water level, see command `READINP`).
`CURRENT`	defines the input grid of the current field (same grid for $x-$ and $y-$components).
`VX`	defines the input grid of the $x-$component of the current field (different grid than $y-$component but same orientation).
`VY`	defines the input grid of the $y-$component of the current field (different grid than $x-$component but same orientation).
`FRICTION`	defines the input grid of the bottom friction coefficient (defined in command `FRICTION`, not to be confused with this option `FRICTION`!).
`WIND`	defines the input grid of the wind velocity field (same grid for $x-$ and $y-$component). If neither of the commands `WIND` and `READINP WIND` is used it is assumed that there is no wind.
`WX`	defines the input grid of the $x-$component of the wind velocity field (different grid than $y-$component but same orientation).
`WY`	defines the input grid of the $y-$component of the wind velocity field (different grid than $x-$component but same orientation).
`NPLANTS`	defines input grid of the horizontally varying vegetation density (defined in command `VEGETATION`).
`TURBVISC`	defines input grid of the horizontally varying turbulent viscosity (defined in command `TURBULENCE`).
`MUDLAYER`	defines input grid of the horizontally varying mud layer thickness (defined in command `MUD`).

AICE	defines the input grid of areal ice fraction, a number from 0 to 1.
	If the sea ice concentration is constant then see command `ICE` for specification.
	If neither of the commands `ICE` and `READINP AICE` are used, SWAN will assume that there is no sea ice.
HICE	defines the input grid of ice thickness, in meters.
HSS	defines the input grid of the sea-swell significant wave height.
	This input field is to be used to compute the source of radiated FIG energy along the coastlines; see command `OBSTACLE FIG`.
TSS	defines the input grid of a sea-swell mean wave period.
	This input field is to be used to compute the source of radiated FIG energy along the coastlines; see command `OBSTACLE FIG`.
DSS	defines the input grid of a sea-swell mean wave direction.
	This input field is to be used to compute the source of radiated FIG energy along the coastlines; see command `OBSTACLE FIG`.
REGULAR	means that the input grid is uniform and rectangular.
CURVILINEAR	means that the input grid is curvilinear; this option is available only if the computational grid is curvilinear as well. The input grid is identical (which is the default) to the computational grid, or it is staggered in $x-$ and/or $y-$direction.
	NOT FOR <u>1D-MODE</u>.
UNSTRUCTURE	means that the input grid is unstructured; this option is available only if the computational grid is unstructured as well. The input grid must be identical to the computational grid.
	NOT FOR <u>1D-MODE</u>.

For a `REGULAR` grid:

[xpinp]	geographic location ($x-$coordinate) of the origin of the input grid in <u>problem coordinates</u> (in m) if Cartesian coordinates are used or in degrees if spherical coordinates are use (see command `COORD`).
	Default: [xpinp] = 0. In case of spherical coordinates there is no default, the user must give a value.
[ypinp]	geographic location ($y-$coordinate) of the origin of the input grid in <u>problem coordinates</u> (in m) if Cartesian coordinates are used or in degrees if spherical coordinates are use (see command `COORD`).
	Default: [ypinp] = 0. In case of spherical coordinates there is no default, the user must give a value.
[alpinp]	direction of the positive $x-$axis of the input grid (in degrees, Cartesian convention). See command `COORD`.
	Default: [alpinp] = 0.
[mxinp]	number of meshes in $x-$direction of the input grid (this number is <u>one less</u> than the number of grid points in this direction!).
[myinp]	number of meshes in $y-$direction of the input grid (this number is <u>one less</u>

	than the number of grid points in this direction!).
	In <u>1D-mode</u>, [myinp] should be 0.
[dxinp]	mesh size in $x-$direction of the input grid,
	in m in case of Cartesian coordinates or
	in degrees if spherical coordinates are used, see command COORD.
[dyinp]	mesh size in $y-$direction of the input grid,
	in m in case of Cartesian coordinates or
	in degrees if spherical coordinates are used, see command COORD.
	In <u>1D-mode</u>, [dyinp] may have any value.
	Default: [dyinp] = [dxinp].

For a CURVILINEAR input (not fully tested for spherical coordinates):

[mxinp]	number of meshes in $\xi-$direction of the input grid (this number is <u>one less</u> than the number of grid points in this direction!).
	Default: [mxinp] = [mxc].
[myinp]	number of meshes in $\eta-$direction of the input grid (this number is <u>one less</u> than the number of grid points in this direction!).
	Default: [myinp] = [myc].
[stagrx]	staggered $x'-$direction with respect to computational grid; default: 0.
	Note: e.g. [stagrx]=0.5 means that the input grid points are shifted a half step in $x'-$direction; in many flow models $x-$velocities are defined in points shifted a half step in $x'-$direction.
[stagry]	staggered $y'-$direction with respect to computational grid; default: 0.
	Note: e.g. [stagry]=0.5 means that the input grid points are shifted a half step in $y'-$direction; in many flow models $y-$velocities are defined in points shifted a half step in $y'-$direction.
EXCEPTION	certain points inside the given grid that are to be ignored during the computation can be identified by means of an exception value as given in the corresponding input file as controlled by the command READINP.
	NOT FOR <u>1D-MODE</u>.
[excval]	exception value; required if the option EXCEPTION is used.
	Note: if [fac] $\neq 1$ (see command READINP), [excval] must be given as [fac] times the exception value.
NONSTATION	the variable is nonstationary (given in a time sequence of fields).
	NOT FOR <u>1D-MODE</u>.
[tbeginp]	begin time of the first field of the variable, the format is:

1 : ISO-notation	19870530.153000
2 : (as in HP compiler)	'30−May−87 15:30:00'
3 : (as in Lahey compiler)	05/30/87.15:30:00
4 :	15:30:00
5 :	87/05/30 15:30:00'
6 : as in WAM	8705301530

This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.

[deltinp]   time interval between fields, the unit is indicated in the next option:
  SEC   unit seconds
  MIN   unit minutes
  HR   unit hours
  DAY   unit days
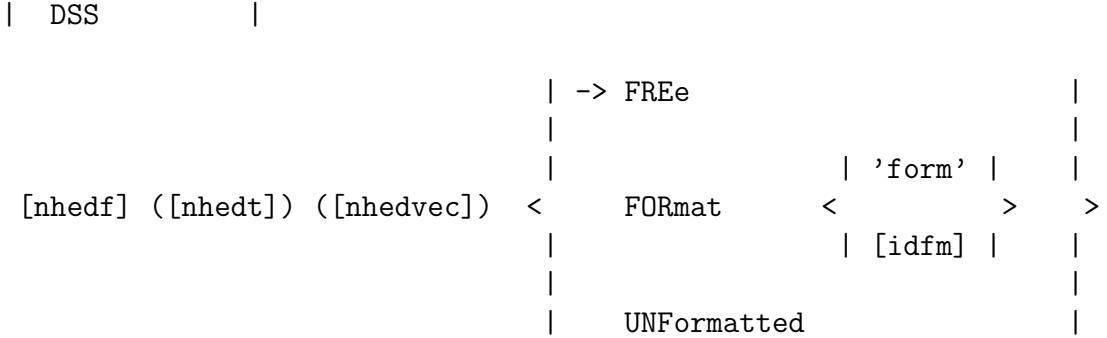
[tendinp]   end time of the last field of the variable, the format is:
  1 : ISO-notation   19870530.153000
  2 : (as in HP compiler)   '30−May−87 15:30:00'
  3 : (as in Lahey compiler) 05/30/87.15:30:00
  4 :   15:30:00
  5 :   87/05/30 15:30:00'
  6 : as in WAM   8705301530

This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.

```
                  |  BOTtom      |
                  |              |
                  |  WLEVel      |
                  |              |
                  |  CURrent     |
                  |              |
                  |  WInd        |
                  |              |
                  |  FRiction    |
                  |              |
                  |  NPLAnts     |
                  |              |      |  'fname1'              |
READinp   <   TURBvisc      >  [fac] <                          >   [idla]        &
                  |              |      |  SERIes    'fname2'    |
                  |  MUDLayer    |
                  |              |
                  |  AICE        |
                  |              |
                  |  HICE        |
                  |              |
                  |  HSS         |
                  |              |
                  |  TSS         |
                  |              |
```

```
              |  DSS          |


                                       | -> FREe                      |
                                       |                              |
                                       |                  | 'form' |  |
         [nhedf] ([nhedt]) ([nhedvec])  <     FORmat       <        >  >
                                       |                  | [idfm] |  |
                                       |                              |
                                       |     UNFormatted              |
```

With this required command the user controls the reading of values of the indicated vari-
ables from file. This command READINP must follow a command INPGRID. Note that for
each stationary or nonstationary field, one combination of INPGRID and READINP suffices
if one has more than one COMPUTE command in a run.

If the variables are in one file, then the READINP commands should be given in the same
sequence as the sequence in which the variables appear in the file.

BOTTOM	with this option the user indicates that bottom levels (in m) are to be read from file (bottom level positive downward relative to an arbitrary horizontal datum level). The sign of the input can be changed with option [fac] $= -1$. (see below).
WLEV	with this option the user indicates that water levels (in m) are to be read from file (water level positive upward relative to the same datum level as used in option BOTTOM). Sign of input can be changed with option [fac] $= -1$. If the water level is constant in space and time, the user can use the command SET to add this water level to the water depth.
CURRENT	rectilinear (curvilinear) input grid: with this option the user indicates that the $x-$ and $y-$component ($\xi-$ and $\eta-$component) (in m/s) are to be read from one and the same file (with one READINP command). With this option SWAN reads first all $x-$components ($\xi-$components), and then all $y-$components ($\eta-$components) (see [idla]). The first component ($x-$ or $\xi-$component) is always eastward oriented and the second one ($y-$ or $\eta-$component) is always northward oriented. There is one exception: in case of rotated rectilinear grid, the $x-$ and $y-$components are taken along the direction of the grid lines. unstructured input grid: with this option the user indicates that the $x-$ and $y-$component (in m/s) are to be read from one and the same file (with one READINP command). With this option SWAN reads first all $x-$components, and then all $y-$components. The order of these values to be read is identical to that of the unstructured computational grid. If the current velocity is relatively large, i.e. the Froude number $U/\sqrt{gd}$ is larger than 0.8, it will be reduced such that the Froude number becomes equal to 0.8.
WIND	rectilinear (curvilinear) input grid: with this option the user indicates that

the $x-$ and $y-$component ($\xi-$ and $\eta-$component) (in m/s) are to be read from one and the same file (with one `READINP` command). With this option SWAN reads first all $x-$components ($\xi-$components), and then all $y-$components ($\eta-$components) (see `[idla]`). The first component ($x-$ or $\xi-$component) is always eastward oriented and the second one ($y-$ or $\eta-$component) is always northward oriented. There is one exception: in case of rotated rectilinear grid, the $x-$ and $y-$components are taken along the direction of the grid lines. unstructured input grid: with this option the user indicates that the $x-$ and $y-$component (in m/s) are to be read from one and the same file (with one `READINP` command). With this option SWAN reads first all $x-$components, and then all $y-$components. The order of these values to be read is identical to that of the unstructured computational grid.

If the wind is constant, see command `WIND`.

FRICTION	with this option the user indicates that friction coefficient is to be read from file for Collins: `[cfw]` and for Madsen: `[kn]` (no space- or time-variable coefficient for the Jonswap expression, see command `FRICTION`). If the coefficients are constant in space and time: see command `FRICTION`.
NPLANTS	with this option the user indicates that horizontally varying vegetation density (per m^2) is to be read from file. If the density is constant then see command `VEGETATION` for specification.
TURBVISC	with this option the user indicates that horizontally varying turbulent viscosity (m^2/s) is to be read from file. If the viscosity is constant then see command `TURBULENCE` for specification.
MUDLAYER	with this option the user indicates that horizontally varying mud layer thickness (in m) is to be read from file. If the thickness is constant then see command `MUD` for specification.
AICE	with this option the user indicates that ice fraction (between 0 and 1) is to be read from file. If the sea ice concentration is constant then see command `ICE` for specification.
HICE	with this option the user indicates that ice thickness (in meters) is to be read from file. If the sea ice thickness is constant then see command `ICE` for specification.
HSS	with this option the user indicates that sea-swell significant wave height (in m) is to be read from file. If the sea-swell significant wave height is constant then see command `OBSTACLE FIG` for specification.
TSS	with this option the user indicates that sea-swell mean wave period (in s) is to be read from file. If the sea-swell mean wave period is constant then see command `OBSTACLE FIG` for specification.
DSS	with this option the user indicates that sea-swell mean wave direction (in degrees) is to be read from file. If the sea-swell mean wave direction is constant then see command `OBSTACLE FIG` for specification.
`[fac]`	SWAN multiplies all values that are read from file by `[fac]`. For instance if the bottom levels are given in unit decimeter, one should make `[fac]`=0.1 to

	obtain levels in m. To change sign of bottom level use a negative value of [fac]. Note that [fac] $= 0$ is not allowed! Default: [fac]$=1$.
'fname1'	name of the file with the values of the variable.
SERIES	with this option (only for MODE NONSTATIONARY) the user indicates that the <u>names</u> of the files containing the nonstationary variable(s) are located in a separate file with name 'fname2' (see below).
'fname2'	name of file that contains the <u>names</u> of the files where the variables are given. These names are to be given in proper time sequence. SWAN reads the next file when the previous file end has been encountered. In these files the input should be given in the same format as in the above file 'fname1' (that implies that a file should start with the start of an input time step).
[idla]	prescribes the order in which the values of bottom levels and other fields should be given in the file.

=1: SWAN reads the map from left to right starting in the upper-left-hand corner of the map (it is assumed that the $x-$axis of the grid is pointing to the right and the $y-$axis upwards). A new <u>line</u> in the map should start on a new <u>line</u> in the file. The lay-out is as follows:

```
1,myc+1      2,myc+1       ...       mxc+1, myc+1
1,myc        2,myc         ...       mxc+1, myc
...          ...           ...       ...
1,1          2,1           ...       mxc+1, 1
```

=2: as [idla]=1 but a new line in the map need not start on a new line in the file.

=3: SWAN reads the map from left to right starting in the lower-left-hand corner of the map. A new <u>line</u> in the map should start on a new <u>line</u> in the file. The lay-out is as follows:

```
1,1          2,1           ...       mxc+1, 1
1,2          2,2           ...       mxc+1, 2
...          ...           ...       ...
1,myc+1      2,myc+1       ...       mxc+1, myc+1
```

=4: as [idla]=3 but a new line in the map need not start on a new line in the file.

=5: SWAN reads the map from top to bottom starting in the lower-left-hand corner of the map. A new <u>column</u> in the map should start on a new <u>line</u> in the file. The lay-out is as follows:

```
1,1          1,2           ...       1, myc+1
2,1          2,2           ...       2, myc+1
```

...	...	...	...
mxc+1,1	mxc+1,2	...	mxc+1, myc+1

	=6: as [idla]=5 but a new column in the map need not start on a new line in the file. Default: [idla]=1. ONLY MEANT FOR STRUCTURED GRIDS.
[nhedf]	is the number of header lines at the start of the file. The text in the header lines is reproduced in the print file created by SWAN (see Section 3.3). The file may start with more header lines than [nhedf] because the start of the file is often also the start of a time step and possibly also of a vector variable (each having header lines, see below, [nhedt] and [nhedvec]). Default: [nhedf]=0.
[nhedt]	only if variable is time dependent: number of header lines in the file at the start of each time level. A time step may start with more header lines than [nhedt] because the variable may be a vector variable which has its own header lines (see below [nhedvec]). Default: [nhedt]=0.
[nhedvec]	for each vector variable: number of header lines in the file at the start of each component (e.g., $x-$ or $y-$component). Default: [nhedvec]=0.
FREE	With this option the user indicates that the values are to be read with free format. Free format is a standard of the computer programming language FORTRAN. The free format conventions in reading from a file are almost the same as the conventions for the command syntax given elsewhere in this manual; the most important differences are:
	1. There are no continuation marks, reading continues until the required number of data has been read, or until a slash (/) is encountered.
	2. Input lines can be longer than 80 characters (depending on the operating system of the computer).
	3. Comment is not allowed.
	With free format empty fields, repetition factors, and closure of a line by a slash, can be used.
FORMAT	with this option the user indicates that fixed format (FORTRAN convention) is to be used when reading the values from file. The format can be defined in one of two ways, by giving the format number [idfm] or the format string 'form'.
'form'	a user−specified format string according to Fortran convention, e.g. '(10X,12F5.0)'.
[idfm]	this format number is interpreted as follows:
	=1: Format according to BODKAR convention (a standard of the Ministry of Transport and Public Works in the Netherlands). Format string: (10X,12F5.0).
	=5: Format (16F5.0), i.e. an input line consists of 16 fields of 5 places each.

=6: Format (`12F6.0`), i.e. an input line consists of 12 fields of 6 places each.

=8: Format (`10F8.0`), i.e. an input line consists of 10 fields of 8 places each.

`UNFORMATTED` is a form of reading without conversion (binary files). Not recommended for ordinary use.

If the file does not contain a sufficient number of data (i.e. less than the number of grid points of the input grid), SWAN will write an error message to the `PRINT` file, and if [`itest`]>0 (see command `TEST`) it will reproduce the data in the `PRINT` file, using the layout according to [`idla`]=1. This echo of the data to print file is also made if the `READINP` command is embedded between two `TEST` commands in the command file as follows:

```
TEST 120
READINP ....
TEST 0
```

`WIND  [vel] [dir]`

With this optional command, the user indicates that the wind field is constant.

[`vel`]   wind velocity at 10 m elevation (m/s).

[`dir`]   wind direction at 10 m elevation (in degrees, Cartesian or Nautical convention, see command `SET`).

Both quantities [`vel`] and [`dir`] are required if this command is used except when the command `READINP WIND` is specified.
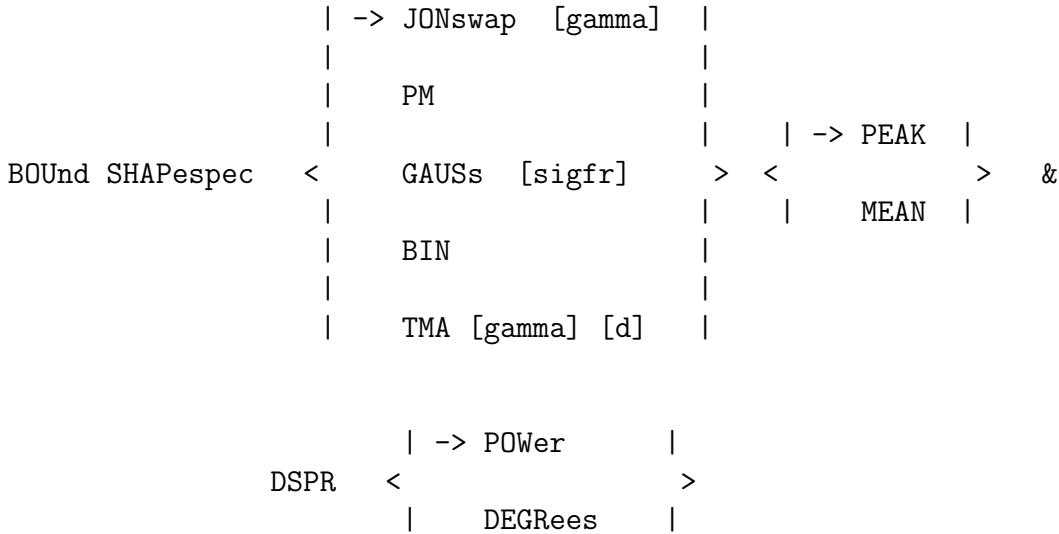
`ICE  [aice] [hice]`

With this optional command, the user indicates that one or more ice fields are constant.

[`aice`]   areal ice fraction, a number from 0 to 1.

[`hice`]   ice thickness (m).

If this command it used, it will read in both quantities. However, if `READINP AICE` is used, the value for [`aice`] here will be ignored, and similarly, if `READINP HICE` is used, the value for [`hice`] here will be ignored. It is permissible to have constant ice fraction and non-constant ice thickness, or vice versa.

4.5.3   Boundary and initial conditions

```
                    | -> JONswap  [gamma]  |
                    |                      |
                    |     PM               |
                    |                      |     | -> PEAK  |
BOUnd SHAPespec  <       GAUSs  [sigfr]    >  <             >  &
                    |                      |     |    MEAN  |
                    |     BIN              |
                    |                      |
                    |     TMA [gamma] [d]  |


                    | -> POWer      |
            DSPR  <                  >
                    |    DEGRees    |
```

This command `BOUND SHAPESPEC` defines the shape of the spectra (both in frequency and direction) at the boundary of the computational grid in case of parametric spectral input (see command `BOUNDSPEC`).

JONSWAP	JONSWAP spectrum will be used. This is the default.
[gamma]	peak enhancement parameter of the JONSWAP spectrum. Default: [gamma]=3.3.
PM	Pierson-Moskowitz spectrum will be used.
GAUSS	a Gaussian-shaped frequency spectrum will be used.
BIN	energy is located in one frequency bin (the frequency bin closest to the [per] value of command BOUNDSPEC).
[sigfr]	width of the Gaussian frequency spectrum expressed as a standard deviation in Hz.
TMA	the shape is JONSWAP though adapted to shallow water.
[d]	the reference depth at the wave maker in meters.
PEAK	the peak period (for definition, see Appendix A) is used as characteristic wave period. This is the default.
MEAN	T_{m01} (for definition, see Appendix A) is used as the characteristic wave period.
DSPR	option for expressing the width of the directional distribution; the distribution function itself is $\cos^m(\theta - \theta_{\text{peak}})$.
POWER	the directional width is expressed with the power m itself, this option is the default (note that the directional resolution should accommodate the directional width, see command CGRID).
DEGREES	the directional width is expressed in terms of the directional standard deviation of the $\cos^m(\theta - \theta_{\text{peak}})$ distribution (for definition, see Appendix A).

(Note that the directional resolution should accommodate the directional width, see command `CGRID`).

If this command is not used, the `JONSWAP` option will be used by SWAN with `[gamma]`=3.3 and `POWER` for the directional width.

```
                          | North |
                          | NW    |
                          | West  |
                          | SW    |   | -> CCW       |
            | -> SIDE  <   South  > <               >          |
            |             | SE    |   | CLOCKWise |            |
            |             | East  |                            |
            |             | NE    |                            |
            |             |       |                            |
BOUndspec <               | [k]   |                            >      &
            |                                                  |
            |                                                  |
            |                | -> XY  <  [x]   [y]  >       |   |
            |                |                             |   |
            |      SEGMent  <        | <  [i]   [j]  > |    >  |
                            |    IJ <                   >  |
                            |        | <  [k]  >       |   |


            |             | PAR    [hs] [per] [dir] [dd]        |
            | CONstant <                                        |
            |             | FILE 'fname' [seq]                  |
          <                                                      >
            |                                                  |
            |             | PAR  < [len] [hs] [per] [dir] [dd] > |
            | VARiable <                                        |
            |             | FILE < [len] 'fname' [seq] >        |
```

This command `BOUNDSPEC` defines parametric spectra at the boundary. It consists of two parts, the first part defines the boundary side or segment where the spectra will be given, the second part defines the spectral parameters of these spectra. Note that in fact only the incoming wave components of these spectra are used by SWAN. The fact that complete spectra are calculated at the model boundaries from the spectral parameters should not be misinterpreted. Only the incoming components are effective in the computation.

There are two ways to define the part of the boundary at which the spectra are imposed. The first (`SIDE`) is easiest if the boundary is one full side of the computational grid, although <u>it should not be used for curved boundaries</u>. The second (`SEGMENT`) can be used if the boundary segment goes around the corner of the grid, or if the segment is only part of one side of the grid.

This `BOUNDSPEC` command can be given a number of times, i.e. to define incident wave fields on various sides or segments of the boundary. One `BOUNDSPEC` command can be used for only one side or one contiguous segment.

Note that commands `SEGMENT` and `VARIABLE` are not supported in case of unstructured mesh version of SWAN in parallel mode.

`SIDE`	the boundary is one full side of the computational grid (in 1D cases either of the two ends of the 1D grid).
`NORTH, ...`	indicates on which side the boundary condition is applied. `N` means the boundary is the north edge (if present) of the computational domain, likewise for `W` is west, `S` is south, `E` is east, `NW` is northwest, `NE` is northeast, `SW` is southwest and `SE` is southeast. Note that the boundary is assumed to be a straight line. (Use the `SEGMENT` command as an alternative.) Another note: in case of Cartesian coordinates, the direction of the problem coordinate system must be defined by the user (see the `SET ...[north]` command), by default the positive $x-$axis points East. ONLY MEANT FOR STRUCTURED GRIDS.
`[k]`	indicates on which <u>side</u> of the <u>unstructured</u> grid the boundary condition is applied. The value of `[k]` corresponds to the boundary marker as indicated in file(s) produced by a grid generator (such as in the last column of the Triangle `.node` file and the Easymesh `.n` file or the last part of file `fort.14`). Boundary markers are tags to identify which vertices occur on a boundary of the mesh. It is assumed that the full side in question is represented by a <u>single</u> boundary marker. ONLY MEANT FOR UNSTRUCTURED MESHES.
`CCW,` `CLOCKWISE`	see description of `[len]` below; these option are only effective if the option `VARIABLE` is used (see below).
`SEGMENT`	is used if `SIDE` is not used, i.e. either the boundary segment goes around a corner of the grid, or the segment is only part of one side of the grid. The distance along the segment (see `[len]` below) is measured from the first point of the segment (see `XY` or `IJ` below).
`XY`	the segment is defined by means of a series of points in terms of problem coordinates; these points do not have to coincide with grid points. The (straight) line connecting two points must be close to grid lines of the computational grid (the maximum distance is one hundredth of the length of the straight line).

