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