	This option is the default.
`[x]`, `[y]`	problem coordinates of a point of the boundary segment (see command `COORD`).
`IJ`	the segment is defined by means of a series of computational grid points given in terms of grid indices (origin at 0,0); not all grid points on the segment have to be mentioned. If two points are on the same grid line, intermediate points are assumed to be on the segment as well.
`[i]`, `[j]`	grid indices of a point of the segment. Values of `[i]` range between 0 and `[mxc]` (see command `CGRID`), values of `[j]` between 0 and `[myc]` (inclusive). ONLY MEANT FOR STRUCTURED GRIDS.
`[k]`	index of boundary vertex of the segment. This can be obtained in a grid generator file (`fort.14`, `.node` and `.n` files of ADCIRC, Triangle and Easymesh, respectively). The order must be counterclockwise! ONLY MEANT FOR UNSTRUCTURED MESHES.
`CONSTANT`	with this option the wave spectra are constant along the side or segment.
`VARIABLE`	with this option the wave spectra can vary along the side or segment. The incident wave field is prescribed at a number of points of the side or segment, these points are characterized by their distance from the begin point of the side or segment. The wave spectra for grid points on the boundary of the computational grid are calculated by SWAN by the spectral interpolation technique described in Section 2.6.3.
`PAR`	the wave spectra are defined by means of the following spectral parameters (see command `BOUND SHAPE` for spectral shape).
`[hs]`	the significant wave height (in m).
`[per]`	the characteristic period of the energy spectrum (relative frequency; which is equal to absolute frequency in the absence of currents); `[per]` is the value of the peak period (in s), if option `PEAK` is chosen in command `BOUND SHAPE` or `[per]` is the value of the mean period, if option `MEAN` was chosen in command `BOUND SHAPE`.
`[dir]`	the peak wave direction (θ_{peak}, direction in degrees, constant over frequencies).
`[dd]`	coefficient of directional spreading; a $cos^m(\theta)$ distribution is assumed. `[dd]` is interpreted as the directional standard deviation in degrees, if the option `DEGREES` is chosen in the command `BOUND SHAPE`. Default: `[dd]`=30. `[dd]` is interpreted as the power m, if the option `POWER` is chosen in the command `BOUND SHAPE`. Default: `[dd]`=2.
`[len]`	is the distance from the first point of the side or segment to the point along the side or segment for which the incident wave spectrum is prescribed. Note: these points do no have to coincide with grid points of the computational grid. `[len]` is the distance in m or degrees in the case of spherical

coordinates, **not** in grid steps. The values of `[len]` should be given
in ascending order. The length along a `SIDE` is measured in clockwise or
counterclockwise direction, depending on the options `CCW` or `CLOCKWISE` (see
above). The option `CCW` is the default. In case of a `SEGMENT` the length is
measured from the indicated begin point of the segment.

FILE
means that the incoming wave data are read from a file. There are three types
of files:
- TPAR files containing nonstationary wave parameters,
- files containing stationary or nonstationary 1D spectra
  (usually from measurements),
- files containing stationary or nonstationary 2D spectra
  (from other computer programs or other SWAN runs).

A `TPAR` file is for only one location; it has the string `TPAR` on the first
line of the file and a number of lines which each contain 5 numbers, i.e.:
Time (ISO-notation), Hs, Period (average or peak period depending on the
choice given in command `BOUND SHAPE`), Peak Direction (Nautical or Cartesian,
depending on command `SET`), Directional spread (in degrees or as power of cos
depending on the choice given in command `BOUND SHAPE`).

Example of a `TPAR` file:
```
TPAR
19920516.130000  4.2       12.       -110.     22.
19920516.180000  4.2       12.       -110.     22.
19920517.000000  1.2       8.        -110.     22.
19920517.120000  1.4       8.5       -80.      26
19920517.200000  0.9       6.5       -95.      28
```

The structure of the files containing 1D or 2D spectra is described in
Appendix D (there is no relation with the definition of the boundary file
generated by WAM or WAVEWATCH III). 1D and 2D files can be used for
stationary and nonstationary boundary conditions, and for one or more than
one location. The spectral frequencies (and directions in the case of a
2D spectrum) do not have to coincide with the frequencies and directions
used in the present SWAN run (in a nested run SWAN will interpolate to these
frequencies and directions). The coordinates of locations in the 1D and 2D
files are ignored when SWAN reads this file (SWAN uses the geographical
information in this `BOUNDSPEC` command instead).

'fname'
name of the file containing the boundary condition.

[seq]
sequence number of geographic location in the file (see Appendix D);
useful for files which contain spectra for more than one location.
Default: `[seq]` = 1 (i.e. first location).
Note: a `TPAR` file always contains only one location so in this case
`[seq]` must always be 1.

```
                        | -> CLOSed |
BOUndnest1  NEst 'fname' <           >
                        |    OPEN   |
```

With this optional command a nested SWAN run can be carried out with the boundary conditions obtained from a coarse grid SWAN run (generated in that previous SWAN run with command `NESTOUT` not to be confused with option NEST in this command `BOUNDNEST1`). For this nested SWAN run the user has to give the `CGRID` command to define the computational grid before this `BOUNDNEST1` command. The computational grid for SWAN in geographic space is the area bounded by the SWAN coarse run nest (SWAN boundary points of the nest). This implies that the boundaries of the SWAN coarse run nest and the boundaries of the SWAN nested computational area should be (nearly) identical (see below). The spectral frequencies and directions of the coarse grid run do not have to coincide with the frequencies and directions used in the nested SWAN run (as defined in the `CGRID` command); SWAN will interpolate to these frequencies and directions in the nested run (see Section 2.6.3).

To generate the nest boundary in the coarse grid run, use command `NGRID`. For the nested run, use the command `CGRID` with identical geographical information except the number of meshes (which will be much higher for the nested run).

This `BOUNDNEST1` command is not available for 1D computations; in such cases the commands `SPECOUT` and `BOUNDSPEC` can be used for the same purpose.

A nested SWAN run must use the same coordinate system as the coarse grid SWAN run. For a curvilinear grid, it is advised to use the commands `POINTS` or `CURVE` and `SPECOUT` instead of `NGRID` and `NESTOUT`.

NEST	with this option the user indicates that the boundary conditions (all four sides of the computational grid) are to be retrieved from a file created by a previous SWAN run (the present SWAN run is a nested run). The spectral frequencies (and directions in the case of a 2D spectrum) of the previous run do not have to coincide with the frequencies and directions used in the present SWAN run (see command `CGRID`); SWAN will interpolate the energy densities to these frequencies and directions (see Section 2.6.3).
'fname'	name of the file containing the boundary conditions for the present run, created by the previous SWAN coarse grid run. This file is structured according to the rules given in Appendix D for 2D spectra.
CLOSED	the boundary represented in the file is a closed rectangle; this is always the case if the `NESTOUT` command was used to generate the boundary condition file.

OPEN   the boundary represented in the file is <u>not a closed rectangle</u>.

```
                                    |-> CRAY |
                        | UNFormatted <           > |
                        |               | WKstat |  |
                        |                          |
BOUndnest2  WAMNest 'fname' <                        > [xgc] [ygc] [lwdate]
                        |                          |
                        | FREE                     |
```

CANNOT BE USED IN CASE OF <u>UNSTRUCTURED GRIDS</u>.

With this optional command (**not fully tested**) a nested SWAN run can be carried out with the boundary conditions obtained from a coarse grid WAM run (WAM Cycle 4.5, source code as distributed by the Max Planck Institute in Hamburg). For this nested SWAN run the user has to give the `CGRID` command to define the computational grid before this `BOUNDNEST2` command. The computational grid for SWAN in geographic space is the area bounded by the WAM coarse run nest (WAM boundary points of the nest). This implies that the boundaries of the WAM nest and the boundaries of the SWAN computational area should be (nearly) identical (see below). The spectral frequencies and directions of the coarse grid run do not have to coincide with the frequencies and directions used in the nested SWAN run (as defined in the `CGRID` command); SWAN will interpolate to these frequencies and directions in the nested run (see Section 2.6.3).

Note that SWAN will accept output of a WAM output location only if the SWAN grid point on the nest boundary lies within a rectangle between two consecutive WAM output locations with a width equal to 0.1 times the distance between these output locations on either side of the line between these WAM output locations.

This `BOUNDNEST2` command is not available for 1D computations.

Only boundary conditions generated by WAM Cycle 4.5 can be read properly by SWAN.

A nested SWAN run may use either Cartesian or spherical coordinates. A curvilinear grid may be used in the nested grid but the boundaries of this nest should conform to the rectangular course grid nest boundaries.

WAM output files are unformatted (binary); this usually implies that WAM and SWAN have to run on the same computer. For those cases where WAM and SWAN run on different types of machines (binary files do not transfer properly), the option `FREE` is available in this command. The distributed version of WAM does not support the required free format nesting output; WAM users who modify WAM such that it can make formatted output,

must modify WAM such that the files made by WAM can be read in free format, i.e. with at least a blank or comma between numbers.

'fname'   a file name that contains all the names of WAM files containing the nested
                boundary conditions in time-sequence (usually one file per day). For example,
                the contents of 'fname' can look like:
                CBO9212010000
                CBO9212020000
                CBO9212030000
                ....
                SWAN will read the boundary data from these WAM files one after the other.
UNFORMATTED   the user indicates that the WAM files are binary.
CRAY   input will be read from file created by the CRAY version of WAM.
WKSTAT   input will be read from file created by the WORKSTATION version of WAM.
FREE   the user indicates that the WAM files can be read with free format (these files
              are not generated standard by WAM!).
[xgc]   if SWAN is used with <u>Cartesian coordinates</u>:
              longitude of south-west corner of SWAN computational grid (in degrees); if the
              south-west corner of the nest in the WAM computation is on land this value is
              required.
              If SWAN is used with <u>spherical coordinates</u> then [xgc] is ignored by SWAN.
              Default: the location of the first spectrum encountered in the nest file.
[ygc]   if SWAN is used with <u>Cartesian coordinates</u>:
              longitude of south-west corner of SWAN computational grid (in degrees); if the
              south-west corner of the nest in the WAM computation is on land this value is
              required.
              If SWAN is used with <u>spherical coordinates</u> then [ygc] is ignored by SWAN.
              Default: the location of the first spectrum encountered in the nest file.
[lwdate]   length of character string for date-time as used in the WAM files. Possible values
              are: 10 (i.e. YYMMDDHHMM), 12 (i.e. YYMMDDHHMMSS) or 14 (i.e. YYYYMMDDHHMMSS).
              Default: [lwdate] = 12

```
                        | UNFormatted |   | -> CLOS |
BOUndnest3  WW3 'fname' <               > <           > [xgc] [ygc]
                        | FREe        |   |    OPEN  |
```

CANNOT BE USED IN CASE OF <u>UNSTRUCTURED GRIDS</u>.

With this optional command a nested SWAN run can be carried out with the boundary conditions obtained from a coarse grid WAVEWATCH III run. For this nested SWAN run the user has to give the CGRID command to define the computational grid before this

BOUNDNEST3 command. The computational grid for SWAN in geographic space is the area bounded by the WAVEWATCH III nest (WAVEWATCH III boundary points of the nest). This implies that the boundaries of the WAVEWATCH III nest and the boundaries of the SWAN computational area should be (nearly) identical (see below). The spectral frequencies and directions of the coarse grid run do not have to coincide with the frequencies and directions used in the nested SWAN run (as defined in the CGRID command); SWAN will interpolate to these frequencies and directions in the nested run (see Section 2.6.3).

The output files of WAVEWATCH III have to be created with the post-processor of WAVE-WATCH III as output transfer files (formatted or unformatted) with

    WW_3 OUTP (output type 1 sub type 3)

at the locations along the nest boundary (i.e. computational grid points in WAVE-WATCH III). These locations are equal to the corner points of the SWAN nested grid and optionally also distributed between the corner points of the SWAN nested grid (the boundary of the WAVEWATCH III nested grid need not be closed and may cover land). The locations should be output by WAVEWATCH III in sequence (going along the nest boundary, clockwise or counterclockwise). Note that SWAN will accept output of a WAVE-WATCH III output location only if the SWAN grid point on the nest boundary lies within a rectangle between two consecutive WAVEWATCH III output locations with a width equal to 0.1 times the distance between these output locations on either side of the line between these WAVEWATCH III output locations.

This BOUNDNEST3 command is not available for 1D computations.

A nested SWAN run may use either Cartesian or spherical coordinates. A curvilinear grid may be used in the nested grid but the boundaries of this nest should conform to the rectangular course grid nest boundaries.

'fname'	the name of the file that contains the spectra computed by WAVEWATCH III.
UNFORMATTED	the input WW3 files are binary.
FREE	the input WW3 files are formatted.
CLOSED	the boundary condition represented in the file is defined on a closed rectangle.
OPEN	the curve on which the boundary condition is given, is not closed.
[xgc]	if SWAN is used with <u>Cartesian coordinates</u>: longitude of south-west corner of SWAN computational grid (in degrees); if the south-west corner of the nest in the WW3 computation is on land this value is required. If SWAN is used with <u>spherical coordinates</u> then [xgc] is ignored by SWAN. Default: the location of the first spectrum encountered in the nest file.
[ygc]	if SWAN is used with <u>Cartesian coordinates</u>: longitude of south-west corner of SWAN computational grid (in degrees); if the south-west corner of the nest in the WW3 computation is on land this value is required.

If SWAN is used with <u>spherical coordinates</u> then [ygc] is ignored by SWAN.
Default: the location of the first spectrum encountered in the nest file.

Note that [xgc] and [ygc] are ignored if SWAN is used with spherical coordinates; if
SWAN is used with Cartesian coordinates the values must be provided by the user.

```
          | -> DEFault
          |
          |  ZERO
          |
INITial  <   PAR  [hs] [per] [dir] [dd]
          |
          |              | -> MULTiple |              | -> FREE
          | HOTStart <                  > 'fname' <
          |              |  SINGle   |              | UNFormatted
```

This command can be used to specify the initial values for a stationary (INITIAL HOTSTART
only) or nonstationary computation. The initial values thus specified override the default
initialization (see Section 2.6.3). Note that it is possible to obtain an initial state by
carrying out a previous stationary or nonstationary computation.

DEFAULT	the initial spectra are computed from the local wind velocities, using the deep-water growth curve of Kahma and Calkoen (1992), cut off at values of significant wave height and peak frequency from Pierson and Moskowitz (1964). The average (over the model area) spatial step size is used as fetch with local wind. By default, the shape of the spectrum is JONSWAP with a $\cos^2$-directional distribution (options are available: see command BOUND SHAPE).
ZERO	the initial spectral densities are all 0; note that if waves are generated in the model only by wind, waves can become non-zero only by the presence of the "A" term in the growth model; see the keyword AGROW in command GEN3.
PAR	the spectra in the entire computational area are generated from integral parameters [hs] etc. in the same way as done for the boundary using the command BOUNDSPEC.
[hs]	the significant wave height.
[per]	characteristic wave period of the energy spectrum (either peak or mean period, as determined by the options PEAK and MEAN in the command BOUND SHAPE).
[dir]	the peak wave direction (direction in degrees, Nautical or Cartesian convention, see command SET).
[dd]	the coefficient of directional spreading; a $\cos^m(\theta)$ distribution is assumed. See the options DEGREES and POWER in the command BOUND SHAPE.
HOTSTART	initial wave field is read from file; this file was generated in a previous SWAN

run by means of the `HOTFILE` command. If the previous run was nonstationary, the time found on the file will be assumed to be the initial time of computation. It can also be used for stationary computation as first guess. The computational grid (both in geographical space and in spectral space) must be identical to the one in the run in which the initial wave field was computed.

MULTIPLE	input will be read from multiple hotfiles obtained from a previous parallel MPI run. The number of files equals the number of processors. Hence, for the present run the same number of processors must be chosen.
SINGLE	input will be read from a single (concatenated) hotfile.
	In the case of a previous parallel MPI run, the concatenated hotfile can be created from a set of multiple hotfiles using the program `hcat.exe`, see Implementation Manual.
	<u>Note</u>: with this option you may change the number of processors when restart a parallel MPI run.
	ONLY MEANT FOR STRUCTURED GRIDS.
'fname'	name of the file containing the initial wave field.
FREE	the user indicates that the hotfile can be read with free format.
	This option is the default.
UNFORMATTED	the user indicates that the hotfile is binary.

4.5.4 Physics

GEN1 [cf10] [cf20] [cf30] [cf40] [edmlpm] [cdrag] [umin] [cfpm]

With this command the user indicates that SWAN should run in first-generation mode (see Scientific/Technical documentation).

[cf10]	controls the linear wave growth.
	Default: [cf10] = 188.
[cf20]	controls the exponential wave growth.
	Default: [cf20] = 0.59
[cf30]	controls the exponential wave growth.
	Default: [cf30] = 0.12
[cf40]	controls the dissipation rate, i.e., the time decay scale.
	Default: [cf40] = 250.
[edmlpm]	maximum non-dimensionless energy density of the wind sea part of the spectrum according to Pierson Moskowitz.
	Default: [edmlpm] = 0.0036
[cdrag]	drag coefficient.
	Default: [cdrag] = 0.0012

[umin]   minimum wind velocity (relative to current; all wind speeds are taken at 10 m
                above sea level).
                Default: [umin] = 1.
[cfpm]   coefficient which determines the Pierson Moskowitz frequency:
                $\sigma_{PM} = 2\pi\, g$ [cfpm] $/U_{10}$
                Default: [cfpm] = 0.13

GEN2 [cf10] [cf20] [cf30] [cf40] [cf50] [cf60] [edmlpm] [cdrag] [umin] [cfpm]

With this command the user indicates that SWAN should run in second-generation mode
(see Scientific/Technical documentation). The variables are identical to those in the GEN1
command except that [cf50] and [cf60] are added.

[cf50]   controls the spectral energy scale of the limit spectrum.
                Default: [cf50] = 0.0023
[cf60]   controls the spectral energy scale of the limit spectrum.
                Default: [cf60] = −0.223

```
             |      JANSsen [cds1] [delta]  |                                  |
             |                              |         | -> WU  |                |
             |      KOMen    [cds2] [stpm]    > DRAG <          >               |
             |                              |         |    FIT |                |
             | -> WESTHuysen                |                                  |
             |                                                                 |
             |      ST6      [a1sds] [a2sds] [p1sds] [p2sds]          &  |
GEN3    <                                                                  > (AGROW [a])
             |         | -> UP |     | -> HWANG |                           |
             |         <         > <      FAN    >  VECTAU|SCATAU     &  |
             |         |  DOWN  |     |    ECMWF  |                           |
             |                                                                 |
             |            |     TRUE10                |                       |
             |            <                            > DEBias [cdfac]    |
             |            | -> U10Proxy [windscaling] |                       |
```

With this command the user indicates that SWAN should run in third-generation mode for
wind input, quadruplet interactions and whitecapping. Triads, bottom friction and depth-
induced breaking are not activated by this command. See also the Scientific/Technical

documentation for more information. The option `GEN3 WESTH` is the default. Note that SWAN converts U_{10} to U_* using a wind drag formula to be specified below.

The choices with respect to option `GEN3 ST6` are elaborated on here. Some background information on these choices can be found in Rogers et al. (2012) (henceforth denoted as RBW12).

- [a1sds], [a2sds], [p1sds], and [p2sds]. These correspond to a_1, a_2, L, and M, respectively, in RBW12. The examples given below are calibrated (same method as in RBW12). The calibration is affected by the `VECTAU` and `U10PROXY` settings. We recommend that this calibration be kept to the examples given. However, it is possible to recalibrate using the same method as RBW12.

- `UP` vs. `DOWN`. The command `UP` is the default and strongly recommended. Corresponds to selection of normalization by $E_T(f)$ or $E(f)$ as in RBW12 (right column, page 1333).

- `HWANG`, `FAN`, or `ECMWF`. This corresponds to the selection of the wind drag formula. `HWANG` is the default and is unchanged from RBW12. `FAN` is from Fan et al. (2012). `ECMWF` follows the WAM Cycle 4 (Janssen) methodology. `FAN` and `ECMWF` use iterative procedures. The user is warned that selection of non-default `FAN` or `ECMWF` will significantly change outcome, e.g. a Hs decrease from 2.48 to 2.28 m. All calibrations were performed using the default `HWANG`. Also note that the usual drag formula, either Wu (1982) or Zijlema et al. (2012), will not be applied.

- `VECTAU` vs. `SCATAU`. The command `VECTAU` is the default and strongly recommended. It permits vector calculation for the stress calculation, rather than the simplified scalar calculation of Eq. (12) in RBW12.

- `TRUE10` vs. `U10PROXY`. Default is `U10PROXY` with [windscaling] = 32, a change from [windscaling] = 28 as used by RBW12. Non-default `TRUE10` directly uses the U10-based formula of Donelan et al. (2006), and is not recommended. `U10PROXY` directs SWAN to replace the Donelan et al. (2006) U_{10} with [windscaling] $\times U_*$. As noted by RBW12, Komen et al. (1984) (and so the default form of SWAN's Sds) use this approach also (with [windscaling] = 28). Increasing [windscaling] from 28 to 32 or 35 will improve prediction of mean square slope.

- `DEBIAS`. This option is effective only if `HWANG` is also used. This allows the user to counter bias in the input wind fields by providing a multiplier on the drag coefficient. Accommodation of bias in wind fields follows the idea of ST4 in WW3 (Ardhuin et al., 2010) via the `Betamax` parameter and ST6 in WW3 (Zieger et al., 2015) via the [cdfac] parameter. This parameter differs from `Betamax` insofar as former has the advantage that it is designed to be determined by evaluating by the winds, prior to the running of the wave model. By contrast the `Betamax` parameter is set by trial-and-error repeat runs of the wave model to reduce bias. Of course, the downside of

the `DEBIAS` method is that it does not guarantee small bias in the wave model when it is run, though in our experience, it has resulted in small bias. `[cdfac]` can be simply calculated as $\mathrm{mean}(\tau_{obs})/\mathrm{mean}(\tau_{model})$, where τ is the wind stress, and both (observation and model, respectively, with careful attention to anemometer height when applicable) are calculated via the same formula (e.g. Hwang, 2011) from U_{10}. This method of selecting the wind adjustment using U_*^2 (at least partially) accounts for the higher importance of high wind speeds in a wave model, making it better than an adjustment based on simple U_{10} bias. If the user has not evaluated the winds, it is recommended to omit this command, or use `DEB 1.`, which has the same effect as omitting it. The effect of $\sqrt{\texttt{[cdfac]}}$ is similar to changing the `[fac]` option (see command `READINP`) when reading in winds, though there are differences due to the nonlinear features of the drag formula: typically small, but larger with very strong winds. Also note that using the `[fac]` option will modify wind field outputs from SWAN.

Below are the ST6 calibration examples.

```
GEN3 ST6 4.7E-7 6.6E-6 4.0 4.0 UP HWANG VECTAU U10PROXY 28.0 AGROW
GEN3 ST6 4.7E-7 6.6E-6 4.0 4.0 UP FAN VECTAU U10PROXY 28.0 AGROW

GEN3 ST6 2.8E-6 3.5E-5 4.0 4.0 UP HWANG VECTAU U10PROXY 32.0 AGROW
GEN3 ST6 2.8E-6 3.5E-5 4.0 4.0 UP HWANG VECTAU U10PROXY 32.0 DEBIAS 0.89 AGROW

GEN3 ST6 6.5E-6 8.5E-5 4.0 4.0 UP HWANG VECTAU U10PROXY 35.0 AGROW
```

Note the different values of coefficients `[a1sds]` and `[a2sds]` in case of different `U10PROXY` settings! Usually one of the following two lines is recommended in regular SWAN simulations. Here, the command `SSWELL` for swell dissipation must be indicated using a separate line (see below).

```
GEN3 ST6 4.7E-7 6.6E-6 U10P 28. AGROW
GEN3 ST6 2.8E-6 3.5E-5 U10P 32. AGROW
```

Finally, the following two lines represent the original model described by RBW12 (see their Table 1, page 1336). Also `SSWELL` must be indicated using a separate line (see below).

```
GEN3 ST6 5.7E-7 8.0E-6 4.0 4.0 UP HWANG U10PROXY 28.0 AGROW
GEN3 ST6 5.7E-7 8.0E-6 4.0 4.0 UP AGROW
```

`JANSSEN`	linear growth	: Cavaleri and Malanotte-Rizzoli (1981), activated only if the keyword `AGROW` is present (see below)
	exponential growth: Janssen (1989, 1991).	
`[cds1]`	coefficient for determining the rate of whitecapping dissipation $(=C_{\mathrm{ds}}/\tilde{s}_{\mathrm{PM}}^4)$. Default: `[cds1]` $= 4.5$.	
`[delta]`	coefficient which determines the dependency of the whitecapping on wave number	

	(mix with Komen et al. formulation).
	Default: [delta] = 0.5.
KOMEN	linear growth : Cavaleri and Malanotte-Rizzoli (1981), activated only if the keyword AGROW is present (see below)
	exponential growth: Komen et al. (1984).
[cds2]	coefficient for determining the rate of whitecapping dissipation ($=C_{ds}$).
	Default: [cds2] = 2.36e-5.
[stpm]	value of the wave steepness for a Pierson-Moskowitz spectrum ($=\tilde{s}_{PM}^2$).
	Default: [stpm] = 3.02e-3.
WESTH	nonlinear saturation-based whitecapping combined with wind input of Yan (1987).
	This option is the default.
DRAG	indicates the wind drag formulation.
WU	wind drag formula according to Wu (1982).
	This option is the default.
FIT	drag coefficient is based on second order polynomial fit (see Zijlema et al., 2012).
ST6	wind input and whitecapping from Rogers et al. (2012).
[a1sds]	coefficient related to local dissipation term T_1.
[a2sds]	coefficient related to cumulative dissipation term T_2.
[p1sds]	power coefficient controlling strength of dissipation term T_1.
	Default: [p1sds] = 4.
[p2sds]	power coefficient controlling strength of dissipation term T_2.
	Default: [p2sds] = 4.
UP	select $E_T(f)$ for normalization of exceedance level.
	This option is the default.
DOWN	select $E(f)$ for normalization of exceedance level.
HWANG	wind drag formula according to Hwang (2011).
	This option is the default.
	Note: the drag formula of Zijlema et al (2012) will not be applied!
FAN	wind drag formula according to Fan et al. (2012).
ECMWF	wind drag formula based on WAM Cycle 4 (Janssen).
VECTAU	use vector integral for computing wind stress.
	This option is the default.
SCATAU	use scalar integral for computing wind stress.
TRUE10	wind velocity based on U_{10}.
U10PROXY	$U_{10} = $ [windscaling] $\times U_*$.
	This option is the default.
[windscalin]	factor to scale U_{10} with U_*.
	Default: [windscaling] = 28.
DEBIAS	allows user to counter bias in the input wind field.
[cdfac]	multiplier on drag coefficient.
	Default: [cdfac] = 1.
AGROW	if this keyword is <u>used</u>, the wave growth term of Cavaleri and Malanotte (1981) is activated.

if this keyword is <u>NOT used</u>, the wave growth term of Cavaleri and Malanotte (1981) is NOT activated.

<u>Note</u> that in nonstationary runs SWAN start with `INIT ZERO` (see command `INIT`), wave energy remains zero unless wave energy penetrates over the boundary or `AGROW` is activated. In case of stationary runs, however, SWAN will start with a first guess.

[a]   if the wave growth term of Cavaleri and Malanotte (1981) is activated, [a] is the proportionality coefficient in that term.
Default: [a] = 0.0015.

```
        | -> ARDhuin [cdsv]
SSWELL <
        |    ZIEger  [b1]
```

With this command the user can influence the type of swell dissipation included in the computations. The Zieger option is intended for use with negative wind input via the `NEGATINP` command. Zieger non-breaking dissipation follows the method used in WAVEWATCH III version 4 and does not include the steepness-dependent swell coefficient introduced in WAVEWATCH III version 5. As noted already, if `GEN3 ST6...` command is used, this `SSWELL` command should be provided.

Examples:

```
  SSWELL ARDHUIN 1.2

  SSWELL ZIEGER 0.00025
  NEGATINP 0.04
```

ARDHUIN   non-breaking dissipation of Ardhuin et al. (2010).
[cdsv]   coefficient related to laminar atmospheric boundary layer.
              Default: [cdsv] = 1.2
ZIEGER   non-breaking dissipation of Young et al. (2013), updated by Zieger et al. (2015).
[b1]   non-dimensional proportionality coefficient.

```
NEGatinp  [rdcoef]
```

With this optional command the user activates negative wind input. This is intended only for use with non-breaking swell dissipation `SSWELL ZIEGER`. Parameter `[rdcoef]` is a

fraction between 0 and 1, representing the strength of negative wind input. As an example, with [rdcoef]=0.04, for a spectral bin that is opposed to the wind direction, the wind input factor $W(k, \theta)$ is negative, and its magnitude is 4% of the corresponding value of the spectral bin that is in the opposite direction (i.e. in the wind direction). See Zieger et al. (2015) eq. 11, where a_0 is their notation for [rdcoef]. Default [rdcoef]=0.0 and [rdcoef]=0.04 is recommended, though as implied by Zieger et al. (2015), this value is not well-established, so the user is encouraged to experiment with other values.

```
             |   KOMen [cds2] [stpm] [powst] [delta] [powk]
WCAPping <
             | -> AB    [cds2] [br]   CURrent [cds3]
```

With this command the user can influence whitecapping which is usually included in the computations. Can be de-activated with command OFF WCAP.

KOMEN	whitecapping according to Komen et al. (1984) is applied.
[cds2]	coefficient for determining the rate of whitecapping dissipation $(=C_{ds})$.
	Default: [cds2] = 2.36e-5.
[stpm]	value of the wave steepness for a Pierson-Moskowitz spectrum $(=\tilde{s}_{PM}^2)$.
	Default: [stpm] = 3.02e-3.
[powst]	power of steepness normalized with the wave steepness of a Pierson-Moskowitz spectrum.
	Default: [powst] = 2.
[delta]	coefficient which determines the dependency of the whitecapping on wave number.
	Default: [delta] = 1.
	Note that this default has been changed since version 40.91A. The setting [delta] = 1 will improve the prediction of the wave energy at low frequencies, and hence the mean wave period. The original default was [delta] = 0, which corresponds to WAM Cycle 3. See the Scientific/Technical documentation for further details.
[powk]	power of wave number normalized with the mean wave number.
	Default: [powk] = 1.
AB	whitecapping according to Alves and Banner (2003) is applied.
	See also the paper of Van der Westhuysen et al. (2007).
	This is the default.
[cds2]	proportionality coefficient due to Alves and Banner (2003).
	Default: [cds2] = 5.0e-5.
[br]	threshold saturation level.
	Default: [br] = 1.75e-3.
CURRENT	indicates that enhanced current-induced dissipation as proposed by Van der Westhuysen (2012) is to be added.
[cds3]	proportionality coefficient.

Default: [cds3] = 0.8.

QUADrupl [iquad] [lambda] [Cnl4] [Csh1] [Csh2] [Csh3]

With this option the user can influence the computation of nonlinear quadruplet wave interactions which are usually included in the computations. Can be de-activated with command OFF QUAD.

Note that the DIA approximation of the quadruplet interactions is a poor approximation for long-crested waves and frequency resolutions that are deviating much more than 10% (see command CGRID).

Note that DIA is usually updated per sweep, either semi-implicit ([iquad] = 1) or explicit ([iquad] = 2). However, when ambient current is included, the bounds of the directional sector within a sweep may be different for each frequency bin (particularly the higher frequencies are modified by the current). So there may be some overlap of frequency bins between the sweeps, implying non-conservation of wave energy. To prevent this the user is advised to choose the integration of DIA per iteration instead of per sweep, i.e. [iquad] = 3.

If you want to speed up your computation a bit more, than the choice [iquad] = 8 is a good choice.

[iquad]   the quadruplets can be integrated by four different numerical procedures:
             = 1   semi-implicit computation of the nonlinear transfer with DIA per sweep
             = 2   fully explicit computation of the nonlinear transfer with DIA per sweep
             = 3   fully explicit computation of the nonlinear transfer with DIA per iteration
             = 8   fully explicit computation of the nonlinear transfer with DIA per iteration,
                    but neighbouring interactions are interpolated in piecewise constant manner.
             other techniques for the computation of quadruplets are
             = 4   Multiple DIA
             = 51   XNL (deep water transfer)
             = 52   XNL (deep water transfer with WAM depth scaling)
             = 53   XNL (finite depth transfer)
             Default: [iquad] = 2.
[lambda]   coefficient for quadruplet configuration in case of DIA.
             Default: [lambda]=0.25.
[Cnl4]   proportionality coefficient for quadruplet interactions in case of DIA.
             Default: [Cnl4]=3×10^7.
[Csh1]   coefficient for shallow water scaling in case of DIA.
             Default: [Csh1]=5.5.

[Csh2]   coefficient for shallow water scaling in case of DIA.
              Default: [Csh2]=0.833333.
[Csh3]   coefficient for shallow water scaling in case of DIA.
              Default: [Csh3]=−1.25.

```
            | -> CONstant [alpha] [gamma]
BREaking  <
            |    BKD [alpha] [gamma0] [a1] [a2] [a3]
```

With this command the user can influence depth-induced wave breaking in shallow water.

If this command is not used, SWAN will account for wave breaking anyhow (with default options and values). If the user wants to specifically ignore wave breaking, he should use the command: OFF BREAKING.

CONSTANT   indicates that a constant breaker index is to be used.
[alpha]   proportionality coefficient of the rate of dissipation.
              Default: [alpha] = 1.0.
[gamma]   the breaker index, i.e. the ratio of maximum individual
              wave height over depth.
              Default: [gamma] = 0.73.
BKD   indicates that the breaker index scales with both the
              bottom slope $(=\beta)$ and the dimensionless depth $(=kd)$
[alpha]   proportionality coefficient of the rate of dissipation.
              Default: [alpha] = 1.0.
[gamma0]   the reference γ for horizontal slopes.
              Default: [gamma0] = 0.54.
[a1]   first tunable coefficient for the breaker index.
              Default: [a1] = 7.59.
[a2]   second tunable coefficient for the breaker index.
              Default: [a2] = -8.06.
[a3]   third tunable coefficient for the breaker index.
              Default: [a3] = 8.09.

```
            | -> JONswap CONstant [cfjon]
            |
            |    COLLins [cfw]
FRICtion  <
```

```
|    MADsen   [kn]
|
|    RIPples [S] [D]
```

With this optional command the user can activate bottom friction. If this command is not used, SWAN will not account for bottom friction.

In SWAN four different formulations are available, i.e., that of Hasselmann et al. (1973, JONSWAP), Collins (1972), Madsen et al. (1988) and Smith et al. (2011).

The default option is: JONSWAP with a constant friction coefficient. The recommended value for typical sandy bottoms is 0.038 m^2s^{-3}. Note that this value is to be applied for both wind sea and swell conditions. (The use of the previous default value of 0.067 m^2s^{-3} is discouraged, even for wind sea conditions!) For smoother seafloors, like the Gulf of Mexico, a lower value of 0.019 m^2s^{-3} is advised.

JONSWAP	indicates that the semi-empirical expression derived from the JONSWAP results for bottom friction dissipation (Hasselmann et al., 1973, JONSWAP) should be activated. This option is the default.
CONSTANT	this default option indicates that the JONSWAP coefficient is constant.
[cfjon]	coefficient of the JONSWAP formulation.
	Default: [cfjon] = 0.038.
COLLINS	indicates that the expression of Collins (1972) should be activated.
[cfw]	Collins bottom friction coefficient.
	Default: [cfw] = 0.015.
	Note that [cfw] is allowed to vary over the computational region; in that case use the commands INPGRID FRICTION and READINP FRICTION to define and read the friction data. The command FRICTION is still required to define the type of friction expression. The value of [cfw] in this command is then not required (it will be ignored).
MADSEN	indicates that the expression of Madsen et al. (1988) should be activated.
[kn]	equivalent roughness length scale of the bottom (in m).
	Default: [kn] = 0.05.
	Note that [kn] is allowed to vary over the computational region; in that case use the commands INPGRID FRICTION and READINP FRICTION to define and read the friction data. This command FRICTION is still required to define the type of friction expression. The value of [kn] in this command is then not required (it will be ignored).
RIPPLES	indicates that the expression of Smith et al. (2011) should be activated.
	Here friction depends on the formation of bottom ripples and sediment size.
[S]	the specific gravity of the sediment.
	Default: [S] = 2.65.
[D]	the sediment diameter (in m).

Default: [D] = 0.0001.

```
        |                       / -> COLL |
        | -> DCTA [trfac] [p]   \    NONC |
        |                                 |
        |     LTA [trfac]                 |
TRIad <                                    >   &
        |     FTIM [trfac]                |
        |                                 |
        |     SPB [trfac] [a]             |


            | -> ELDeberky [urcrit] |              |    FG
   BIPHase <                          >   TRAnsfer <    MS
            | DEWIT [lpar]          |              |    BRedmose
                                                   | -> QUadwave
```

With this command the user can activate the triad wave-wave interactions. If this command is not used, SWAN will not account for triads.

DCTA	indicates that the DCTA method of Booij et al. (2009) should be activated. This option is the default.
[trfac]	scaling factor that controls the intensity of the triad interaction due to DCTA. Default: [trfac] = 4.4.
[p]	shape coefficient to force the high-frequency tail. Default: [p] = 4/3.
COLL	indicates that the triad interactions due to DCTA are restricted to collinear ones only. This is the default.
NONC	indicates to include noncollinear interactions within the DCTA framework.
LTA	indicates that the extended LTA method should be activated.
[trfac]	scaling factor that controls the intensity of the triad interaction due to LTA. Default: [trfac] = 1.0.
FTIM	indicates that the full triad interaction model (FTIM) should be activated.
[trfac]	scaling factor that controls the intensity of the triad interaction due to FTIM. Default: [trfac] = 1.0.
SPB	indicates that the SPB method of Becq-Girard et al. (1999) should be activated.
[trfac]	scaling factor that controls the intensity of the triad interaction due to SPB. Default: [trfac] = 0.9.
[a]	calibration parameter for tuning K in Eq. (5.1) of Becq-Girard et al. (1999). This parameter is associated with relaxation of the resonance condition and

	is a function of the local wave number: $K = a \cdot k_{\text{loc}}$.

is a function of the local wave number: $K = a \cdot k_{\text{loc}}$.
Note that with the current tuning the nonlinear interaction coefficient of
Madsen and Sørensen (1993) will be employed, unless specified otherwise
(see the keyword TRANSFER below).
Default: [a] = 0.95.

BIPHASE   defines the parametrization of biphase.
            Note: this option does not applied to the SPB method.

ELDEBERKY   the biphase parametrization as function of Ursell number as given by
            Eldeberky (1996) will be used. This is the default.

[urcrit]   the critical Ursell number appearing in the parametrization.
            Note: the value of [urcrit] is setted by Eldeberky (1996) at 0.2 based on a
            laboratory experiment, whereas Doering and Bowen (1995) employed the value
            of 0.63 based on the field experiment data.
            Default: [urcrit] = 0.63.

DEWIT   De Wit (2022) proposed a parametrization of the biphase evolution based on
            the local bed slope and peak wave period.

[lpar]   scales spatial averaging of the De Wit's biphase in terms of a multiple of peak
            wave length of the incident wave field.
            Note: [lpar] = 0 means no averaging.
            Default: [lpar] = 0.

TRANSFER   defines the interaction coefficient to describe the nonlinear energy transfers
            in triads of shoaling waves.
            Note: this option does not applied to the DCTA method.

FG   Freilich and Guza (1984) suggested the use of the Boussinesq-wave model
            of Peregrine (1967) to compute the interaction coefficient.

MS   the nonlinear transfer coefficient derived from the Boussinesq-wave theory
            of Madsen and Sørensen (1993) is employed.

BREDMOSE   The exact transfer coefficient (second order Stokes solution) of
            Bredmose et al (2005) is applied.

QUADWAVE   Akrish et al (2024) proposed the parametrized transfer coefficient that
            optimizes the nonlinearity of the fully dispersive quadratic wave model
            of Bredmose et al (2005).
            This is the default.

VEGEtation [iveg] < [height] [diamtr] [nstems] [drag] >

With this command the user can activate wave damping due to vegetation based on the
Dalrymple's formula (1984) as implemented by Suzuki et al. (2011). This damping is
uniform over the wave frequencies. An alternative is the frequency-dependent (canopy)
dissipation model of Jacobsen et al. (2019). If this command is not used, SWAN will not

account for vegetation effects.

The vegetation (rigid plants) can be divided over a number of vertical segments and so, the possibility to vary the vegetation vertically is included. Each vertical layer represents some characteristics of the plants. These variables as indicated below can be repeated as many vertical layers to be chosen.

Note that with respect to the Jacobsen et al. (2019) method, vertical layering of the vegetation is not yet implemented.

[iveg]	indicates the method for the vegetation computation: = 1 Suzuki et al. (2011) = 2 Jacobsen et al. (2019) Default: [iveg] = 1.
[height]	the plant height per layer (in m).
[diamtr]	the diameter of each plant stand per layer (in m).
[nstems]	the number of plant stands per square meter for each layer. Note that [nstems] is allowed to vary over the computational region to account for the zonation of vegetation. In that case use the commands INPGRID NPLANTS and READINP NPLANTS to define and read the vegetation density. The (vertically varying) value of [nstems] in this command will be multiplied by this horizontally varying plant density. Default: [nstems] = 1.
[drag]	the drag coefficient per layer.

MUD   [layer]   [rhom]   [viscm]

With this command the user can activate wave damping due to mud based on Ng (2000). If this command or the commands INPGRID MUDLAY and READINP MUDLAY are not used, SWAN will not account for muddy bottom effects.

[layer]	the thickness of the mud layer (in m). Note that [layer] is allowed to vary over the computational region to account for the zonation of muddy bottom. In that case use the commands INPGRID MUDLAY and READINP MUDLAY to define and read the layer thickness of mud. The value of [layer] in this command is then not required (it will be ignored).
[rhom]	the density of the mud layer (in kg/m^3). Default: [rhom] = 1300.
[viscm]	the kinematic viscosity of the mud layer (in m^2/s). Default: [viscm] = 0.0076.

```
        | -> R19    [c0] [c1] [c2] [c3] [c4] [c5] [c6]
SICE  <     D15    [Chf]
        |   M18    [Chf]
        |   R21B   [Chf npf]
```

Using this command, the user activates a sink term to represent the dissipation of wave energy by sea ice. The R19 method is empirical/parametric: a polynomial based on wave frequency (Rogers, 2019). This polynomial (in 1/m) has seven dimensional coefficients; see Scientific/Technical documentation for details. If this command is not used, SWAN will not account for sea ice effects.

Note that it is also necessary to describe the ice, using the ICE command (for uniform and stationary ice) or INPgrid/READinp commands (for variable ice).

The default R19 setting is the case of c2=1.06×10^{-3} and c4=2.3×10^{-2}. Thus, the following commands are equivalent

- SICE

- SICE R19

- SICE R19 0.0 0.0 1.06E-3 0.0 2.3E-2 0.0 0.0

This recovers the polynomial of Meylan et al. (2014), calibrated for a case of ice floes, mostly 10 to 25 m in diameter, in the marginal ice zone near Antarctica. Examples for other calibrations can be found in the Scientific/Technical documentation.

The three non-default methods all include dependence on ice thickness. These are

1. D15: The method of Doble et al. (2015), with default value of [Chf]=0.1.

2. M18: A method taken from Meylan et al. (2018), with default value of [Chf]=0.059.

3. R21B: A method proposed by Rogers et al. (2021b), with default values of [Chf]=2.9 and [npf]=4.5.

Additional details about these three methods, and information about other calibrations can be found in the Scientific/Technical documentation.

[aice]   ice concentration as a fraction from 0 to 1.
              Note that [aice] is allowed to vary over the computational region to account
              for the zonation of ice concentration. In that case use the commands
              INPGRID AICE and READINP AICE to define and read the sea concentration.
              The value of [aice] in this command is then not required (it will be

ignored).

[c0]	polynomial coefficient (in 1/m) for determining the rate of sea ice dissipation.
[c1]	polynomial coefficient (in s/m) for determining the rate of sea ice dissipation.
[c2]	polynomial coefficient (in s^2/m) for determining the rate of sea ice dissipation.
[c3]	polynomial coefficient (in s^3/m) for determining the rate of sea ice dissipation.
[c4]	polynomial coefficient (in s^4/m) for determining the rate of sea ice dissipation.
[c5]	polynomial coefficient (in s^5/m) for determining the rate of sea ice dissipation.
[c6]	polynomial coefficient (in s^6/m) for determining the rate of sea ice dissipation.
[Chf]	a simple coefficient of proportionality.
[npf]	controls the degree of dependence on frequency and ice thickness.

```
TURBulence  [ctb]   (CURrent [tbcur])
```

With this optional command the user can activate turbulent viscosity. This physical effect is also activated by reading values of the turbulent viscosity using the READGRID TURB command, but then with the default value of [ctb]. The command READGRID TURB is necessary if this command TURB is used since the value of the viscosity is assumed to vary over space.

[ctb]	the value of the proportionality coefficient appearing in the energy dissipation term. Default: [ctb] = 0.01.
CURRENT	if this keyword is present the turbulent viscosity will be derived from the product of the depth and the absolute value of the current velocity. If the command READGRID TURB is used, this option is ignored; the values read from file will prevail.
[tbcur]	the factor by which depth × current velocity is multiplied in order to get the turbulent viscosity. Default: [tbcur] = 0.004.

```
BRAGg [ibrag] [nreg] [cutoff]                              &

      | -> FT
    <
      |     FILE 'fname' [idla] [mkx] [mky] [dkx] [dky]
```

Using this optional command, the user activates a source term to represent the scattering of waves due to changes in the small-scale bathymetry based on the theory of Ardhuin and

Herbers (2002). If this command is not used, SWAN will not account for Bragg scattering.

The underlying process is related to the bed elevation spectrum that describes the random variability of the bathymetry at the scale of the wave length on top of a slowly varying depth. To input this spectrum in the model, two options are available. One option is to read a spectrum from a file. This single bottom spectrum will subsequently be applied in all active grid points. The assumption being made here is that the inputted bottom is gently sloping. Note that the bottom spectrum must be given as a function of the wave number $\vec{k}$.

Another option is to compute the spectrum by a Fourier transform from $\vec{x}$ to $\vec{k}$ of the bed modulations around a computational grid point. First, one must define a square region with a fixed size around the grid point in order to perform the Fourier transform. The size should correspond to a multiple of the wave length at which refraction is resolved (i.e. consistent with the mild slope assumption). Next, the amplitude modulation of the small-scale bathymetry is obtained by substracting a slowly varying bed level from the inputted high-resolution bathymetric data within this square region. Here, the smooth bed level is achieved using a bilinear fit. During the computation, however, SWAN employs the gently sloping bed as the mean of the original bathymetry within the given square around each computational grid point. Finally, the corresponding bottom spectrum is computed with an FFT.

An important note to be made here is the fact that adding the Bragg scattering source term to the action balance equation gives rise to a fairly stiff equation. The best remedy is to run SWAN in the <u>nonstationary mode</u> with a relatively small time step or in the <u>stationary mode</u> with some under relaxation (see command `NUM STAT [alfa]`).

`[ibrag]`	indicates the computation of Bragg scattering term:
	= 1 source term is calculated <u>per sweep</u> and bottom spectrum is interpolated at the difference wave number *a priori* (thus requiring storage)
	= 2 source term is calculated <u>per sweep</u> and bottom spectrum is interpolated at the difference wave number per sweep (no storage)
	= 3 source term is calculated <u>per iteration</u> and bottom spectrum is interpolated at the difference wave number per iteration (no storage)
	Default: `[ibrag]` = 1.
`[nreg]`	size of square region around computational grid point (centered) for computing the mean depth and, if desired, the bed elevation spectrum. It is expressed in terms of the number of grid points (per direction) of the inputted bottom grid.
`[cutoff]`	cutoff to the ratio between surface and bottom wave numbers.
	<u>Note</u>: see the Scientific/Technical documentation for details.
	Default: `[cutoff]` = 5.
`FT`	if this keyword is present the bottom spectrum will be computed in each active grid point using an FFT.

Note: the depth in each computational grid point is computed as the average of the inputted (high-resolution) bed levels within the square region.

FILE   means that the bed elevation spectrum $F^B(k_x, k_y)$ is read from a file.
Note: this spectrum is taken to be uniform over the entire computational domain.

'fname'   name of the file containing the bottom spectrum.

[idla]   prescribes the order in which the spectra values should be given in the file; see command READINP.

[mkx]   number of cells in $x-$direction of the wave number grid related to bottom spectrum (this number is <u>one less</u> than the number of points in this direction!)

[mky]   number of cells in $y-$direction of the wave number grid related to bottom spectrum (this number is <u>one less</u> than the number of points in this direction!)
Default: [mky] = [mkx].

[dkx]   mesh size in $x-$direction of the wave number grid related to bottom spectrum (1/m).

[dky]   mesh size in $y-$direction of the wave number grid related to bottom spectrum (1/m).
Default: [dky] = [dkx].

LIMiter [ursell] [qb]

With this command the user can de-activate permanently the quadruplets when the actual Ursell number exceeds [ursell]. Moreover, as soon as the actual fraction of breaking waves exceeds [qb] then the action limiter will not be used in case of decreasing action density.

[ursell]   the upper threshold for Ursell number.
Default: [ursell] = 10.0.

[qb]   the threshold for fraction of breaking waves.
Default: [qb] = 1.0.

```
          | -> TRANSm [trcoef]                  |
          |                                     |
          |    TRANS1D < [trcoef] >             |
          |                                     |
OBSTacle <      TRANS2D < [trcoef] >            >            &
          |                                     |
          |        | -> GODA [hgt] [alpha] [beta]   |
          |   DAM <                             |
          |        |     DANGremond [hgt] [slope] [Bk]  |
```

```
                    | -> RSPEC       |
        ( REFL [reflc] <                  > )                        &
                    |      RDIFF [pown] |

        ( FREEboard [hgt] [gammat] [gammar] Quay ) LINe <[xp] [yp]>
```

CANNOT BE USED IN <u>1D-MODE</u>.

With this optional command the user provides the characteristics of a (line of) sub-grid obstacle(s) through which waves are transmitted or against which waves are reflected (possibly both at the same time). The obstacle is sub-grid in the sense that it is narrow compared to the spatial meshes; its length should be at least one mesh length.

The location of the obstacle is defined by a sequence of corner points of a line. The obstacles interrupt the propagation of the waves from one grid point to the next wherever this obstacle line is located between two neighbouring grid points (of the computational grid; the <u>resolution of the obstacle</u> is therefore equal to the computational grid spacing). This implies that an obstacle to be effective must be located such that it crosses at least one grid line. This is always the case when an obstacle is larger than one mesh length.

1. If a straight line is defined with more than two points, then the sum of the reflection of the parts may differ from the situation when you define it with just two points. This is due to the way obstacles are handled numerically in SWAN. It defines from computational grid point to its neighbor whether there is a crossing with an obstacle. In defining which directions of the wave spectrum should be reflected, i.e which directions are pointed towards the obstacle, it uses the obstacle coordinates as defined by the user to define the angle of inclusion. This angle will be smaller if more points are defined, and so the reflected energy will be less for the computational grid point. This problem becomes smaller if the computational grid points are closer to the obstacle.

   So the advise is to define obstacles with the least amount of points possible.

2. In case of sharp angles in the obstacles, it is very likely that there are more than one crossing between two computational grid points. In this case SWAN does not give correct reflection results.

   - Avoid sharp angles in the obstacle definition.
   - If necessary, put corner point of the sharp edge exactly on a line between two computational grid points, but not exactly on the grid point.

3. At the boundaries of the computational area, the reflected spectrum is not taken into account. This can only be resolved by a different treatment of the boundaries in the

program. Until this time, it is recommended to place obstacles at the inner area of the computational grid, not at or through the boundaries.

4. Obstacle lines are only effective when the obstacle line is bordered by wet points on both sides. In practice, this may give problems when a reflection line is also used to specify a boundary between wet and land points. This can be avoided by shifting the position of the reflection line or by creating wet points on the land side of the obstacle line.

The computation of transmission and reflection is problematic if an obstacle runs exactly through one or more grid points of the computational <u>structured</u> grid; SWAN will move the obstacle over a small distance (1% of the mesh size) if this occurs. Note that this will not be done in case of unstructured grids.

The reflection results are incorrect if more than one obstacle crosses the same grid line between two neighbouring grid points. SWAN is not able to detect this, so the user must check if his model fulfills this condition.

TRANSM	with this option the user indicates that the transmission coefficient is a constant.
[trcoef]	constant transmission coefficient, formulated in terms of wave height, i.e. ratio of transmitted significant wave height over incoming significant wave height. Default: [trcoef]=0.0 (no transmission = complete blockage).
TRANS1D	with this option the user indicates that the transmission coefficient is frequency dependent. For each frequency the user can specify a transmission coefficient as indicated below. The number of these transmission values must be equal to the number of frequencies, i.e. [msc] + 1.
[trcoef]	transmission coefficient per frequency, formulated in terms of wave height, i.e. ratio of transmitted significant wave height over incoming significant wave height.
TRANS2D	with this option the user indicates that the transmission coefficient is frequency and direction dependent. For each direction the user can assign different transmission coefficients to frequencies. The number of these transmission values must be equal to the number of frequencies multiplied by the number of directions.
[trcoef]	transmission coefficient per frequency for each direction, formulated in terms of wave height, i.e. ratio of transmitted significant wave height over incoming significant wave height. It is advised to put the values assigned to all frequencies on a single line for each direction. So the number of lines equals the number of directions. Each line may be terminated with a continuation mark &.
DAM	with this option the user indicates that the transmission coefficient depends on the incident wave conditions at the obstacle and on the obstacle height (which may be submerged).
GODA	with this option the user indicates to use the Goda/Seelig formula (1979) for computing transmission coefficient.
[hgt]	the elevation of the top of the obstacle above reference level (same reference level as for bottom etc.); use a negative value if the top is below that reference

	level. If this command is used, this value is required.
[alpha]	coefficient determining the transmission coefficient for Goda's transmission formula. Default: [alpha]=2.6.
[beta]	another coefficient determining the transmission coefficient for Goda's transmission formula. Default: [beta]=0.15.
DANGREMOND	with this option the user indicates to use the d'Angremond/Van der Meer formula (1996) for computing the transmission coefficient.
[hgt]	the elevation of the top of the obstacle above reference level (same reference level as for bottom etc.); use a negative value if the top is below that reference level. If this command is used, this value is required.
[slope]	the slope of the obstacle (in degrees). If this command is used, this value is required.
[Bk]	the crest width of the obstacle. If this command is used, this value is required.
REFL	if this keyword is present the obstacle will reflect wave energy (possibly in combination with transmission). Reflections will be computed only if the spectral directions cover the full 360°, i.e. if in the command CGRID the option CIRCLE is activated.
[reflc]	constant reflection coefficient, formulated in terms of wave height, i.e. ratio of reflected significant wave height over incoming significant wave height. Restriction: $0 \leq$ [reflc] ≤ 1. Default: [reflc]=1, if the keyword REFL is present, otherwise [reflc]=0. Note: the program checks if the criterion [reflc]^2+[trcoef]$^2 \leq 1$ is fulfilled.
RSPEC	indicates specular reflection which is the default. The angle of reflection equals the angle of incidence.
RDIFF	indicates diffuse reflection, i.e. specular reflection where incident waves are scattered over reflected direction.
[pown]	each incoming direction θ is scattered over reflected direction θ_{refl} according to $\cos^{[\mathtt{pown}]}(\theta - \theta_{\mathrm{refl}})$. The parameter [pown] indicates the width of the redistribution function. Default: [pown] = 1.
FREEBOARD	with this option the user indicates that the fixed transmission [trcoef] and reflection [reflc] coefficients are freeboard dependent. The freeboard dependency has no effect on the transmission coefficient as computed using the DAM option.
[hgt]	the elevation of the top of the obstacle or height of the quay above the reference level (same reference level as for the bottom). Use a negative value if the top is below that reference level. Specifying this parameter is required when option FREE is used. In case [hgt] is also specified in the DAM option, both values of [hgt] should be equal for consistency.
[gammat]	shape parameter of relative freeboard dependency of transmission coefficient. This parameter should be higher than zero. See Scientific/Technical documentation

                for background information.
                Default: [gammat] = 1.

[gammar]   shape parameter of relative freeboard dependency of reflection coefficient.
                This parameter should be higher than zero. See Scientific/Technical documentation
                for background information.
                Default: [gammar] = 1.

QUAY   with this option the user indicates that the freeboard dependency of the transmission
                and reflection coefficients also depends on the relative position of an obstacle-linked
                grid point with respect to the position of the obstacle line representing the edge of a
                quay. In case the active grid point is on the deeper side of the obstacle, then the
                correction factors are applied using the parameters [hgt], [gammat] and [gammar].
                In case the active grid point is on the shallower side of the obstacle, the reflection
                coefficient is set to 0 and the transmission coefficient to 1. This option only works
                in combination with the keyword FREE. See Scientific/Technical documentation
                for background information.

LINE   with this required keyword the user defines the location of the obstacle(s).

[xp], [yp]   coordinates of a corner point of the line that defines the location of the
                obstacle(s) (in <u>problem coordinates</u>):
                if Cartesian coordinates are used in m or
                if spherical coordinates are used in degrees (see command COORD).
                At least two corner points must be provided.

```
OBSTacle  FIG [alpha1] [hss] [tss] [dss] [dd]  REFL [reflc]   LINe <[xp] [yp]>
```

CANNOT BE USED IN <u>1D-MODE</u>.

With this optional command the user specifies the obstacles along which the free infra-gravity (FIG) energy is radiated. By placing the obstacles close to the shorelines SWAN will include the FIG source term along the coastlines according to the parametrization of Ardhuin et al. (2014).

The location of the obstacle is defined by a sequence of corner points of a line. For an obstacle line to be effective its length is at least one mesh size large. It is recommended to place the obstacles at the inner area of the computational grid, not at or through the boundaries. In particular, each obstacle line must be bordered by wet points on both sides.

In addition, the orientation of the obstacle line determines from which side of the obstacle the FIG wave energy is radiated away. If the begin point of the line is below or left of the end point, that is, pointing upwards/to the right, then FIG energy is radiated from the west/north side of the line. If the begin point is above or right of the end point (pointing

downwards/to the left), then FIG energy is radiated away from the east/south side of the obstacle line.

FIG	with this option the user indicates that FIG source term is included along the obstacle(s). It will be included only if the spectral directions cover the full 360°, i.e. if in the command CGRID the option CIRCLE is activated.
[alpha1]	calibration parameter (in 1/s) for determining the rate of radiating FIG energy from the shorelines.
[hss]	the sea-swell significant wave height (in m).
[tss]	a sea-swell mean wave period (in s).
[dss]	the sea-swell mean wave direction (in degrees). Default: [dss]=-999.
[dd]	power m of directional spreading $cos^m(\theta)$ for radiated FIG. Default: [dd]=0.
REFL	if this keyword is present then any shoreward propagating (FIG) wave is specular reflected.
[reflc]	constant reflection coefficient, formulated in terms of wave height, i.e. ratio of reflected significant wave height over incoming significant wave height. Restriction: $0 \leq$ [reflc] ≤ 1. Default: [reflc]=1, if the keyword REFL is present, otherwise [reflc]=0.
LINE	with this required keyword the user defines the location of the obstacle(s).
[xp], [yp]	coordinates of a corner point of the line that defines the location of the obstacle(s) (in problem coordinates): if Cartesian coordinates are used, in m, or if spherical coordinates are used, in degrees (see command COORD). At least two corner points must be provided.

Note that either [hss] or [tss] or [dss] or all three are allowed to vary over the computational domain. In that case use the commands INPGRID HSS and READINP HSS and/or the commands INPGRID TSS and READINP TSS and/or the commands INPGRID DSS and READINP DSS to define and read the sea-swell wave height/period/direction. It is permissible to have one or two constant sea-swell parameters, while the other(s) is (are) non-constant. The command OBST FIG is still required to define the obstacles. The values of [hss] and/or [tss] and/or [dss] in this command are then not required (they will be ignored).

Also noted that if [dss] = -999 or [dd] = 0, then no directional spreading for radiated FIG energy will be included.

SETUP [supcor]

CANNOT BE USED IN CASE OF <u>UNSTRUCTURED GRIDS</u>.

If this optional command is given, the wave-induced set-up is computed and accounted for in the wave computations (during the computation it is added to the depth that is obtained from the READ BOTTOM and READ WLEVEL commands). This approximation in SWAN can only be applied to open coast (unlimited supply of water from outside the domain, e.g. nearshore coasts) in contrast to closed basin, e.g. lakes and estuaries, where this option should not be used. Note that set-up is not computed correctly with spherical coordinates. Note that set-up is not supported in case of parallel runs using either MPI or OpenMP!

[supcor] by default the wave-induced set-up is computed with a constant added such that the set-up is zero in the deepest point in the computational grid. The user can modify this constant by the value of [supcor]. The user can thus impose a set-up in any one point (and only one) in the computational grid by first running SWAN, then reading the set-up in that point and adding or subtracting the required value of [supcor] (in m; positive if the set-up has to rise).
Default: [supcor]=0.

DIFFRACtion [idiffr] [smpar] [smnum] [cgmod]

If this optional command is given, the diffraction is included in the wave computation. But the diffraction approximation in SWAN does not properly handle diffraction in harbours or in front of reflecting obstacles (see Scientific/Technical documentation). Behind breakwaters with a down-wave beach, the SWAN results seem reasonable. The spatial resolution near (the tip of) the diffraction obstacle should be 1/5 to 1/10 of the dominant wave length.

Without extra measures, the diffraction computations with SWAN often converge poorly or not at all. Two measures can be taken:

1. (RECOMMENDED) The user can request under-relaxation. See command NUMERIC parameter [alpha] and Scientific/Technical documentation (Eq. (3.31)). Very limited experience suggests [alpha] = 0.01.

2. Alternatively, the user can request smoothing of the wave field for the computation of the diffraction parameter (the wave field remains intact for all other computations and output). This is done with a repeated convolution filtering. The mother filter is

$$E_{i,j}^n = E_{i,j}^{n-1} - a\left[E_{i-1,j} + E_{i,j-1} - 4E_{i,j} + E_{i+1,j} + E_{i,j+1}\right]^{n-1}$$

For $a = 0.2$ (recommended), the final width of the filter is $\varepsilon_x = \frac{1}{2}\sqrt{3n}\Delta x$ (in $x-$direction and similarly in $y-$direction) and n is the number of repetitions (see Scientific/Technical documentation, Eq. (2.100)). Note that this smoothing option can not be applied in case of unstructured meshes.

[idiffr]   indicates the use of diffraction. If [idiffr]=0 then no diffraction is taken
                into account.
                Default: [idiffr]=1.
[smpar]   smoothing parameter for the calculation of $\nabla \cdot \sqrt{E_{\text{tot}}}$. During every
                smoothing step all grid points exchange [smpar] times the energy with their
                neighbours. Note that [smpar] is parameter a in the above text.
                Default: [smpar] $= 0$.
[smnum]   number of smoothing steps (n in the above text). For $a = 0.2$, it should be
                approximately equal to $\lfloor \frac{4\varepsilon_x^2}{3\Delta x^2} \rfloor$.
                Default: [smnum] $= 0$.
[cgmod]   adaption of propagation velocities in geographic space due to diffraction.
                If [cgmod]=0 then no adaption.
                Default: [cgmod]=1.

SURFBeat   [df] [nmax] [emin]   UNIForm/LOGarithmic

CANNOT BE USED IN CASE OF <u>CURVILINEAR</u> or <u>UNSTRUCTURED</u> GRIDS AND
NOT IN <u>1D-MODE</u>.

Using this optional command, the user activates the Infragravity Energy Module (IEM) of
Reniers and Zijlema (2022). Besides the energy balance equation for a sea-swell wave field,
another energy balance is included to account for the transfer of sea-swell energy to the
bound infragravity (BIG) wave. This infragravity energy balance also involves a nonlinear
transfer, expressed by the biphase, through the phase coupling between the radiation stress
forcing and the BIG wave. For the prediction of the biphase for obliquely incident waves,
an evolution equation is provided under the assumption that the bottom slopes are mild
and alongshore uniform.

The IEM framework is applied as follows. First, we assume that the conditions under which
the surfbeat is modelled are stationary, and that the overall prediction of the sea-swell and
infragravity wave fields (both bound and free) is carried out with two COMPUTEs.

During the first COMPUTE both the short and bound long wave spectra are computed. In this
respect, the user specifies a frequency range for the sea-swell spectrum that is bounded be-
low by an infragravity frequency cut-off f_{ig} (see command CGRID). Basically, this spectrum
is subject to propagation, shoaling, refraction, surf breaking and bottom friction (other
processes should not be included). In addition, an offshore directionally spread spectrum
must be imposed on the <u>west side</u> of the computational domain. (Currently, it is assumed
that a regular grid is defined with the direction of the positive $x-$axis pointing eastward.)

Next, to add BIG components with frequencies less than or equal to f_{ig}, the infragravity

energy balance is solved. This equation is forced by bichromatic wave groups related to all pairs in the sea-swell spectrum with a frequency difference less or equal to f_{ig}. In addition, this equation is solved in tandem with the evolution equation for the biphase.

By the finish of the first `COMPUTE`, the user may include some plotting commands related to both the short and long wave spectra, including the integral parameters.

Finally, the BIG waves are assumed to reflect at the shoreline (on the east side of the domain). Accordingly, the user must specify an obstacle line alongshore (parallel with $y-$axis) with a reflection coefficient (see command `OBST REFL ... LINE ...`; for reasons of consistency, the same obstacle line must be specified in the first `COMPUTE` with a transmission coefficient of 1, so that the wave field will not be affected).

The reflected ig waves are assumed to be free and their evolution can be predicted by the conventional energy balance equation during the second `COMPUTE`. In view of this, a frequency range $[[df], f_{ig}]$ must be specified which can be either uniform or logarithmic.

`[df]`	the constant size of BIG frequency bin (in Hz).
	Default: `[df]`=0.01.
`[nmax]`	the maximum number of short-wave pairs for creating bichromatic wave groups.
	Default: `[nmax]` = 50000.
`[emin]`	the energy threshold in fraction of energy spectrum peak.
	With this threshold one takes into account those short wave components to create bichromatic wave groups while their energy levels are larger than `[emin]` $\times E_{max}$ with E_{max} the peak of the spectrum.
	Default: `[emin]` = 0.05.
`UNIFORM`	frequencies for reflected ig waves are uniformly distributed.
	This is the default.
`LOGARITHMIC`	frequencies for reflected ig waves are logarithmically distributed.

```
SCAT [iqcm]                        &

    ( GRId [rfac] )                &

    ( TRUnc [alpha] [qmax] )
```

Using this optional command, the user activates a source term that allows for the generation and propagation of cross correlations between scattered waves due to variations in the bathymetry and mean currents. Such variations are rapid compared to the distance between the crossing waves (at the scale of $100-1000$ m) and is particularly relevant for cases involving narrowband waves (swells) in coastal regions with shallow water and ambient currents. In turn, the immediate spatial effects of coherent scattering, interference,

refraction and diffraction can cause large-scale changes in the wave parameters.

The underlying modelling concept has been introduced and developed by Smit and Janssen (2013), Smit et al. (2015a,b) and Akrish et al. (2020) and is now known as the quasi-coherent (QC) model. The QC framework has been made consistent with the action balance equation through the addition of a scattering source term and is hereby adopted in the current operational version of SWAN (version 41.41). This source term involves a convolution integral which relates the spectral representation of wave action, including cross correlations, and the response of the small-scale medium variations (through the dispersion relation).

The modelling strategy by means of the QC scattering term provides the ability to readily nest a QC model into a conventional, regional-scale SWAN (or other spectral) model. However, when setting up a QC model, other existing (shallow-water) source terms (e.g., surf breaking, triad wave-wave interactions) should not be included as they do not account for the cross correlations among wave components of the scattered field and, in turn, their effects on wave interference patterns. Therefore, the user should be aware of the currently limited use of the QC model in support of the complete description of the wave field, including the dissipation and nonlinear effects. The inclusion of QC-consistent depth-induced wave breaking and nonlinear (triad) interactions will be considered in the near future (see also Smit et al., 2015b and Smit and Janssen, 2016).

In order to apply the QC approximation properly, an incident wave spectrum must be imposed at the wave maker. This provides input used in defining the coherent radius of the scattered wave field and in designating the grid spacing in wave number space. The definition of the coherent region is especially relevant for the discrete Fourier transform of the modulation of the dispersion relation (owing to the medium variations). Furthermore, the grid domain in wave number space defines a region in which the effects of cross correlations are resolved. This will be constructed by SWAN with the aid of the discrete frequency-direction sector (see command `CGRID SECTOR`). The associated resolution is determined by the characteristic width (or standard deviation) of the incoming spectrum, Δk (in 1/m), and the user-defined resolution factor $r_f \geq 1$, and is expressed as $\Delta k / r_f$. The correlation (or coherent) length scale is then given by $2\pi\, r_f / \Delta k$.

The unbounded convolution integral of the scattering source term is computed as the sum over a finite range of wave numbers. The extent of this range reflects the scale to which variations in the medium (seabed and/or mean currents) affect the wave field. The convolution sum is thus limited to the range $[-q_{\max}\,,\, q_{\max}]$ with $q_{\max}$ the maximum scattering wave number. This maximum can either be directly set or can be taken as a multiple of the mean wave number at the wave maker.

[iqcm]   indicates the modelling and computation of QC scattering:
                = 0   no scattering
                = 1   scattering due to non-uniform bathymetry and currents

	(the latter only if applicable; see command `INPGRID CURRENT`)
	$= 2$ wave-current interaction under the assumption of a slowly varying bathymetry
	Default: $[\mathtt{iqcm}] = 1$.
GRID	with this option the user controls the grid resolution of the wave number space. It is defined as a multiple of the characteristic width of the incoming wave spectrum.
[rfac]	the resolution factor through which the incident spectral width is multiplied. Note that this factor must be larger or equal 1. Default: $[\mathtt{rfac}] = 1$.
TRUNC	with this option the user truncates the infinite convolution sum at either the multiple of the mean wave number at the wave maker (the default option), or at the maximum scattering wave number. When specifying both parameters, then their mimimum is considered as the final limit on the sum.
[alpha]	the coefficient by which the mean wave number is multiplied to set the limit on the convolution sum. Default: $[\mathtt{alpha}] = 1$.
[qmax]	the maximum scattering wave number (in 1/m).

```
        |  WINDGrowth |
        |             |
        |  QUADrupl   |
        |             |
        |  WCAPping   |
OFF <                 >
        |  BREaking   |
        |             |
        |  REFrac     |
        |             |
        |  FSHift     |
        |             |
        |  BNDCHK     |
```

With this optional command the user can change the default inclusion of various physical processes (e.g. for research purposes). This command is not recommended for operational use.

WINDGROWTH	switches off wind growth (in commands `GEN1`, `GEN2` and `GEN3`).
QUADRUPL	switches off quadruplet wave-wave interactions (in command `GEN3`).

WCAPPING	switches off whitecapping (in command GEN3).
BREAKING	switches off depth-induced breaking dissipation.
	Caution: wave heights may diverge in very shallow water.
REFRAC	switches off refraction (action transport in $\theta-$direction).
FSHIFT	switches off frequency shifting in frequency space (action transport in $\sigma-$space).
BNDCHK	switches off the checking of the difference between imposed and computed significant wave height at the boundary of the computational grid (see also command SET).

4.5.5   Numerics

```
          |     BSBT
PROP    <                       | Sec |
          |     GSE  [waveage] <  MIn  >
          |                     |  HR |
          |                     | DAy |
```

Command to choose:

- the BSBT scheme (stationary and nonstationary) instead of the default S&L scheme (in case of nonstationary cases) or the default SORDUP scheme (in case of stationary cases) or

- the alleviation of the garden-sprinkler effect (GSE).

BSBT	the BSBT scheme will be used in the computations.
GSE	garden-sprinkler effect is to be counteracted in the S&L propagation scheme (default for nonstationary regular grid computations) or in the propagation scheme for unstructured grids by adding a diffusion term to the basic equation. This may affect the numerical stability of SWAN (see Scientific/Technical documentation).
[waveage]	the time interval used to determine the diffusion which counteracts the so-called garden-sprinkler effect. The default value of [waveage] is zero, i.e. no added diffusion. The value of [waveage] should correspond to the travel time of the waves over the computational region.

Notes:

- All schemes (BSBT, SORDUP and S&L) can be used in combination with curvilinear grids. With the higher order schemes (S&L and SORDUP) it is important to use a gradually varying grid, otherwise there may be a severe loss of accuracy. If sharp transitions in the grid cannot be avoided it is safer to use the BSBT scheme.

- In the computation with unstructured meshes, a lowest order upwind scheme will be employed. This scheme is very robust but rather diffusive. This may only be significant for the case when swell waves propagate over relative large distances (in the order of thousands of kilometers) within the model domain. However and most fortunately, in such a case, this will alleviate the garden-sprinkler effect.

- Alleviating the garden-sprinkler effect by adding some diffusion makes the SWAN computation conditionally stable. You can either use i) a smaller time step, ii) a lower value of [waveage], iii) better resolution in the directional space, or iv) worse resolution in the geographic space, in order of preference, to make the model stable when necessary.

```
NUMeric ( STOPC [dabs] [drel] [curvat] [npnts]                        &

                  | -> STAT [mxitst] [alfa] |
               <                              >  [limiter]       ) &
                  |    NONSTAT [mxitns]      |

        ( DIRimpl [cdd]                                          ) &

        ( SIGIMpl [css] [eps2] [outp] [niter]                    ) &

        ( CTheta [cfl]                                           ) &

        ( CSigma [cfl]                                           ) &

        ( SETUP [eps2] [outp] [niter]                            )
```

With this optional command the user can influence some of the numerical properties of SWAN.

STOPC   With this option the user can influence the criterion for terminating the iterative procedure in the SWAN computations (both stationary and nonstationary). The criterion make use of the second derivative, or curvature, of the iteration curve of the significant wave height. As the solution of a simulation approaches full convergence, the curvature of the iteration curve will tend to zero. SWAN stops the process **if** the relative change in H_s from one iteration to the next is less than [drel] **and** the curvature of the iteration curve of H_s normalized with H_s is less than [curvat] **or** the absolute change in H_s from one iteration to the next is less than [dabs]. Both conditions need to be fulfilled in more than fraction [npnts]% of all wet grid points.

With respect to the QC modelling, another stopping criteria will be employed. Namely, SWAN stops the iteration process if the absolute change in H_s from one iterate to another is less than [dabs] $\times H_{\text{inc}}$, where H_{inc} is the representative incident wave height, or the relative change in H_s from one to the next iteration is less than [drel]. These criteria must be fulfilled in more than [npnts]% of all active, well-defined points.

[dabs]	Default: [dabs] $= 0.005$ [m] or [dabs] $= 0.05$ $[-]$ in case of QC model.
[drel]	Default: [drel] $= 0.01$ $[-]$
[curvat]	Default: [curvat] $= 0.005$ $[-]$
	Note that [curvat] is not used in the QC model.
[npnts]	Default: [npnts] $= 99.5$ $[-]$
STAT	indicates the use of parameters in a stationary computation.
[mxitst]	the maximum number of iterations for stationary computations.
	The computation stops when this number is exceeded.
	Default: [mxitst] $= 50$.
	Note that [mxitst] can be set to 0 if one wants to check the input to the
	model without making computations.
[alfa]	proportionality constant used in the frequency-dependent under-relaxation
	technique. Based on experiences, a suggestion for this parameter is [alfa] $= 0.01$.
	In case of diffraction computations, the use of this parameter is recommended.
	Default: [alfa] $= 0.00$.
	NOT MEANINGFUL FOR NONSTATIONARY COMPUTATIONS.
NONSTAT	indicates the use of parameters in a nonstationary computation.
[mxitns]	the maximum number of iterations per time step for nonstationary computations.
	The computation moves to the next time step when this number is exceeded.
	Default: [mxitns] $= 1$.
	Note that [mxitns] can be set to 0 if one wants to check the input to the
	model without making computations.
[limiter]	determines, in both stationary and nonstationary runs, the maximum change per
	iteration of the energy density per spectral (σ,θ)-bin, given in
	terms of a fraction of the omni-directional Phillips level (see Scientific/
	Technical documentation).
	Default: [limiter] $= 0.1$.
DIRIMPL	this option is used to influence the numerical scheme for refraction.
[cdd]	A value of [cdd]=0 corresponds to a central scheme and has the largest
	accuracy (diffusion ≈ 0) but the computation may more easily generate
	spurious fluctuations. A value of [cdd]=1. corresponds to a first order
	upwind scheme and it is more diffusive and therefore preferable if (strong)
	gradients in depth or current are present.
	Default: [cdd] $= 0.5$.
SIGIMPL	controls the accuracy of computing the frequency shifting and the stopping criterion
	and amount of output for the SIP solver (used in the computations in the presence

	of currents or time varying depth).
CTHETA	this option prevents an excessive directional turning at a single grid point or vertex due to a very coarse bathymetry or current locally. This option limits the directional turning rate c_θ based on the CFL restriction. (See Eq. 3.41 of Scientific/ Technical documentation). See also the final remark in Section 2.6.3. Note that if this command is not specified, then the limiter is not activated.
[cfl]	upper limit for the CFL restriction for c_θ. A suggestion for this parameter is [cfl] = 0.9. Default: [cfl] = 0.9 (when command CTHETA is activated).
CSIGMA	this option prevents an excessive frequency shifting at a single grid point or vertex due to a very coarse bathymetry or current locally. This option limits the frequency shifting rate c_σ based on the CFL restriction. See also the final remark in Section 2.6.3. Note that if this command is not specified, then the limiter is not activated.
[cfl]	upper limit for the CFL restriction for c_σ. A suggestion for this parameter is [cfl] = 0.9. Default: [cfl] = 0.9 (when command CSIGMA is activated).
SETUP	controls the stopping criterion and amount of output for the SOR solver in the computation of the wave-induced set-up.
[css]	A value of [css]=0 corresponds to a central scheme and has the largest accuracy (diffusion ≈ 0) but the computation may more easily generate spurious fluctuations. A value of [css]=1. corresponds to a first order upwind scheme and it is more diffusive and therefore preferable if (strong) gradients in depth or current are present. Default: [css] = 0.5.
[eps2]	Relative stopping criterion to terminate the linear solver (SIP or SOR). The criterion for the SIP solver is based on $\|A\vec{N}_k - \vec{b}\|_2 \leq$ [eps2] $\|\vec{b}\|_2$ where A is a matrix, $\vec{N}$ is the action density vector, $\vec{b}$ is the right hand vector and k is the iteration number. The criterion for the SOR solver is based on $\|\overline{\eta}_{k+1} - \overline{\eta}_k\|_\infty \leq$ [eps2] where $\overline{\eta}$ is the set-up. Default: [eps2] = 1.e-4 in case of SIP and [eps2] = 1.e-6 in case of SOR.
[outp]	output for the iterative solver:
	0 = no output
	1 = additional information about the iteration process is written to the PRINT file
	2 = gives a maximal amount of output concerning the iteration process
	3 = summary of the iteration process
	Default: [outp] = 0.
[niter]	maximum number of iterations for the linear solver. Default: [niter] = 20 in case of SIP and [niter] = 1000 in case of SOR.

4.6   Output

There are two categories of output commands:

1. <u>Locations</u>
   commands defining sets of output <u>locations</u> at which the user requires output. Each
   set is indicated with a name (`'sname'` in this manual) which must be unique and not
   more than 8 characters long.

   Types of sets of output points:

FRAME	to define a set of output locations on a regular grid
GROUP	to define a set of output locations on a regular or curvilinear grid
CURVE	to define a set of output locations along a curve
RAY	to define a set of output locations along a depth or bottom contour line (with `ISOLINE`)
ISOLINE	to define a set of output locations along a depth- or bottom contour line (with `RAY`)
POINTS	to define a set of isolated output locations
NGRID	to define a set of output locations for a nested grid to be used in a subsequent SWAN run

   Commands `FRAME`, `GROUP`, `RAY`, `ISOLINE` and `NGRID` <u>cannot</u> be used in 1D-MODE
   and command `GROUP` <u>cannot</u> be used in case of unstructured meshes. If one gives one
   name for two sets of output locations, the first set is lost (first in the sequence in the
   command file). Two special names `BOTTGRID` and `COMPGRID` are reserved for use by
   SWAN (see below). The user may not define sets with these names.

2. <u>Write / plot</u>
   commands defining data file output (<u>write</u>) at the above defined set(s) of output
   locations:

BLOCK	write spatial distributions (only for FRAMEs and GROUPs)
TABLE	write output for (set of) output location(s)
SPECOUT	write to data file the variance / energy (see command `SET`) density spectrum for (set of) output location(s)
NESTOUT	write to data file two-dimensional action density spectra (relative frequency) along the boundary of a nested grid (see command `NGRID`) to be used in a subsequent SWAN run.

   Commands `BLOCK` and `NESTOUT` <u>cannot</u> be used in <u>1D-MODE</u>.

4.6.1 Output locations

```
FRAme 'sname' [xpfr] [ypfr] [alpfr] [xlenfr] [ylenfr] [mxfr] [myfr])
```

CANNOT BE USED IN <u>1D-MODE</u>.

With this optional command the user defines output on a <u>rectangular, uniform</u> grid in a <u>regular</u> frame.

If the set of output locations is identical to a part of the computational grid, then the user can use the alternative command `GROUP`.

`'sname'`	name of the frame defined by this command
`[xpfr]`	$x-$coordinate of the origin of the frame in <u>problem coordinates</u>
	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command `COORD`)
`[ypfr]`	$y-$coordinate of the origin of the frame in <u>problem coordinates</u>
	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command `COORD`)
`[alpfr]`	direction of the $x-$axis of the frame (in degrees, Cartesian convention; must be 0 in case of spherical coordinates)
`[xlenfr]`	length of the frame in $x-$direction
	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command `COORD`)
`[ylenfr]`	length of the frame in $y-$direction
	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command `COORD`)
`[mxfr]`	number of meshes in $x-$direction of the rectangular grid in the frame (one less than the number of grid points in this direction)
	Default: `[mxfr]`=20
`[myfr]`	number of meshes in $y-$direction of the rectangular grid in the frame (one less than the number of grid points in this direction)
	Default: `[myfr]`=20

Some output may be required on a frame that is identical with the input (bottom/current) grid or with the computational grid (e.g. for test purposes or to avoid interpolation errors in the output). These frames need not be defined by the user with this command `FRAME`; the frames are always generated automatically by SWAN under the names `'sname' = 'BOTTGRID'` (for the bottom/current grid) and `'sname' = 'COMPGRID'` (for the computational grid).

```
GROUP 'sname' SUBGrid [ix1] [ix2] [iy1] [iy2]
```

CANNOT BE USED IN <u>1D-MODE</u> AND IN CASE OF <u>UNSTRUCTURED GRIDS</u>.

With this optional command the user defines a group of output locations on a <u>rectangular</u> or <u>curvilinear</u> grid that is <u>identical</u> with (part of) the <u>computational grid</u> (rectilinear or curvilinear). Such a group may be convenient for the user to obtain output that is not affected by interpolation errors (which would occur when an output grid is used that is not identical with (part of) the computational grid).

Command `CGRID` should precede this command `GROUP`.

The subgrid contains those points (ix,iy) of the computational grid for which:
[ix1] $\leq$ ix $\leq$ [ix2] and [iy1] $\leq$ iy $\leq$ [iy2]

For convenience the size of the group, the corner coordinates and the angle with the problem coordinate system are written to `PRINT` file. The <u>origin</u> of the computational grid is (ix=0,iy=0)!

'sname'	name of the set of output locations defined by this command
[ix1]	lowest grid index of subgrid in terms of computational grid in ix-direction
[iy1]	lowest grid index of subgrid in terms of computational grid in iy-direction
[ix2]	highest grid index of subgrid in terms of computational grid in ix-direction
[iy2]	highest grid index of subgrid in terms of computational grid in iy-direction

Limitations:
[ix1]$\geq$0, [ix2]$\leq$[mxc], [iy1]$\geq$0, [iy2]$\leq$[myc] ([mxc] and [myc] as defined in the command `CGRID`).

```
CURve 'sname' [xp1] [yp1]  < [int] [xp] [yp] >
```

With this optional command the user defines output along a curved line. Actually this curve is a broken line, defined by the user with its corner points. The values of the output quantities along the curve are interpolated from the computational grid. This command may be used more than once to define more curves.

In some cases output is required on (part of) the boundary. To make this easier the following output curves are pre-defined (i.e. they do not have to be defined by the user): the curve `BOUNDARY` which corresponds to the whole outer boundary, and the curves `BOUND_01`, `BOUND_02`, etc. corresponding to parts of the boundary. In regular and curvilinear grids these parts are the four sides of the computational grid; in unstructured grids they are defined in the grid definition file. Examples:

- TABLE 'BOUNDARY' HEAD 'boundary.tab' XP YP

- TABLE 'BOUND_02' HEAD 'bnd2.tab' XP YP

The result is a file where the coordinates of the whole boundary and boundary part 2 are printed. This information can be useful when preparing a BOUNDSPEC command for any type of computational grid.

'sname'	name of the curve
[xp1],[yp1]	problem coordinates of the first point of the curve
	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command COORD)
[int]	SWAN will generate output at [int]−1 equidistant locations between two
	subsequent corner points of the curve
[xp],[yp]	problem coordinates of a corner point of the curve. Repeat the group
	[int] [xp] [yp] in proper order if there are more corner points on the curve.

RAY 'rname' [xp1] [yp1] [xq1] [yq1] < [int] [xp] [yp] [xq] [yq] >

CANNOT BE USED IN 1D-MODE.

With this optional command the user provides SWAN with information to determine output locations along the depth contour line(s) defined subsequently in command ISOLINE (see below).

These locations are determined by SWAN as the intersections of the depth contour line(s) and the set of straight rays defined in this command RAY. These rays are characterized by a set of master rays defined by their start and end positions ([xp],[yp]) and ([xq],[yq]). Between each pair of sequential master rays thus defined SWAN generates [int]−1 intermediate rays by linear interpolation of the start and end positions.

Note that the rays thus defined have nothing in common with wave rays (e.g. as obtained from conventional refraction computations).

Also note that when using rays, the input grid for bottom and water level should not be curvilinear.

'rname'	name of the set of rays defined by this command.
[xp1],[yp1],	problem coordinates of the begin and end points of the first master ray
[xq1],[yq1]	if Cartesian coordinates are used in m
	if spherical coordinates are used in degrees (see command COORD)
[int]	number of subdivisions between the previous master ray and the

following master ray defined by the following data (number of
subdivisions is one more than the number of interpolated rays)

[xp],[yp],   <u>problem coordinates</u> of the begin and end points of each subsequent master ray
[xq],[yq]   if Cartesian coordinates are used in m
              if spherical coordinates are used in degrees (see command `COORD`)

```
                         | -> DEPth   |
ISOline  'sname'  'rname' <              >  [dep]
                         |    BOTtom  |
```

CANNOT BE USED IN <u>1D-MODE</u>.

With this optional command the user defines a set of output locations along one depth or
bottom level contour line (in combination with command `RAY`).

'sname'   name of the set of output locations defined by this command
'rname'   name of the set of rays (as defined in command `RAY`)
[dep]   the depth (in m) of the depth contour line along which output locations are
              generated by SWAN. If the keyword `DEPTH` is employed, the stationary
              water depth is used, if the keyword `BOTTOM` appears, the water level is ignored,
              i.e. the depth with respect to datum level is used.

The set of output locations along the depth contour lines created with this command is of
the type `CURVE`.

```
                   |  < [xp] [yp] >  |
POINts   'sname'  <                   >
                   |  FILE  'fname'  |
```

With this optional command the user defines a set of individual output locations (points).
The coordinates of these points are given in the command itself or read from a file (option
`FILE`).

'sname'   name of the points
[xp],[yp]   <u>problem coordinates</u> of one output location
              if Cartesian coordinates are used in m
              if spherical coordinates are used in degrees (see command `COORD`)
'fname'   name of the file containing the output locations.

```
                | [xpn] [ypn] [alpn] [xlenn] [ylenn] [mxn] [myn]
                |
NGRid 'sname' <                      | -> TRIAngle |
                | UNSTRUCtured  <                  > 'fname'
                |                    |    EASYmesh |
```

CANNOT BE USED IN <u>1D-MODE</u>.

If the user wishes to carry out nested SWAN run(s), a separate coarse-grid SWAN run is required. With this optional command `NGRID`, the user defines in the <u>present</u> coarse-grid run, a set of output locations along the boundary of the <u>subsequent</u> nested computational grid. The set of output locations thus defined is of the type `NGRID`.

Command `NESTOUT` is required after this command `NGRID` to generate some data for the (subsequent) nested run (not with command `BLOCK` because a set of locations of the type `NGRID` does represent an outline and not a geographic region).

`'sname'`	name of the set of output locations along the boundaries of the following nested computational grid defined by this command
`[xpn]`	geographic location of the origin of the computational grid of <u>this</u> coarse-grid run in the <u>problem coordinate</u> system ($x-$coordinate) if Cartesian coordinates are used in m if spherical coordinates are used in degrees (see command `COORD`)
`[ypn]`	geographic location of the origin of the computational grid of <u>this</u> coarse-grid run in the <u>problem coordinate</u> system ($y-$coordinate) if Cartesian coordinates are used in m if spherical coordinates are used in degrees (see command `COORD`)
`[alpn]`	direction of the positive $x-$axis of the computational grid of <u>this</u> coarse-grid run (in degrees, Cartesian convention).
`[xlenn]`	length in the $x-$direction of the nested grid if Cartesian coordinates are used in m if spherical coordinates are used in degrees (see command `COORD`)
`[ylenn]`	length in the $y-$direction of the nested grid if Cartesian coordinates are used in m if spherical coordinates are used in degrees (see command `COORD`)
`[mxn]`	number of meshes of the output grid in the $x-$direction of this grid (this number is <u>one less</u> than the number of grid points in this direction!). `[mxn]` does not have to be equal to the number of meshes in the nested computation; SWAN will interpolate the required information. Default: `[mxn]` is chosen such that the mesh size of the output grid is (roughly) equal to the mesh size of the coarse grid, but at least 1.

`[myn]`	number of meshes of the output grid in the $y-$direction of this grid (this number is <u>one less</u> than the number of grid points in this direction!). `[myn]` does not have to be equal to the number of meshes in the nested computation; SWAN will interpolate the required information.
	Default: `[myn]` is chosen such that the mesh size of the output grid is (roughly) equal to the mesh size of the coarse grid, but at least 1.
`UNSTRUCTURE`	with this option the user indicates that the subsequent nested grid is an unstructured one. Only grids generated by Triangle and Easymesh are supported by SWAN.
`TRIANGLE`	the necessary grid information is read from two files as produced by Triangle. The `.node` and `.ele` files are required. The basename of these files must be indicated with parameter `'fname'`.
`EASYMESH`	the necessary grid information is read from two files as produced by Easymesh. The `.n` and `.e` files are required. The basename of these files must be indicated with parameter `'fname'`.
`'fname'`	basename of the required files, i.e. without extension.

4.6.2   Write or plot computed quantities

For definitions of output parameters, see Appendix A.

<u>WARNING:</u>
When integral parameters are computed by the user from the output spectrum of SWAN, differences with the SWAN-computed parameters may occur. The reasons are:

- SWAN accepts at the boundaries of the computational grid only the user-imposed incoming wave components and it replaces the user-imposed outgoing wave components with computed components (propagating to the boundary from the interior region).

- during the computation of the parameters, SWAN adds an analytical (diagnostic) high-frequency tail to the discrete spectrum.

- SWAN has an option to only compute within a pre-set directional sector (pre-set by the user). Wave components outside this sector are totally ignored by SWAN (no additions or replacements).

This is particularly relevant along the boundaries of SWAN where the user-imposed integral parameters (boundary conditions) may differ from the SWAN-computed parameters. The user is informed by means of a warning in the output (`PRINT` file) when the computed significant wave height differs more than 10%, say, from the user-imposed significant wave height (command `BOUNDSPEC`). The actual value of this difference can be set by the user (see the `SET` command; Section 4.4).

```
        | ..........|
QUANTity <               > 'short' 'long' [lexp] [hexp]  [excv]            &
        | ..........|


    [power]                 (For output quantities PER, RPER and WLEN)     &

    [ref]                   (For output quantity TSEC)                     &

    [fswell]                (For output quantity HSWELL)                   &

    [fmin] [fmax]           (For all integral parameters, like HS, (R)TM01 ...) &

     |-> PROBLEMcoord |
    <                 >  (For directions (DIR, TDIR, PDIR)
     |    FRAME       |    and vectors (FORCE, WIND, VEL, TRANSP))
```

With this command the user can influence

- the naming of output quantities,

- the accuracy of writing output quantities,

- the definition of some output quantities and

- reference direction for vectors.

```
 |...|
<     >       the output parameters are the same as given in command BLOCK.
 |...|
```

'short'   user preferred short name of the output quantity (e.g. the name appearing in
             the heading of a table written by SWAN). If this option is not used, SWAN
             will use a realistic name.

'long'   long name of the output quantity (e.g. the name appearing in the heading of a
             block output written by SWAN). If this option is not used, SWAN will use a
             realistic name.

[lexp]   lowest expected value of the output quantity.

[hexp]   highest expected value of the output quantity; the highest expected value is
             used by SWAN to determine the number of decimals in a table with heading.
             So the QUANTITY command can be used in case the default number of decimals
             in a table is unsatisfactory.

[excv]   in case there is no valid value (e.g. wave height in a dry point) this
             exception value of the output quantity is written in a table or block output.

The following data are accepted only in combination with some specific output quantities.

[power]	power p appearing in the definition of PER, RPER and WLEN (see Appendix A). Note that the value for [power] given for PER affects also the value of RPER; the power for WLEN is independent of that of PER or RPER. Default: [power]=1.
[ref]	reference time used for the quantity TSEC. Default value: starting time of the first computation, except in cases where this is later than the time of the earliest input. In these cases, the time of the earliest input is used.
[fswell]	upper limit of frequency range used for computing the quantity HSWELL (see Appendix A). Default: [fswell] = 0.1 Hz.
[fmin]	lower limit of frequency range used for computing integral parameters. Default: [fmin] = 0.0 Hz.
[fmax]	upper limit of frequency range used for computing integral parameters. Default: [fmax] = 1000.0 Hz (acts as infinity).
PROBLEMCOORD—	vector components are relative to the $x-$ and $y-$axes of the <u>problem</u> coordinate system:

- directions are counterclockwise relative to the positive $x-$axis of the <u>problem</u> coordinate system if Cartesian direction convention is used (see command SET)
- directions are relative to <u>North</u> (clockwise) if Nautical direction convention is used (see command SET)

FRAME	If output is requested on sets created by command FRAME or automatically (COMPGRID or BOTTGRID):

- vector components are relative to the $x-$ and $y-$axes of the <u>frame</u> coordinate system
- directions are counterclockwise relative to the positive $x-$axis of the <u>frame</u> coordinate system if Cartesian direction convention is used (see command SET)
- directions are relative to <u>North</u> (clockwise) if Nautical direction convention is used (see command SET)

Examples:

`QUANTITY Xp hexp=100.`	for simulations of lab. experiments
`QUANTITY HS TM01 RTMM10 excv=-9.`	to change the exception value for H_s, T_{m01} and relative T_{m-10}
`QUANTITY HS TM02 FSPR fmin=0.03 fmax=0.5`	to compute H_s, T_{m02} and frequency spreading by means of integration over $f \in [0.03, 0.5]$

```
QUANTITY Hswell fswell=0.08          to change the value of [fswell]
QUANTITY Per short='Tm-1,0' power=0.  to redefine average wave period
QUANTITY Transp Force Frame          to obtain vector components and
                                     direction with respect to the frame
```

```
OUTPut OPTIons 'comment' (TABle [field]) (BLOck [ndec] [len]) (SPEC [ndec])
```

This command enables the user to influence the format of block, table and spectral output.

comment   a comment character; is used in comment lines in the output
            Default: `comment` = %

field   length of one data field in a table. Minimum is 8 and maximum is 16.
            Default: `field` = 12

ndec   number of decimals in block (if appearing after keyword `BLOCK`) or
            2D spectral output (if appearing after keyword `SPEC`). Maximum is 9.
            Default: `ndec` = 4 (in both block and spectral outputs)

len   number of data on one line of block output. Maximum is 9999.
            Default: `len` = 6

```
                 | -> HEADer   |
BLOck  'sname' <                  > 'fname' (LAYout [idla])
                 |    NOHEADer |


        | HSign      |
        |            |
        | HSWEll     |
        |            |
        | DIR        |
        |            |
        | PDIR       |
        |            |
        | TDIR       |
        |            |
        | TM01       |
        |            |
        | RTM01      |
        |            |
```

```
| RTP        |
|            |
| TPS        |
|            |
| PER        |
|            |
| RPER       |
|            |
| TMM10      |
|            |
| RTMM10     |
|            |
| TM02       |
|            |
| FSPR       |
|            |
| DSPR       |
|            |
| QP         |
|            |
| DEPth      |
|            |
| WATLev     |
|            |
| BOTLev     |
|            |
| VEL        |
|            |
| FRCoef     |
|            |
| WIND       |
|            |
| AICE       |
|            |
| HICE       |
|            |
| HBIG       |
|            |
| PROPAgat   |
|            |
| PROPXy     |
|            |
| PROPTheta  |
```

```
              |             |
              | PROPSigma   |
              |             |
              | GENErat     |
              |             |
              | GENWind     |
              |             |
              | REDIst      |
              |             |
              | REDQuad     |
              |             |
              | REDTriad    |                                        | -> Sec  |
   <     <              >   [unit] > (OUTput [tbegblk] [deltblk]) <       MIn   >
              | DISSip      |                                        |    HR   |
              |             |                                        |    DAy  |
              | DISBot      |
              |             |
              | DISSUrf     |
              |             |
              | DISWcap     |
              |             |
              | DISSWell    |
              |             |
              | DISVeg      |
              |             |
              | DISMud      |
              |             |
              | DISIce      |
              |             |
              | RADStr      |
              |             |
              | QB          |
              |             |
              | GAMMA       |
              |             |
              | TRAnsp      |
              |             |
              | FORce       |
              |             |
              | UBOT        |
              |             |
              | URMS        |
              |             |
```

```
                  | TMBOT     |
                  |           |
                  | WLENgth   |
                  |           |
                  | LWAVP     |
                  |           |
                  | STEEpness |
                  |           |
                  | BFI       |
                  |           |
                  | NPLants   |
                  |           |
                  | DHSign    |
                  |           |
                  | DRTM01    |
                  |           |
                  | LEAK      |
                  |           |
                  | TIME      |
                  |           |
                  | TSEC      |
                  |           |
                  | XP        |
                  |           |
                  | YP        |
                  |           |
                  | DIST      |
                  |           |
                  | SETUP     |
                  |           |
                  | PTHSign   |
                  |           |
                  | PTRTP     |
                  |           |
                  | PTWLEN    |
                  |           |
                  | PTDIR     |
                  |           |
                  | PTDSPR    |
                  |           |
                  | PTWFRAC   |
                  |           |
                  | PTSTEEpne |
```

```
        |              |
        | PARTITion    |
```

CANNOT BE USED IN <u>1D-MODE</u>.

With this optional command the user indicates that one or more <u>spatial distributions</u> should be written to a <u>file</u>.

`'sname'`	name of frame or group (see commands `FRAME` or `GROUP`)
`HEADER`	with this option the user indicates that the output should be written to a file with header lines. The text of the header indicates run identification (see command `PROJECT`), time, frame name or group name (`'sname'`), variable and unit. The number of header lines is 8.
	Note: the numerical values in the file are in the units indicated in the header.
`NOHEADER`	with this option the user indicates that the output should be written to a file without header lines.
`'fname'`	name of the data file where the output is to be written to.
	Default for option `HEADER` is the `PRINT` file. In case of `NOHEADER` the filename is required. Below a few remarks on the file formats.

Basically, the output files generated by SWAN are human-readable files that use ASCII character encoding. Such files can be open and edit in any text editor or can be viewed in Matlab or Excel. However, if the user specifies the extension of the output file as '**.mat**', a binary MATLAB file will be generated. This file requires less space on your computer and can be loaded in MATLAB much faster than an ASCII file. Also note that the output parameters are stored as single precision. (Hence, use the Matlab command `double` for conversion to double precision, if necessary.) Binary MATLAB files are particularly useful for the computation with unstructured grids. A number of MATLAB scripts are provided with the SWAN source code that can be used to plot wave parameters as maps in a simple way.

Another option is to write the output to a netCDF format (Network Common Data Form). The file extension must be in this case '**.nc**'. This format is self-describing and machine independent. Moreover, it is an open standard and portable. This will enhance accessibility of data exchange and also easily facilitate using output from one application as input to another. Like MATLAB files, storage and retrieval of netCDF files is very fast.

Since version 41.41, SWAN can generate VTK files that can be viewed in Paraview, an open-source, general-purpose visualization package, available for Windows, Mac and Linux (see https://www.paraview.org). The basic extension is '**.vtk**', but SWAN will generate various XML-based file formats depending on

the grid types (***.vts** associated with structured grids and ***.vtu** containing unstructured mesh data). Like netCDF files, the VTK XML files are binary, self-descriptive (include plain text metadata) and portable (cross-platform). In addition, a key benefit is that there is no need to collect VTK files residing on separate processes of a distributed memory machine (after execution of SWAN in parallel). Paraview can simply visualize the whole domain that consists of several subdomains.

`LAY-OUT`	with this option the user can prescribe the lay-out of the output to file with the value of `[idla]`.
`[idla]`	see command `READINP` (options are: `[idla]`=1, 3, 4). Option 4 is recommended for postprocessing an ASCII file by MATLAB, however, in case of a generated binary MATLAB file option 3 is recommended. Default: `[idla]` = 1. ONLY MEANT FOR STRUCTURED GRIDS.

For definitions of the output quantities, see Appendix A.

Note that the wave parameters in the output of SWAN are computed from the wave spectrum over the prognostic part of the spectrum <u>with the diagnostic tail added</u>. Their value may therefore deviate slightly from values computed by the user from the output spectrum of SWAN which does not contain the diagnostic tail.

`HSIGN`	significant wave height (in m).
`HSWELL`	swell wave height (in m).
`DIR`	mean wave direction (Cartesian or Nautical convention, see command `SET`). For Cartesian convention: relative to x−axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with `BLOCK` command in combination with command `FRAME`, see command `QUANTITY`.
`PDIR`	peak wave direction in degrees. For Cartesian convention: relative to x−axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with `BLOCK` command in combination with command `FRAME`, see command `QUANTITY`.
`TDIR`	direction of energy transport in degrees. For Cartesian convention: relative to x−axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with `BLOCK` command in combination with command `FRAME`, see command `QUANTITY`.
`TM01`	mean absolute wave period (in s).
`RTM01`	mean relative wave period (in s).
`RTP`	peak period (in s) of the variance density spectrum (relative frequency spectrum).
`TPS`	'smoothed' peak period (in s).
`PER`	mean absolute wave period (in s).
`RPER`	mean relative wave period (in s).

TMM10	mean absolute wave period (in s).
RTMM10	mean relative wave period (in s).
TM02	mean absolute zero-crossing period (in s).
FSPR	the normalized width of the frequency spectrum.
DSPR	directional spreading of the waves (in degrees).
QP	peakedness of the wave spectrum (dimensionless).
DEPTH	water depth (in m) (not the bottom level!).
WATLEV	water level (in m).
	Output is in both active and non-active points.
	Note: exception value for water levels must be given!
	(See command INPGRID WLEVEL EXCEPTION).
BOTLEV	bottom level (in m).
	Output is in both active and non-active points.
	Note: exception value for bottom levels must be given!
	(See command INPGRID BOTTOM EXCEPTION).
VEL	current velocity (vector; in m/s).
	Relative to $x-$axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with BLOCK command in combination with command FRAME, see command QUANTITY.
FRCOEF	friction coefficient (equal to [cfw] or [kn] in command FRICTION).
WIND	wind velocity (vector; in m/s).
	Relative to $x-$axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with BLOCK command in combination with command FRAME, see command QUANTITY.
AICE	ice concentration (as a fraction from 0 to 1).
HICE	ice thickness (in meters).
HBIG	bound ig wave height (in m).
	Note: only to be specified for surfbeat (IEM) during first COMPUTE.

The quantities below are the contributions to the energy balance equation, containing both transport terms and source terms. These output quantities are defined as the integral over all frequencies and directions of the absolute value of each term in the equation. In this way we can estimate the associated time scale. Besides these terms we may also compute energy transfer between waves and currents due to radiation stress. Further details can be found in the ICCE paper of

Holthuijsen, L.H., Zijlema, M. and Van der Ham, P.J. (2009)
Wave physics in a tidal inlet, in: J.M. Smith (Ed.), Proc. 31st ICCE, pp. 437-448

PROPAGAT	sum of PROPXY, PROPTHETA and PROPSIGMA (in W/m² or m²/s, depending on command SET).

PROPXY	energy propagation in geographic space; sum of $x-$ and $y-$direction terms (in W/m^2 or m^2/s, depending on command SET).
PROPTHETA	energy propagation in theta space (in W/m^2 or m^2/s, depending on command SET).
PROPSIGMA	energy propagation in sigma space (in W/m^2 or m^2/s, depending on command SET).
GENERAT	total energy generation (in W/m^2 or m^2/s, depending on command SET).
GENWIND	energy generation due to wind (in W/m^2 or m^2/s, depending on command SET).
REDIST	total energy redistribution (in W/m^2 or m^2/s, depending on command SET).
REDQUAD	energy redistribution due to quadruplets (in W/m^2 or m^2/s, depending on command SET).
REDTRIAD	energy redistribution due to triads (in W/m^2 or m^2/s, depending on command SET).
DISSIP	total energy dissipation (in W/m^2 or m^2/s, depending on command SET).
DISBOT	energy dissipation due to bottom friction (in W/m^2 or m^2/s, depending on command SET).
DISSURF	energy dissipation due to surf breaking (in W/m^2 or m^2/s, depending on command SET).
DISWCAP	energy dissipation due to whitecapping (in W/m^2 or m^2/s, depending on command SET).
DISSWELL	energy dissipation due to swell dissipation (in W/m^2 or m^2/s, depending on command SET).
DISVEG	energy dissipation due to vegetation (in W/m^2 or m^2/s, depending on command SET).
DISMUD	energy dissipation due to mud (in W/m^2 or m^2/s, depending on command SET).
DISICE	energy dissipation due to sea ice (in W/m^2 or m^2/s, depending on command SET).
RADSTR	energy transfer between waves and currents due to radiation stress (in W/m^2 or m^2/s, depending on command SET).

QB	fraction of breaking waves due to depth-induced breaking.
GAMMA	breaker index derived from the beta-kd model.
TRANSP	transport of energy (vector; in W/m or m^3/s, depending on command SET). Relative to $x-$axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with BLOCK command in combination with command FRAME, see command QUANTITY.

FORCE	wave-induced force per unit surface area (vector; in N/m^2).
	Relative to $x-$axis of the problem coordinate system (counterclockwise);
	possible exception: in the case of output with BLOCK command
	in combination with command FRAME, see command QUANTITY.
UBOT	the rms-value of the <u>maxima</u> of the orbital velocity near the bottom (in m/s).
	Output only if command FRICTION is used. If one wants to output UBOT but
	friction is ignored in the computation, then one should use the command
	FRICTION with the value of the friction set to zero (FRICTION COLLINS 0).
URMS	the rms-value of the orbital velocity near the bottom (in m/s).
	If one wants to output URMS but friction is ignored in the computation,
	then one should use the command FRICTION with the value of the friction
	set to zero (FRICTION COLLINS 0).
TMBOT	the bottom wave period (in s).
WLEN	average wave length (in m).
LWAVP	peak wave length (in m).
STEEPNESS	average wave steepness (dimensionless).
BFI	Benjamin-Feir index (dimensionless).
NPLANTS	number of plants per square meter.
DHSIGN	the difference in significant wave height as computed in the last two iterations.
	This is <u>not</u> the difference between the computed values and the final limit of
	the iteration process, at most an indication of this difference.
DRTM01	the difference in average wave period (RTM01) as computed in the last two
	iterations. This is <u>not</u> the difference between the computed values and the
	final limit of the iteration process, at most an indication of this difference.
LEAK	numerical loss of energy equal to $c_\theta E(\omega, \theta)$ across boundaries
	$\theta_1 = $ [dir1] and $\theta_2 = $ [dir2] of a directional sector (see
	command CGRID).
TIME	Full date-time string as part of line used in TABLE only. Useful only in case of
	nonstationary computations.
TSEC	Time in seconds with respect to a reference time (see command QUANTITY).
	Useful only in case of nonstationary computations.
XP	user instructs SWAN to write the $x-$coordinate in the <u>problem coordinate system</u>
	of the output location.
YP	user instructs SWAN to write the $y-$coordinate in the <u>problem coordinate system</u>
	of the output location.
DIST	if output has been requested along a curve (see command CURVE) then the distance
	along the curve can be obtained with the command TABLE. DIST is the distance
	along the curve measured from the first point on the curve to the output location
	on the curve in meters (also in the case of spherical coordinates).
SETUP	Set-up due to waves (in m).
PTHSIGN	user requests partition of the significant wave height (in m).
	Partition of wave spectra is based on the watershed algorithm of
	Hanson and Phillips (2001). First partition is due to wind sea and

	the remaining partitions are the swell, from highest to lowest significant wave height. There will be at most 10 partitions.
PTRTP	user requests partition of the relative peak period (in s).
PTWLEN	user requests partition of the average wave length (in m).
PTDIR	user requests partition of the peak wave direction in degrees. For Cartesian convention: relative to $x-$axis of the problem coordinate system (counterclockwise); possible exception: in the case of output with BLOCK command in combination with command FRAME, see command QUANTITY.
PTDSPR	user requests partition of the directional spreading (in degrees).
PTWFRAC	user requests partition of the wind fraction (dimensionless). This indicates the fraction of that partition that is actively being forced by the wind.
PTSTEEP	user requests partition of the wave steepness (dimensionless).
PARTIT	user instructs SWAN to generate the raw spectral partition file meant for wave system tracking post-processing. Details on the file format and meaning of different parameters may be found in *http://polar.ncep.noaa.gov/waves/workshop/pdfs/ WW3-workshop-exercises-day4-wavetracking.pdf.* Note that this command should not be combined with any other parameters in BLOCK, although the following parameters will be automatically included, namely: coordinates, depth, wind, current, Hs, Tp, wave direction, directional spreading, and wave length. Also note that PARTIT cannot be used as an output parameter in TABLE.
[unit]	this controls the scaling of output. The program divides computed values by [unit] before writing to file, so the user should multiply the written value by [unit] to obtain the proper value. Default: if HEADER is selected, value is written as a 5 position integer. SWAN takes [unit] such that the largest number occurring in the block can be printed. If NOHEADER is selected, values are printed in floating-point format, [unit] = 1.
OUTPUT	the user requests output at various times. If the user does not use this option, the program will give BLOCK output for the last time step of the computation.
[tbegblk]	begin time of the first field of the variable, the format is: 1 : ISO-notation 19870530.153000 2 : (as in HP compiler) '30$-$May$-$87 15:30:00' 3 : (as in Lahey compiler) 05/30/87.15:30:00 4 : 15:30:00 5 : 87/05/30 15:30:00' 6 : as in WAM 8705301530 This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.
[deltblk]	time interval between fields, the unit is indicated in the next option: SEC unit seconds

```
              MIN    unit minutes
              HR     unit hours
              DAY    unit days
```

```
                      | -> HEADer   |
                      |             |
TABle  'sname'  <        NOHEADer  >  'fname'                                    &
                      |             |
                      |   INDexed   |

           | ...      |                                       | -> Sec  |
     <  <             >   > (OUTput [tbegtbl] [delttbl] <      MIn   >)
           | ...      |                                       |   HR    |
                                                              |   DAy   |
```

With this optional command the user indicates that for <u>each location</u> of the output location
set 'sname' (see commands POINTS, CURVE, FRAME or GROUP) one or more variables should
be written to a file. The keywords HEADER and NOHEADER determine the appearance of the
table; the filename determines the destination of the data.

'sname'	name of the set of POINTS, CURVE, FRAME or GROUP
HEADer	output is written in fixed format to file with headers giving name of variable and unit per column. A disadvantage of this option is that the data are written in fixed format; numbers too large to be written will be shown as: ****. Number of header lines is 4.
NOHEADer	output is written in floating point format to file and has no headers; it is intended primarily for processing by other programs. With some spreadsheet programs, however, the HEADER option works better.
INDexed	a table on file is produced which can be used directly (without editing) as input to ARCVIEW, ARCINFO, etc. The user should give two TABLE commands, one to produce one file with XP and YP as output quantities, the other with HS, RTM01 or other output quantities, such as one wishes to process in ARCVIEW or ARCINFO. The first column of each file produced by SWAN with this command is the sequence number of the output point. The last line of each file is the word END.
'fname'	name of the data file where the output is to be written to. Default for option HEADER is output to the PRINT file. In case of NOHEADER the filename is required.
|...| < >	the output parameters are the same as given in command BLOCK.

```
 |...|
```
OUTPUT   the user requests output at various times. If the user does not use this option, the program will give `TABLE` output for the last time step of the computation.

[tbegtbl]   begin time of the first field of the variable, the format is:

1 : ISO-notation	19870530.153000
2 : (as in HP compiler)	'30−May−87 15:30:00'
3 : (as in Lahey compiler)	05/30/87.15:30:00
4 :	15:30:00
5 :	87/05/30 15:30:00'
6 : as in WAM	8705301530

This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.

[delttbl]   time interval between fields, the unit is indicated in the next option:

SEC	unit seconds
MIN	unit minutes
HR	unit hours
DAY	unit days

Unless specifying (see command `BLOCK`), the $x-$ and $y-$components of the vectorial quantities `VEL`, `FORCE` and `TRANSPORT` are always given with respect to the <u>problem coordinate</u> system.

The number of decimals in the table varies for the output parameters; it depends on the value of [hexp], given in the command `QUANTITY`.

```
                     |    SPEC1D |    | -> ABSolute |    | -> S |
SPECout  'sname' <            > <                   > <        > 'fname' &
                 | -> SPEC2D |    |    RELative |    |    L |


                                  | -> Sec  |
         OUTput [tbegspc] [deltspc] <    MIn   >
                                  |    HR   |
                                  |    DAy  |
```

With this optional command the user indicates that for each location of the output location set `'sname'` (see commands `POINTS`, `CURVE`, `FRAME` or `GROUP`) the 1D or 2D variance / energy (see command `SET`) density spectrum (either the relative frequency or the absolute frequency spectrum) is to be written to a data file. The name `'fname'` is required in this command.

'sname'   name of the set of `POINTS`, `CURVE`, `FRAME` or `GROUP`

SPEC2D	means that 2D (frequency-direction) spectra are written to file according to the format described in Appendix D. Note that this output file can be used for defining boundary conditions for subsequent SWAN runs (command `BOUNDSPEC`).
SPEC1D	means that 1D (frequency) spectra are written to file according to the format described in Appendix D. Note that this output file can be used for defining boundary conditions for subsequent SWAN runs (command `BOUNDSPEC`).
ABS	means that spectra are computed as function of <u>absolute</u> frequency (i.e. the frequency as measured in a fixed point).
REL	means that spectra are computed as function of <u>relative</u> frequency (i.e. the frequency as measured when moving with the current).
S	frequencies above the infragravity frequency cut-off f_{ig} are taken into account. Note: only relevant for surfbeat (IEM) modelling.
L	frequencies below the infragravity frequency cut-off f_{ig} are taken into account. Note: only relevant for surfbeat (IEM) modelling.
'fname'	name of the data file where the output is written to. When the extension is '**.nc**', a netCDF file will be generated automatically.
OUTPUT	the user requests output at various times. If the user does not use this option, the program will give `SPECOUT` output for the last time step of the computation.
[tbegspc]	begin time of the first field of the variable, the format is:

	1 : ISO-notation	19870530.153000
	2 : (as in HP compiler)	'30−May−87 15:30:00'
	3 : (as in Lahey compiler)	05/30/87.15:30:00
	4 :	15:30:00
	5 :	87/05/30 15:30:00'
	6 : as in WAM	8705301530

This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.

[deltspc]	time interval between fields, the unit is indicated in the next option:

SEC	unit seconds
MIN	unit minutes
HR	unit hours
DAY	unit days

```
                                        | -> Sec  |
NESTout 'sname' 'fname' OUTput [tbegnst] [deltnst] <     MIn   >
                                        |    HR   |
                                        |    DAy  |
```

CANNOT BE USED IN <u>1D-MODE</u>

With this optional command the user indicates that the 2D spectra along a nest boundary
'sname' (see command NGRID) should be written to a data file with name 'fname'. This
name is required in this command.

'sname'	name of the set of output locations, as defined in a command NGRID
'fname'	name of the data file where the output is written to. The file is structured according to the description in Appendix D, i.e. also the information about the location of the boundary are written to this file. SWAN will use this as a check for the subsequent nested run.
OUTPUT	the user requests output at various times. If the user does not use this option, the program will give NESTOUT output for the last time step of the computation.
[tbegnst]	begin time of the first field of the variable, the format is:

         1 : ISO-notation   19870530.153000
         2 : (as in HP compiler)   '30$-$May$-$87 15:30:00'
         3 : (as in Lahey compiler) 05/30/87.15:30:00
         4 :   15:30:00
         5 :   87/05/30 15:30:00'
         6 : as in WAM   8705301530
        This format is installation dependent. See Implementation Manual or ask the
        person who installed SWAN on your computer. Default is ISO-notation.

[deltnst]	time interval between fields, the unit is indicated in the next option:

        SEC   unit seconds
        MIN   unit minutes
        HR   unit hours
        DAY   unit days

4.6.3 Write or plot intermediate results

```
                               |         | < [i] [j] >  |   |
                               | -> IJ <                 > |
TEST  [itest] [itrace]  POINTS <         | < [k] >      |   >   &
                               |                            |
                               |    XY < [x] [y] >          |

      (PAR 'fname')  (S1D 'fname') (S2D 'fname')
```

If SWAN produces unexpected results, this optional command can be used to instruct
the program to produce intermediate results during a SWAN run (test output). A TEST
command may change between commands in the file to change the level of test output
during a SWAN run. This change occurs during the execution of the run. A TEST command

controls the test output until the next `TEST` command. Such a next `TEST` command may have level 0, thus stopping test output.

[itest]	the level of test output. For values under 100 the amount is usually reasonable, for values above 200 it can be very large. For values of [itest] up to 50 the test output can be interpreted by the user. For higher values of [itest] the test output can only be interpreted by those who have the program source listing at their disposal. Note that for sequential or parallel runs, it might be interesting to print the timings (both wall-clock and CPU times in seconds) in the `PRINT` file; for this [itest] should be set to 1.
	Default: [itest] = 1.
[itrace]	SWAN writes a message (name of subroutine) to the `PRINT` file at the first [itrace] entries of each subroutine.
	Default: [itrace] = 0.
POINTS	if this option is used, the user instructs SWAN to produce detailed print output during the computational process for a grid point of the computational grid. Output at a maximum of 50 grid points is possible. This option can be used only after the bathymetry has been read (see command `READINP BOTTOM`).
IJ	the test points are defined by means of grid indices.
[i], [j]	grid indices of a test point. Values of [i] range between 0 and [mxc] (see command `CGRID`), values of [j] between 0 and [myc] (inclusive). ONLY MEANT FOR STRUCTURED GRIDS.
[k]	vertex index of a test point. This can be obtained in a grid generator file (`fort.14`, `.node` and `.n` files of ADCIRC, Triangle and Easymesh, respectively). ONLY MEANT FOR UNSTRUCTURED GRIDS.
XY	the test points are defined in terms of problem coordinates; SWAN will determine the nearest grid points. Output will be made for this selected grid point.
[x], [y]	coordinates of a test point (problem coordinates in m in case of Cartesian coordinates, or longitude and latitude in degrees in case of spherical coordinates, see command `COORD`).
PAR	integral parameters for test points are written: HSIGN, RTM01 (see Appendix A for definitions) and Swind, Swcap, Ssurf, Sfric, Snl3 and Snl4 which are the integrals over frequency and direction of the respective source terms (wind input, whitecapping, depth-induced breaking, bottom friction, absolute value of the triad wave-wave interactions and absolute value of the quadruplet wave-wave interactions).
S1D	if the keyword `S1D` appears variance densities and 6 source terms (see end of this list of options) as computed will be printed as 1D spectral (frequency) output. The definition of this file is given in Appendix D. This output will be made after every iteration in the case of `MODE STATIONARY`, and after every time step in the case `MODE NONSTATIONARY` (see command `MODE`).
'fname'	name of the file to which the output is written; default filename: SWSRC1D.
S2D	if the keyword `S2D` appears variance densities and 6 source terms (see end of

this list of options) as computed will be printed as 2D (frequency and direction) spectral output. The format of this file is defined in Appendix D. This output will be made after every iteration in the case of `MODE STATIONARY`, and after every time step in the case `MODE NONSTATIONARY` (see command `MODE`).

'fname'   name of the file to which the output is written; default filename: `SWSRC2D`.

Note that the keywords `PAR`, `S1D` and `S2D` need to be given in that order.

The source terms written due to the presence of the keyword `S1D` or `S2D` are source terms of variance density. The 6 source terms are: wind input, whitecapping, bottom friction, breaking, 3-wave interactions and 4-wave interactions.

When a number `[maxmes]` of error messages, see command `SET`, have been written to the `PRINT` file, the computation will stop. If necessary make `[maxmes]` larger using command `SET`, and rerun the program.

4.7 Lock-up

```
                  |      STATionary   [time]                         |
COMPute   ( <                                                  > )
                  |                              | -> Sec |          |
                  | -> NONSTat  [tbegc] [deltc] <    MIn   > [tendc] |
                  |                              |    HR  |          |
                  |                              |    DAy |          |
```

This command orders SWAN to start the computation(s).

If the SWAN <u>mode</u> is stationary (see command `MODE`), then only the command `COMPUTE` should be given here (no options!).
If the SWAN <u>mode</u> is nonstationary (see command `MODE`), then the computation can be

- either stationary (at the specified time: option `STATIONARY` here) or

- nonstationary (over the specified period of time: `[tbegc]` etc.).

To verify input to SWAN (e.g., all input fields such as water depth, wind fields, etc.), SWAN can be run without computations (that is: zero iterations by using command `NUM STOPC MXITST = 0`).

In the case `MODE NONSTATIONARY` several commands `COMPUTE` can appear, where the wave state at the end of one computation is used as initial state for the next one, unless a command `INIT` appears in between the two `COMPUTE` commands. This enables the user to

make a stationary computation to obtain the initial state for a nonstationary computation and/or to change the computational time step during a computation, to change a boundary condition etc. This also has the advantage of not using a hotfile since, it can be very large in size.

For small domains, i.e. less than 100 km or 1 deg, a stationary computation is recommended. Otherwise, a nonstationary computation is advised.

For a nonstationary computation, a time step of at most 10 minutes is advised. (When you are choosing a time step larger than 10 minutes, the action density limiter (see command NUM) becomes probably a part of the physics.)

Also, the time step should be chosen such that the Courant number is smaller than 10 for the fastest (or dominant) wave. Otherwise, a first order upwind scheme is recommended in that case; see command PROP BSBT. If you want to run a high resolution model with a very large time step, e.g. 1 hour, you may apply multiple COMPUT STAT commands.

For a sufficiently small time step ($\leq$ 10 minutes), no more than 1 iteration per time step is recommended (see command NUM ... NONSTAT [mxitns]).

STATIONARY	a stationary computation is to be made.
[time]	time level for which the stationary run is to be made, the format is:
	1 : ISO-notation 19870530.153000
	2 : (as in HP compiler) '30$-$May$-$87 15:30:00'
	3 : (as in Lahey compiler) 05/30/87.15:30:00
	4 : 15:30:00
	5 : 87/05/30 15:30:00'
	6 : as in WAM 8705301530
	This format is installation dependent. See Implementation Manual or ask the person who installed SWAN on your computer. Default is ISO-notation.
NONSTATION	a nonstationary computation is to be made.
[tbegc]	the start date and time of the nonstationary computation, format see [time]. Default: the time read from a hotfile (see command INIT HOTSTART), or the end time [tendc] of the previous nonstationary computation or the [time] of the previous stationary computation in the same SWAN run (if any).
[deltc]	the time step of the nonstationary computation, the unit is indicated in the next option:
	SEC unit seconds
	MIN unit minutes
	HR unit hours
	DAY unit days
[tendc]	the end time of the nonstationary computation, format see [time].

```
                   | -> FREE
HOTFile 'fname' <
                   | UNFormatted
```

This command can be used to write the entire wave field at the end of a computation to a so-called hotfile, to be used as initial condition in a subsequent SWAN run (see command `INITIAL HOTSTART`) This command must be entered immediately after a `COMPUTE` command.

The user may choose the format of the hotfile to be written either as free or unformatted. If the free format is chosen, then this format is identical to the format of the files written by the `SPECOUT` command (option SPEC2D). This hotfile is therefore an ASCII file which is human readable.

An unformatted (or binary) file usually requires less space on your computer than an ASCII file. Moreover, it can be read by a subsequent SWAN run much faster than an ASCII file. Especially, when the hotfile might become a big file, the choice for unformatted is preferable. Note that your compiler and OS should follow the same ABI (Application Binary Interface) conventions (e.g. word size, endianness), so that unformatted hotfiles may transfer properly between different OS or platforms. This implies that the present and subsequent SWAN runs do not have to be carried out on the same operating system (e.g. Windows, Linux) or on the same computer, provided that distinct ABI conventions have been followed.

`'fname'`	name of the file to which the wave field is written. <u>Note</u>: for parallel MPI runs, more than one hotfile will be generated depending on the number of processors (`fname-001`, `fname-002`, etc.).
`FREE`	the user indicates that the hotfile is written with free format. This option is the default.
`UNFORMATTED`	the user indicates that the hotfile is written unformatted.

`STOP`

This required command marks the end of the commands in the command file. Note that the command `STOP` may be the last command in the input file; any information in the input file beyond this command is ignored.

Appendix A

Definitions of variables

In SWAN a number of variables are used in input and output. Most of them are related to waves. The definitions of these variables are mostly conventional.

HSIGN   Significant wave height, denoted as H_s in meters, and defined as

$$H_s = 4\sqrt{\int \int E(\omega, \theta) d\omega d\theta}$$

where $E(\omega, \theta)$ is the variance density spectrum and ω is the absolute radian frequency determined by the Doppler shifted dispersion relation. However, for ease of computation, H_s can be determined as follows:

$$H_s = 4\sqrt{\int \int E(\sigma, \theta) d\sigma d\theta}$$

HSWELL   Significant wave height associated with the low frequency part of the spectrum, denoted as $H_{s,\text{swell}}$ in meters, and defined as

$$H_{s,\text{swell}} = 4\sqrt{\int_0^{\omega_{\text{swell}}} \int_0^{2\pi} E(\omega, \theta) d\omega d\theta}$$

with $\omega_{\text{swell}} = 2\pi f_{\text{swell}}$ and $f_{\text{swell}} = 0.1$ Hz by default (this can be changed with the command QUANTITY).

TMM10   Mean absolute wave period (in s) of $E(\omega, \theta)$, defined as

$$T_{m-10} = 2\pi \frac{\int \int \omega^{-1} E(\omega,\theta) d\omega d\theta}{\int \int E(\omega,\theta) d\omega d\theta} = 2\pi \frac{\int \int \omega^{-1} E(\sigma,\theta) d\sigma d\theta}{\int \int E(\sigma,\theta) d\sigma d\theta}$$

TM01   Mean absolute wave period (in s) of $E(\omega, \theta)$, defined as

$$T_{m01} = 2\pi \left(\frac{\int \int \omega E(\omega,\theta) d\omega d\theta}{\int \int E(\omega,\theta) d\omega d\theta} \right)^{-1} = 2\pi \left(\frac{\int \int \omega E(\sigma,\theta) d\sigma d\theta}{\int \int E(\sigma,\theta) d\sigma d\theta} \right)^{-1}$$

TM02   Mean absolute wave period (in s) of $E(\omega, \theta)$, defined as

$$T_{m02} = 2\pi \left(\frac{\int \int \omega^2 E(\omega,\theta) d\omega d\theta}{\int \int E(\omega,\theta) d\omega d\theta} \right)^{-1/2} = 2\pi \left(\frac{\int \int \omega^2 E(\sigma,\theta) d\sigma d\theta}{\int \int E(\sigma,\theta) d\sigma d\theta} \right)^{-1/2}$$

DIR   Mean wave direction (in ^{o}, Cartesian or Nautical convention),
                    as defined by (see Kuik *et al.* (1988)):

$$\text{DIR} = \frac{180}{\pi} \arctan \left(\frac{\int \sin\theta E(\sigma,\theta) d\sigma d\theta}{\int \cos\theta E(\sigma,\theta) d\sigma d\theta} \right)$$

                    This direction is the direction normal to the wave crests.

PDIR   Peak direction of $E(\theta) = \int E(\omega, \theta) d\omega = \int E(\sigma, \theta) d\sigma$
                    (in ^{o}, Cartesian or Nautical convention).

TDIR   Direction of energy transport (in ^{o}, Cartesian or Nautical convention).
                    Note that if currents are present, TDIR is different from the mean wave
                    direction DIR.

RTMM10   Mean relative wave period (in s) of $E(\sigma, \theta)$, defined as

$$RT_{m-10} = 2\pi \frac{\int \int \sigma^{-1} E(\sigma,\theta) d\sigma d\theta}{\int \int E(\sigma,\theta) d\sigma d\theta}$$

                    This is equal to TMM10 in the absence of currents.

RTM01   Mean relative wave period (in s) of $E(\sigma, \theta)$, defined as

$$RT_{m01} = 2\pi \left(\frac{\int \int \sigma E(\sigma,\theta) d\sigma d\theta}{\int \int E(\sigma,\theta) d\sigma d\theta} \right)^{-1}$$

                    This is equal to TM01 in the absence of currents.

RTP   Relative peak period (in s) of $E(\sigma)$ (equal to absolute peak period
                    in the absence of currents).
                    Note that this peak period is related to the absolute maximum bin of the
                    discrete wave spectrum and hence, might not be the 'real' peak period.

TPS   Relative peak period (in s) of $E(\sigma)$.
                    This value is obtained as the maximum of a parabolic fitting through the
                    highest bin and two bins on either side the highest one of the discrete
                    wave spectrum. This 'non-discrete' or 'smoothed' value is a better
                    estimate of the 'real' peak period compared to the quantity `RTP`.

PER   Average absolute period (in s) of $E(\omega, \theta)$, defined as

$$T_{m,p-1,p} = 2\pi \frac{\int \int \omega^{p-1} E(\omega,\theta) d\omega d\theta}{\int \int \omega^p E(\omega,\theta) d\omega d\theta}$$

                    The power p can be chosen by the user by means of the `QUANTITY`

command. If $p = 1$ (the default value) PER is identical to TM01 and if $p = 0$, PER = TMM10.

RPER   Average relative period (in s), defined as

$$RT_{m,p-1,p} = 2\pi \frac{\int\int \sigma^{p-1} E(\sigma,\theta) d\sigma d\theta}{\int\int \sigma^p E(\sigma,\theta) d\sigma d\theta}$$

Here, if $p = 1$, RPER=RTM01 and if $p = 0$, RPER=RTMM10.

FSPR   The normalized frequency width of the spectrum (frequency spreading), as defined by Battjes and Van Vledder (1984):

$$\text{FSPR} = \frac{|\int_0^\infty E(\omega)e^{i\omega\tau} d\omega|}{E_{\text{tot}}}, \qquad \text{for } \tau = T_{m02}$$

DSPR   The one-sided directional width of the spectrum (directional spreading or directional standard deviation,in ^{o}), defined as

$$\text{DSPR}^2 = \left(\frac{180}{\pi}\right)^2 \int_0^{2\pi} (2\sin(\frac{\theta-\bar{\theta}}{2}))^2 D(\theta) d\theta$$

and computed as conventionally for pitch-and-roll buoy data (Kuik *et al.* (1988); this is the standard definition for WAVEC buoys integrated over all frequencies):

$$(\text{DSPR}\tfrac{\pi}{180})^2 = 2\left(1 - \sqrt{\left[\left(\frac{\int \sin\theta E(\sigma,\theta) d\sigma d\theta}{\int E(\sigma,\theta) d\sigma d\theta}\right)^2 + \left(\frac{\int \cos\theta E(\sigma,\theta) d\sigma d\theta}{\int E(\sigma,\theta) d\sigma d\theta}\right)^2\right]}\right)$$

QP   The peakedness of the wave spectrum, defined as

$$Q_p = 2\frac{\int\int \sigma E^2(\sigma,\theta) d\sigma d\theta}{(\int\int E(\sigma,\theta) d\sigma d\theta)^2}$$

This quantity represents the degree of randomness of the waves. A smaller value of Q_p indicates a wider spectrum and thus increased the degree of randomness (e.g., shorter wave groups), whereas a larger value indicates a narrower spectrum and a more organised wave field (e.g., longer wave groups).

MS   As input to SWAN with the commands `BOUNDPAR` and `BOUNDSPEC`, the directional distribution of incident wave energy is given by $D(\theta) = A(\cos\theta)^m$ for all frequencies. The parameter m is indicated as MS in SWAN and is not necessarily an integer number. This number is related to the one-sided directional spread of the waves (DSPR) as follows:

Table A.1: Directional distribution.

MS	DSPR (in ^{o})
1.	37.5
2.	31.5
3.	27.6
4.	24.9
5.	22.9
6.	21.2
7.	19.9
8.	18.8
9.	17.9
10.	17.1
15.	14.2
20.	12.4
30.	10.2
40.	8.9
50.	8.0
60.	7.3
70.	6.8
80.	6.4
90.	6.0
100.	5.7
200.	4.0
400.	2.9
800.	2.0

PROPAGAT   Energy propagation per unit time in $\vec{x}-$, $\theta-$ and $\sigma-$space (in W/m^2 or m^2/s, depending on the command SET).

GENERAT   Energy generation per unit time due to the wind input (in W/m^2 or m^2/s, depending on the command SET).

REDIST   Energy redistribution per unit time due to the sum of quadruplets and triads (in W/m^2 or m^2/s, depending on the command SET).

DISSIP   Energy dissipation per unit time due to the sum of bottom friction, whitecapping and depth-induced surf breaking (in W/m^2 or m^2/s, depending on the command SET).

RADSTR   Work done by the radiation stress per unit time, defined as

$$\int_0^{2\pi}\int_{\sigma_{\text{low}}}^{\sigma_{\text{high}}} |S_{\text{tot}} - \frac{\partial E}{\partial t} - \nabla_{\vec{x}} \cdot [(\vec{c}_g + \vec{U})E] - \nabla_{(\sigma,\theta)} \cdot (\vec{c}_{(\sigma,\theta)}E)|d\sigma d\theta$$

(in W/m^2 or m^2/s, depending on the command SET).

WLEN	The mean wave length, defined as

$$\text{WLEN} = 2\pi \left(\frac{\int \int k^p E(\sigma,\theta) d\sigma d\theta}{\int \int k^{p-1} E(\sigma,\theta) d\sigma d\theta} \right)^{-1}$$

As default, $p = 1$ (see command `QUANTITY`).

STEEPNESS	Wave steepness computed as HSIG/WLEN.
BFI	The Benjamin-Feir index or the steepness-over-randomness ratio, defined as

$$\text{BFI} = \sqrt{2\pi} \times \text{STEEPNESS} \times \text{QP}$$

This index can be used to quantify the probability of freak waves.

QB	Fraction of breakers in expression of Battjes and Janssen (1978).
TRANSP	Energy transport with components $P_x = \rho g \int \int c_x E(\sigma,\theta) d\sigma d\theta$ and $P_y = \rho g \int \int c_y E(\sigma,\theta) d\sigma d\theta$ with x and y the problem coordinate system, except in the case of output with `BLOCK` command in combination with command `FRAME`, where x and y relate to the $x-$axis and $y-$axis of the output frame.
VEL	Current velocity components in $x-$ and $y-$direction of the problem coordinate system, except in the case of output with `BLOCK` command in combination with command `FRAME`, where x and y relate to the $x-$axis and $y-$axis of the output frame.
WIND	Wind velocity components in $x-$ and $y-$direction of the problem coordinate sytem, except in the case of output with `BLOCK` command in combination with command `FRAME`, where x and y relate to the $x-$axis and $y-$axis of the output frame.
FORCE	Wave-induced force per unit surface area (gradient of radiation stresses) with x and y the problem coordinate system, except in the case of output with `BLOCK` command in combination with command `FRAME`, where x and y relate to the $x-$axis and $y-$axis of the output frame.

$$F_x = -\frac{\partial S_{xx}}{\partial x} - \frac{\partial S_{xy}}{\partial y}$$

$$F_y = -\frac{\partial S_{yx}}{\partial x} - \frac{\partial S_{yy}}{\partial y}$$

where S is the radiation stress tensor as given by

$$S_{xx} = \rho g \int (n \cos^2 \theta + n - \tfrac{1}{2}) E d\sigma d\theta$$

$$S_{xy} = S_{yx} = \rho g \int n \sin \theta \cos \theta E d\sigma d\theta$$

$$S_{yy} = \rho g \int (n\sin^2\theta + n - \tfrac{1}{2})Ed\sigma d\theta$$

	and n is the group velocity over the phase velocity.
UBOT	Root-mean-square value (in m/s) of the maxima of the orbital motion near the bottom $U_{\mathrm{bot}} = \sqrt{2}U_{\mathrm{rms}}$.
URMS	Root-mean-square value (in m/s) of the orbital motion near the bottom.

$$U_{\mathrm{rms}} = \sqrt{\int_0^{2\pi}\int_0^{\infty} \frac{\sigma^2}{\sinh^2 kd}E(\sigma,\theta)d\sigma d\theta}$$

TMBOT	Near bottom wave period (in s) defined as the ratio of the bottom excursion amplitude to the root-mean-square velocity $T_{\mathrm{b}} = \sqrt{2}\pi a_{\mathrm{b}}/U_{\mathrm{rms}}$ with

$$a_{\mathrm{b}} = \sqrt{2\int_0^{2\pi}\int_0^{\infty}\frac{1}{\sinh^2 kd}E(\sigma,\theta)d\sigma d\theta}$$

LEAK	Numerical loss of energy equal to $c_\theta E(\omega,\theta)$ across boundaries θ_1=[dir1] and θ_2=[dir2] of a directional sector (see command `CGRID`).
TIME	Full date-time string.
TSEC	Time in seconds with respect to a reference time (see command `QUANTITY`).
SETUP	The elevation of mean water level (relative to still water level) induced by the gradient of the radiation stresses of the waves.
Cartesian convention	The direction is the angle between the vector and the positive $x-$axis, measured counterclockwise. In other words: the direction where the waves are going <u>to</u> or where the wind is blowing <u>to</u>.
Nautical convention	The direction of the vector from geographic North measured clockwise. In other words: the direction where the waves are coming <u>from</u> or where the wind is blowing <u>from</u>.

Appendix B

Command syntax

B.1   Commands and command schemes

The actual commands of the user to SWAN must be given in one file containing all commands. This file is called the <u>command file</u>. It must be presented to SWAN in ASCII. It is important to make a distinction between the <u>description</u> of the commands in this User Manual and the <u>actual</u> commands in the command file. The descriptions of the commands in this User Manual are called <u>command schemes</u>. Each such command scheme includes a diagram and a description explaining the structure of the command and the meaning of the keyword(s) and of the data in the command. The proper sequence of the commands is given in Section 4.2.

B.2   Command

B.2.1   Keywords

Each command instructs SWAN to carry out a certain action which SWAN executes before it reads the next command. A command must always start with a keyword (which is also the name of the command) which indicates the primary function of that command; see list in Section 4.1). A simple command may appear in its command scheme as:

```
KEYword data
```

A command may contain more than one keyword (which refines the instructions to SWAN), e.g.,

```
KEY1word KEY2word data
```

where `KEY2word` is the second keyword.

Spelling of keywords

In every command scheme, keywords appear as words in both lower- and upper-case letters. When typing the command or keyword in the command file, the user **must at least** copy literally the part with upper-case letters. SWAN reads only this part. SWAN is case insensitive except for one instance (character strings), see below. When typing the keyword in the command file, any extension of the part with upper-case letters is at the users discretion as long as the extension is limited to letters or digits, as well as the characters − and _. So, in the first command outlined above one may write: `KEY` or `KEYW` or `KEY−word` or `keyhole`, etc., whereas with the abovementioned second command scheme, `key1 KEY2 data` may appear in the command file.

In the command file

- a keyword is closed by a blank or one of the following characters = or :

- a keyword is not enclosed by square brackets or quotes,

- a keyword followed by a comma (,) is interpreted as a keyword followed by an empty data field (see below).

Required and optional keywords

All keywords in a command are required except when an option is available.

Optional keywords are indicated in the command scheme with the following signs enclosing the keywords concerned:

```
 |  KEY1word ...... data ....... |
<                                 >
 |  KEY2word ...... data ....... |
```

For the above example it may appear as:

```
           |  KEY2word data |
 KEY1word  <                 >
           |  KEY3word data |
```

In case the user does not indicate an option in a command, SWAN chooses the alternative indicated with an arrow (`->`) appearing in the command scheme (the default option). In the above example, it may appear as:

```
           |    KEY2word data |
 KEY1word  <                  >
           | -> KEY3word data |
```

where `KEY3WORD` is the default option.

Repetitions of keywords and/or other data

The use of keywords is sometimes repetitive, e.g. in a sequence of data and keywords containing many locations in $x, y-$space. In such a case, the command scheme indicates this repetitive nature by placing the keywords (and data) concerned between angle brackets `< >`. For instance,

```
KEY1word <data KEY2word data>
```

In the actual command in the command file the user must give such a sequence. It ends with either

- end of line

- a keyword other than the ones mentioned in the repetition group

- the character / or ;

If more than one line is required for a command, the user may continue on the next line as described in Section B.4. The repetition may consist of one instance (in fact, no repetition at all).

B.2.2   Data

Most commands contain data, either character data or numerical data.

Character data and numerical data

Character data (character strings) are represented in the command schemes by names, enclosed in quotes (' ').

Numerical data are represented in the command schemes by names enclosed in square brackets ([ ]).

As a rule, an error message will result if numerical data is given where character data should be given.

Spelling of data

Character data are represented as character strings (sequence of characters and blanks) between quotes (in the command scheme and in the command file). SWAN interprets an end of line as an end quote (a character data field can therefore never extend over more than one line).

In a command scheme the character string is always a name (which is placed between quotes as indicated). In the command file such a name can be entered in two ways:

- Replace the name by another character string at the users discretion (between quotes; this is the only occurrence where SWAN is case sensitive; e.g. for text to appear in a plot.
  Example:
  command scheme: `KEYword 'City' data`
  command file: `KEY 'Amsterdam' data`

- Copy the name of the variable (without the quotes) literally followed by an = sign and a name at the users discretion (between quotes). SWAN interprets the copied name in the command file as a keyword with all the characteristics of a keyword such as ending a sequence of optional data (see below). As with other keywords the name of the variable is case-insensitive.
  Example:
  command scheme: `KEYword 'City' data`
  command file: `KEY city='Amsterdam' data`

As a rule, an error message will result if numerical data is given where character data should be given.

Numerical data are simple numbers, e.g. 15 or −7 (integer data), or 13.7 or 0.8E−4 (real data). Whether or not integer number or real number should be given by the user is indicated in the description of the command scheme.

Note that a decimal point is not permitted in an integer number. On the other hand, an integer number is accepted by SWAN where a real number should be given.

In a command scheme, the number is always indicated with a name (which is placed between square brackets). In the command file such a name can be entered in two ways:

- Replace the name by a number (not between square brackets).
  Example:
  command scheme: `KEYword [nnn]`
  command file: `KEY 314`

- Copy the name of the variable (without the quotes) literally followed by an = sign and the number (not between square brackets). SWAN interprets the copied name in the command file as a keyword with all the characteristics of a keyword such as ending a sequence of optional data (see below). As with other keywords the name of the variable is case-insensitive.
  Example:
  command scheme: `KEYword [nnn]`
  command file: `KEY nnn=314`

Required data and optional data

All data must be given by the user in the command file in the same order as they appear in the command scheme. They are separated by blanks or comma's.

Required data (indicated in the description of each individual command) must be given explicitly as character string or numbers.

Optional data are indicated

(a) in the text of each individual command or

(b) for sets of data: in parenthesis around the data concerned

```
( data )
```

For example:

```
KEY1word KEY2word 'name' ([nnn] [mmm]) [zzz]
```

or

(c) some optional data are indicate in the same way as optional keywords are indicated:

```
| .....data.....|
<              >
| .....data.....|
```

Optional data of the kind (a) or (b) may be omitted by giving blanks between comma's (SWAN then substitutes reasonable default values). If after a required datum all data is optional (till the next keyword or the next end-of-line), then the comma's may be omitted too. Optional data of the kind (c) are to be treated in the same way as optional keywords.

B.3 Command file and comments

All text after one $ or between two $ signs on one line in the command file is ignored by SWAN as comment. Such comments may be important to the user e.g., to clarify the meaning of the commands used. In fact, this option has been used to create the edit file `swan.edt` (see Appendix C). Anything appearing after two $ signs is not interpreted

as comment, but again as data to be processed (possibly interrupted again by $ or two
$ signs). Since version 40.20, the exclamation mark '!' can be used as comment sign.
Everthing behind a ! is interpreted as comment, also if ! or $ are in that part of the input
line.

B.4   End of line or continuation

A command in the command file may be continued on the next line if the previous line
terminates with a continuation mark & or _ (underscore).

Appendix C

File `swan.edt`

Below the file `swan.edt` is presented in which all the commands that can be used with SWAN are specified.

```
!   PROJECT  'name'  'nr'
!            'title1'
!            'title2'
!            'title3'
!
!   SET  [level]  [nor]  [depmin]  [maxmes]                        &
!        [maxerr]  [grav]  [rho]  [cdcap]  [uscap]  [inrhog]       &
!        [hsrerr]  CARTesian|NAUTical  [pwtail]                    &
!        [froudmax]  [icewind]  [excmark]  [sort]  [nsweep]  CURV  &
!        [printf]  [prtest]
!
!   MODE  / STATIONARY \  / TWODimensional
!         \ DYNAMIC    /  \ ONEDimensional
!
!   COORDinates  /  -> CARTesian          \    REPeating
!                \  SPHErical     CCM|QC  /
!
!   CGRID  / REGular [xpc] [ypc] [alpc] [xlenc] [ylenc] [mxc] [myc] \
!          <  CURVilinear [mxc] [myc]  (EXC [xexc] [yexc]) [alpc]    >   &
!           \ UNSTRUCtured                                          /
!
!          / CIRcle                \
!          \ SECtor [dir1] [dir2] /  [mdc]  [flow]  [fhig]  [msc]
!
!   INPgrid                                                        &
!      BOT | WLEV | CUR | VX | VY | FR | WI | WX | WY | NPLA | TURB | MUDL  &
```

```
!        AICE | HICE | HSS | TSS | DSS                                    &
!
!        | REG [xpinp] [ypinp] [alpinp]  [mxinp] [myinp]  [dxinp] [dyinp] |
!        |                                                                |
!    <  CURVilinear [stagrx] [stagry] [mxinp] [myinp]                  >  &
!        |                                                                |
!        | UNSTRUCtured                                                   |
!
!        (EXCeption  [excval])                                            &
!
!        (NONSTATionary [tbeginp] [deltinp] SEC|MIN|HR|DAY [tendinp])
!
!                          | -> ADCirc
!    READgrid UNSTRUCtured <  TRIAngle \
!                          | EASYmesh / 'fname'
!
!    READinp    BOTtom | WLevel | CURrent | FRiction | WInd | COOR | NPLAnts &
!               TURB | MUDL | AICE | HICE | HSS | TSS | DSS                &
!
!        [fac]  / 'fname1'        \
!               \ SERIES 'fname2' /  [idla] [nhedf] ([nhedt]) (nhedvec])    &
!
!        FREE | FORMAT 'form' | [idfm] | UNFORMATTED
!
!    WIND  [vel] [dir]
!
!    ICE  [aice] [hice]
!
!                     | JONswap  [gamma]  |
!                     | PM                |
!    BOUnd SHAPespec    <  GAUSs  [sigfr]     >  PEAK|MEAN    DSPR   POWer|DEGRees
!                     | BIN               |
!                     | TMA   [gamma] [d] |
!
!           / -> SIDE  N|NW|W|SW|S|SE|E|NE | [k]  CCW|CLOCKWise          \
!    BOUndspec <                                                          > &
!           \    SEGment  / -> XY  < [x]  [y] >            \         /
!                         \    IJ  < [i]  [j] > | < [k] >  /
!
!         / UNIForm  / PAR  [hs] [per] [dir] [dd]
!        <              \ FILE  'fname'  [seq]
!         \ VARiable  / PAR  < [len] [hs] [per] [dir] [dd] >
!                       \ FILE < [len] 'fname' [seq] >
```

```
!
!    BOUndnest1  NEst 'fname'  CLOSed|OPEN
!
!    BOUndnest2  WAMNest 'fname' / UNFormatted CRAY|WKstat \
!                            \ FREE                   / [xgc] [ygc] [lwdate]
!
!                        | UNFormatted |   | -> CLOS |
!    BOUndnest3  WW3 'fname' <             > <          > [xgc] [ygc]
!                        | FREe      |   |    OPEN |
!
!           | -> DEFault
!           |
!    INITial  <   ZERO
!           |
!           |  PAR  [hs] [per] [dir] [dd]
!           |
!           |          | -> MULTiple |          | -> FREE
!           |  HOTStart <              > 'fname' <
!           |          |   SINGle   |          | UNFormatted
!
!    GEN1  [cf10] [cf20] [cf30] [cf40] [edmlpm] [cdrag] [umin]
!
!    GEN2  [cf10] [cf20] [cf30] [cf40] [cf50] [cf60] [edmlpm] [cdrag] [umin]
!
!        |     JANSsen [cds1] [delta]     |                      |
!        |                            |                      |
!        |     KOMen   [cds2] [stpm]      |       |-> WU    |        |
!        |                          > DRAG <   FIT   >        |
!        |     YAN                   |       | SWELL |        |
!        |                            |                      |
!        | -> WESTH [cds2] [br]          |                      |
!        |                            |                      |
!        |     BABANIN [a1sds] [a2sds] [p1sds] [p2sds] [cdsv]   &      |
!        |             | -> UP |                              |
!    GEN3 <       [feswell] <        > VECTAU   TRUE10                > &
!        |             | DOWN   |                              |
!        |                            |                      |
!        |     ST6    [a1sds] [a2sds] [p1sds] [p2sds]        &      |
!        |        | -> UP |    | -> HWANG |                     |
!        |         <        > <    FAN    >  VECTAU|SCATAU    &      |
!        |        | DOWN   |   |   ECMWF |                     |
!        |                            |                      |
!        |           |     TRUE10                |            |
```

```
!           |          <                                     >  DEBias [cdfac]        |
!           |              | -> U10Proxy [windscaling] |                          |
!
!        (AGROW [a])
!
!
!          |     ROGers  [cdsv] [feswell]
!   SSWELL <  -> ARDhuin [cdsv]
!          |     ZIEger  [b1]
!
!   NEGatinp  [rdcoef]
!
!
!          |    KOMen    [cds2] [stpm] [powst] [delta] [powk]
!          |
!          |    JANSsen [cds1]   [delta] [pwtail]
!          |
!          |    LHIG     [cflhig]
!          |
!  WCAP <      BJ       [bjstp] [bjalf]
!          |
!          |    KBJ      [bjstp] [bjalf] [kconv]
!          |
!          | -> AB       [cds2] [br]   CURrent [cds3]
!
!
!   QUADrupl [iquad] [lambda] [cnl4] [csh1] [csh2] [csh3]
!
!                           | CNL4 < [cnl4] >              |
!   MDIA LAMbda < [lambda] > <                              >
!                           | CNL4_12 < [cnl4_1] [cnl4_2] > |
!
!        | -> CON [alpha] [gamma]                                    |
!        |                                                           |
!        |    VAR [alpha] [gammin] [gammax] [gamneg] [coeff1] [coeff2] |
!        |                                                           |
!  BRE <      RUE [alpha] [a] [b]                                    >   &
!        |                                                           |
!        |    BKD [alpha] [gamma0] [a1] [a2] [a3] [npnts]            |
!        |                                                           |
!        |    TG  [alpha] [gamma] [pown]                             |
!
!     ( DIRectionality [spread] )                                        &
```

```
!
!       ( FREQDep [power] [fmin] [fmax] )
!
!
!                |                    | -> CONstant [cfjon]
!             | -> JONswap <
!                |              |      VARiable [cfj1] [cfj2] [dsp1] [dsp2]
!   FRICtion  <
!                |    COLLins [cfw] [cfc]
!                |
!                |    MADsen  [kn]
!                |
!                |    RIPples [S] [D]
!
!
!          |                        / -> COLL |
!       | -> DCTA [trfac] [p]   \    NONC |
!          |                             |
!          |    LTA [trfac] [cutfr] [dint]   |
!   TRIad <                                        >                              &
!          |    FTIM [trfac] [dint]         |
!          |                             |
!          |    SPB [trfac] [a] [b] [dint]   |
!
!             | -> ELDeberky [urcrit] |           |    FG
!    BIPHase <                            > TRAnsfer <    MS
!             | WIT [lpar]              |           |    BRedmose
!                                                   | -> QUadwave
!
!
!   TRIad [itriad] [trfac] [cutfr] [dint] [a] [b] [p] [urcrit] [urslim] [ic]
!
!
!   BRAGg [ibrag] [nreg] [cutoff]                                          &
!
!        | -> FT
!      <
!        |    FILE 'fname' [idla] [mkx] [mky] [dkx] [dky]
!
!   SCAT [iqcm]                                                            &
!
!             | -> WIDth [rfac]                               |
!      ( GRId <                                          > )       &
```

```
!                  | Kxy [kxlow] [kylow] [kxlen] [kylen] [mkxc] [mkyc] |
!
!      ( TRUnc [alpha]  [qmax] )
!
!   VEGEtation [iveg]  < [height] [diamtr] [nstems] [drag] >
!
!   TURBulence  [ctb]  (CURrent [tbcur])
!
!   MUD  [layer]  [rhom]  [viscm]  [rhow]  [viscw]
!
!          | -> R19   [c0] [c1] [c2] [c3] [c4] [c5] [c6]
!   SICE  <     D15   [Chf]
!          |    M18   [Chf]
!          |    R21B  [Chf npf]
!
!   LIMiter [ursell] [qb]
!
!              | -> TRANSm [trcoef]                      |
!              |   TRANS1d < [trcoef] >                  |
!              |   TRANS2d < [trcoef] >                  |
!   OBSTacle   <                                         >            &
!              |        | -> GODA [hgt] [alpha] [beta]   |
!              |   DAM <                                 |
!              |        |   DANGremond [hgt] [slope] [Bk] |
!
!                      | -> RSPEC         |
!       ( REFLec [reflc] <                > )                         &
!                      |   RDIFF [pown] |
!
!       ( FREEboard [hgt] [gammat] [gammar] Quay )                    &
!
!       LINe < [xp] [yp] >
!
!   OBSTacle  FIG [alpha1] [hss] [tss] [dss] [dd] [minfr] [shape]     &
!
!           ( REFLec [reflc] )                                        &
!
!           LINe < [xp] [yp] >
!
!   SURFBeat  [df] [nmax] [emin]  UNIForm/LOGarithmic
!
!   SETUP  [supcor]
!
```

```
!    DIFFRac  [idiffr] [smpar] [smnum] [cgmod]
!
!    OFF WINDGrowth | QUADrupl | WCAPping | BREaking | REFrac | FSHift | BNDCHK
!
!    PROP   /  BSBT
!           \  GSE  [waveage] SEC|MIN|HR|DAY
!
!             | -> STOPC [dabs] [drel] [curvat] [npnts] [dtabs] [curvt] |
!    NUMeric (<                                                          > &
!             |    ACCUR [drel] [dhoval] [dtoval] [npnts]               |
!
!                | -> STAT  [mxitst] [alfa] |
!               <                            >  [limiter]   )           &
!                | NONSTat  [mxitns]        |
!
!          ( DIRimpl [cdd]  DEP|WNUM                              )      &
!
!          ( REFRLim [frlim] [power]                             )      &
!
!            | -> SIGIMpl [css] [eps2] [outp] [niter]
!          ( <                                                   )      &
!            |    SIGEXpl [css] [cfl]
!
!          ( CTheta [cfl]                                        )      &
!
!          ( CSigma [cfl]                                        )      &
!
!          ( SETUP [eps2] [outp] [niter]                    )
!    FRAME   'sname'  [xpfr] [ypfr] [alpfr] [xlenfr] [ylenfr] [mxfr] [myfr]
!
!    GROUP   'sname'  SUBGRID [ix1] [ix2] [iy1] [iy2]
!
!    CURVE   'sname'  [xp1] [yp1]   < [int]  [xp]  [yp] >
!
!    RAY     'rname'  [xp1] [yp1] [xq1] [yq1]                          &
!                     < [int]  [xp]  [yp]  [xq]  [yq]  >
!
!    ISOLINE 'sname'  'rname'  DEPTH|BOTTOM  [dep]
!
!    POINTS  'sname' < [xp]  [yp] >      |     FILE 'fname'
!
!                    | [xpn] [ypn] [alpn] [xlenn] [ylenn] [mxn] [myn]
```

```
!    NGRID   'sname'  <
!                      | UNSTRUCtured / -> TRIAngle \
!                                       \   EASYmesh / 'fname'
!
!              |...|
!    QUANTity  <   >    'short'  'long'  [lexp]  [hexp]  [excv]            &
!              |...|
!
!              [power]   [ref]   [fswell]   [fmin]  [fmax]                 &
!
!              / -> PROBLEMcoord \
!              \ FRAME           /
!
!    OUTPut OPTIons  'comment'  (TABle [field])  (BLOck  [ndec]  [len])    &
!                               (SPEC  [ndec])
!
!    BLOCK   'sname'  HEADER | NOHEADER  'fname' (LAY-OUT [idla])          &
!         <  HSIGN|HSWELL|DIR|PDIR|TDIR|TM01|RTM01|RTP|TM02|FSPR|DSPR|VEL| &
!            FRCOEF|WIND|DISSIP|QB|TRANSP|FORCE|UBOT|URMS|WLEN|STEEPNESS|  &
!            DHSIGN|DRTM01|LEAK|TSEC|XP|YP|DIST|SETUP|TMM10|RTMM10|DEPTH|  &
!            TMBOT|QP|BFI|NPLANT|WATLEV|BOTLEV|TPS|DISBOT|DISSURF|DISWCAP| &
!            GENE|GENW|REDI|REDQ|REDT|REDB|REDC|PROPA|PROPX|PROPT|PROPS|   &
!            RADS|LWAVP|HBIG|GAMMA|DISTUR|TURB|DISMUD|DISSWELL|AICE|DISICE|&
!            PTHSIGN|PTRTP|PTWLEN|PTDIR|PTDSPR|PTWFRAC|PTSTEEP|PARTIT >    &
!            ([unit]) (OUTPUT [tbegblk] [deltblk] SEC|MIN|HR|DAY)
!
!    TABLE   'sname'  HEADER | NOHEADER | INDEXED 'fname'                  &
!         <  HSIGN|HSWELL|DIR|PDIR|TDIR|TM01|RTM01|RTP|TM02|FSPR|DSPR|VEL| &
!            FRCOEF|WIND|DISSIP|QB|TRANSP|FORCE|UBOT|URMS|WLEN|STEEPNESS|  &
!            DHSIGN|DRTM01|LEAK|TIME|TSEC|XP|YP|DIST|SETUP|TMM10|RTMM10|   &
!            DEPTH|TMBOT|QP|BFI|WATLEV|BOTLEV|TPS|DISBOT|DISSURF|DISWCAP|  &
!            GENE|GENW|REDI|REDQ|REDT|REDB|REDC|PROPA|PROPX|PROPT|PROPS|   &
!            RADS|LWAVP|HBIG|GAMMA|DISTUR|TURB|DISMUD|DISSWELL|AICE|DISICE|&
!            PTHSIGN|PTRTP|PTWLEN|PTDIR|PTDSPR|PTWFRAC|PTSTEEP >           &
!            ([unit]) (OUTPUT [tbegtbl] [delttbl] SEC|MIN|HR|DAY)
!
!    SPECout 'sname'  SPEC1D|SPEC2D  ABS|REL  S|L  'fname'                 &
!                     MONth  ESCAle  COMPress                              &
!                     (OUTput [tbeg] [delt] SEC|MIN|HR|DAY)
!
!    NESTout 'sname'  'fname'                                              &
!                     (OUTput [tbeg] [delt] SEC|MIN|HR|DAY)
!
```

```
!                                       / -> IJ < [i] [j] > | < [k] >  \
!    TEST [itest] [itrace] POINTS <                                     >         &
!                                    \    XY < [x] [y] >             /
!
!                         PAR 'fname'  S1D 'fname'  S2D 'fname'
!
!              |  STATionary  [time]                          |
!    COMPute ( <                                               > )
!              |                          | -> Sec  |          |
!              | ([tbegc] [deltc] <     MIn   > [tendc]) |
!              |                          | HR    |
!              |                          | DAy   |
!
!                     | -> FREE
!    HOTFile 'fname'  <
!                     | UNFormatted
!
!    STOP
```

Appendix D

Spectrum files, input and output

This appendix described the format of the files for spectral input (command `BOUNdspec`) and output (commands `SPECout` and `NESTout`) by SWAN. The files are recognized by SWAN or another reading program by the presence of the keyword SWAN and a version number on the first line of the file. This description is valid for version number 1.

These files contain the following information:

- coordinates of locations

- frequencies

- directions (if used for 2D)

- time (if time-dependent)

- spectral energy or variance densities (and average direction and direction spreading if 1D)

Example of a 1D nonstationary spherical coordinates file

```
SWAN    1                            Swan standard spectral file, version
$ Data produced by SWAN version 41.51
$ Project:'projname'     ;   run number:'runnum'
TIME                                 time-dependent data
    1                                time coding option
LONLAT                               locations in spherical coordinates
    2                                number of locations
       1.00       1.00
       1.20       1.00
RFREQ                                relative frequencies in Hz
   25                                number of frequencies
    0.0418
    0.0477
```

```
    0.0545
    0.0622
    0.0710
    0.0810
    0.0924
    0.1055
    0.1204
    0.1375
    0.1569
    0.1791
    0.2045
    0.2334
    0.2664
    0.3040
    0.3470
    0.3961
    0.4522
    0.5161
    0.5891
    0.6724
    0.7675
    0.8761
    1.0000
QUANT
     3                                   number of quantities in table
VaDens                                   variance densities in m2/Hz
m2/Hz                                    unit
   -0.9900E+02                           exception value
CDIR                                     average Cartesian direction in degr
degr                                     unit
   -0.9990E+03                           exception value
DSPRDEGR                                 directional spreading
degr                                     unit
   -0.9000E+01                           exception value
19680606.030000                          date and time
LOCATION    1
  0.3772E-03   190.1    6.3
  0.1039E-02   190.2    6.5
  0.2281E-02   190.3    6.7
  0.3812E-02   190.3    6.7
  0.4255E-02   190.3    6.6
  0.2867E-02   190.1    6.3
  0.1177E-02   189.6    5.8
```

```
  0.3892E-03  192.0   15.2
  0.8007E-03  244.5   22.9
  0.6016E-02  251.4   11.5
  0.1990E-01  251.0   11.0
  0.3698E-01  249.9   10.9
  0.3874E-01  248.1   12.1
  0.2704E-01  246.6   13.0
  0.1672E-01  247.0   13.5
  0.1066E-01  247.7   13.7
  0.5939E-02  247.3   14.0
  0.3247E-02  246.5   14.6
  0.1697E-02  245.9   14.9
  0.8803E-03  245.6   15.1
  0.4541E-03  245.5   15.3
  0.2339E-03  245.4   15.5
  0.1197E-03  245.5   15.6
  0.6129E-04  245.5   15.7
  0.3062E-04  245.3   15.9
LOCATION   2
  0.7129E-02   67.2   25.3
  0.3503E-01   67.5   21.7
  0.1299E+00   68.2   19.7
  0.5623E+00   69.7   18.0
  0.1521E+01   71.4   18.0
  0.3289E+01   74.0   18.8
  0.4983E+01   77.2   20.3
  0.4747E+01   79.9   22.0
  0.2322E+01   79.4   30.7
  0.1899E+01  341.1   56.2
  0.1900E+01  314.6   39.4
  0.6038E+01  324.3   31.9
  0.8575E+01  326.1   31.0
  0.4155E+01  325.1   30.5
  0.1109E+01  322.8   32.9
  0.7494E+00  323.1   33.3
  0.4937E+00  323.1   33.3
  0.2953E+00  323.3   33.7
  0.1661E+00  323.6   34.0
  0.9788E-01  323.7   33.8
  0.5766E-01  323.8   33.6
  0.3397E-01  324.0   33.5
  0.2001E-01  324.1   33.4
  0.1179E-01  324.2   33.3
```

```
   0.6944E-02   324.2    33.2
```

Example of a 2D stationary Cartesian coordinates file

```
SWAN    1                             Swan standard spectral file, version
$ Data produced by SWAN version 41.51
$ Project:'projname'      ;    run number:'runnum'
LOCATIONS                             locations in x-y-space
     1                               number of locations
    22222.22         0.00
RFREQ                                 relative frequencies in Hz
    25                               number of frequencies
     0.0418
     0.0477
     0.0545
     0.0622
     0.0710
     0.0810
     0.0924
     0.1055
     0.1204
     0.1375
     0.1569
     0.1791
     0.2045
     0.2334
     0.2664
     0.3040
     0.3470
     0.3961
     0.4522
     0.5161
     0.5891
     0.6724
     0.7675
     0.8761
     1.0000
CDIR                                  spectral Cartesian directions in degr
    12                               number of directions
    30.0000
    60.0000
    90.0000
   120.0000
```

```
   150.0000
   180.0000
   210.0000
   240.0000
   270.0000
   300.0000
   330.0000
   360.0000
QUANT
    1                                      number of quantities in table
VaDens                                     variance densities in m2/Hz/degr
m2/Hz/degr                                 unit
   -0.9900E+02                             exception value
FACTOR
     0.675611E-06
    51    242    574    956   1288   1482   1481   1286    957    579    244     51
   129    610   1443   2402   3238   3725   3724   3234   2406   1454    613    128
   273   1287   3054   5084   6846   7872   7869   6837   5091   3076   1295    271
   665   3152   7463  12402  16712  19229  19221  16690  12419   7518   3172    662
  1302   6159  14608  24275  32688  37618  37603  32644  24309  14716   6198   1296
  2328  10989  26020  43341  58358  67109  67080  58281  43401  26213  11058   2317
  3365  15922  37712  62733  84492  97150  97110  84380  62820  37991  16021   3349
  3426  16230  38440  63939  86109  99010  98969  85995  64027  38724  16331   3410
  2027   9612  22730  37790  50909  58529  58505  50841  37843  22898   9672   2018
   672   3178   7538  12535  16892  19440  19432  16870  12552   7594   3198    669
   101    479   1135   1890   2542   2924   2923   2539   1892   1144    482    101
     2     11     26     43     57     66     66     57     43     26     11      2
     0      0      0      1      1      1      1      1      1      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
     0      0      0      0      0      0      0      0      0      0      0      0
```

Note that the true variance or energy densities are obtained by multiplying each number by the factor given under the keyword **FACTOR**.

Formal description of the 1D- and 2D-spectral file
_____

This description refers to either **write or read** energy/variance density spectra **to or from** the file.

The description of the file to write or read source terms is identical to this description except that the quantities obviously differ.

The format that is used by SWAN or should be used by the user when offering the file to SWAN is free format (FORTRAN convention) except that all keywords and names of quantities (see below) should start on the first position of the line on which they appear (see Appendix B for the syntax of keywords). This format implies that all information on each line after the required input for SWAN is ignored by SWAN. This can be used to enter user's information at the discretion of the user.

First line	the keyword `SWAN` followed by version number
Then	if nonstationary computation: the keyword `TIME`
	if stationary computation: not present
Then	if nonstationary computation: time coding option; ISO-notation (=1) is recommended
	if stationary computation: not present
Then	• the description of the locations:
	if Cartesian coordinates: the keyword `LOCATIONS`
	if spherical coordinates: the keyword `LONLAT`
	• number of locations
	• for each location
	if Cartesian coordinates: $x-$ and $y-$coordinate (in m, problem coordinates)
	if spherical coordinates: longitude and latitude
	Note that if the file is used for input for SWAN (but not generated by
	SWAN) and the user so desires, the names of locations can be written
	behind the two coordinates; these names are ignored by SWAN when
	reading the file (see remark on format above).
Then	the frequency data (for 1D- and 2D-spectra):
	• the keyword `AFREQ` or `RFREQ` (to distinguish between absolute and relative frequencies)
	• number of frequencies
	• a column with frequencies always in Hz (each on a new line)
Then	the direction data (only for 2D-spectra):
	• the keyword `NDIR` or `CDIR` (to distinguish between nautical and Cartesian direction)
	• number of directions
	• a column with directions always in degrees (each on a new line)
Then	the group describing the quantities in the tables of this file (see the above examples):
	• the keyword `QUANT`
	• number of quantities

for each quantity

- name of the quantity
- unit of the quantity
- exception value of the quantity, i.e. the value that is written instead of a computed value if that is undefined

Note for 1D spectra:
the number of quantities is always 3, and the quantities are always: energy (or variance) density, average direction (`CDIR` for Cartesian direction or `NDIR` for nautical direction) and directional spreading (`DSPR` in terms of `DEGREES` (SWAN *write* the keyword `DSPRDEGR`, SWAN *reads* the keyword `DSPRD` or `DEGR` in case of option `DEGREES` or the keywords `DSPRP` or `POWER` in case of option `POWER` in command `BOUND SHAPE`). The quantities appear in the order in which they appear in this description.

Note for 2D spectra:
the number of quantities is always 1; the quantity is always energy or variance density (`EnDens` is the (short) name of true energy densities, `VaDens` for variance densities).

Then the group with the tables of the quantities:

VVV • date and time (not present for stationary computation)

for each location:

if 2D spectrum:
- the keyword `FACTOR`. This keyword is replaced by the keyword `ZERO` if the spectrum is identical 0 or it is replaced by `NODATA` if the spectrum is undefined (not computed e.g., on land; no numbers follow)
- the factor to multiply the values in the following table
- scaled energy/variance densities (truncated by SWAN to integer values for compact writing; SWAN accepts these values as reals when reading this file; other programs (e.g. for postprocessing) should also accept these values as reals; the values should be multiplied by the factor to get the proper values of the densities).

else, if 1D spectrum:
- the keyword `LOCATION` followed by the index of the location (on the same line). This is replaced by the keyword `NODATA` if the spectrum is undefined (not computed e.g. on land; no numbers follow).
- a table containing three columns: the 3 quantities per frequency: energy (or variance) density, average direction (`CDIR` for Cartesian direction and `NDIR` for nautical direction) and directional spreading (`DSPR` in terms of `DEGREES` (*writing or reading the file*) or `POWER` (*only reading* the file), see note for 1D spectra above); the quantities appear in the order in which they appear in this description.

For nonstationary computations repeat from VVV.

Bibliography

[1] SWAN – Implementation manual. Delft University of Technology, Environmental Fluid Mechanics Section, available from *http://www.swan.tudelft.nl* (Version 41.51, July 2024).

[2] SWAN – Programming rules. Delft University of Technology, Environmental Fluid Mechanics Section, available from *http://www.swan.tudelft.nl* (Version 1.3, August 2006).

[3] SWAN – Scientific and Technical documentation. Delft University of Technology, Environmental Fluid Mechanics Section, available from *http://www.swan.tudelft.nl* (Version 41.51, July 2024).

Index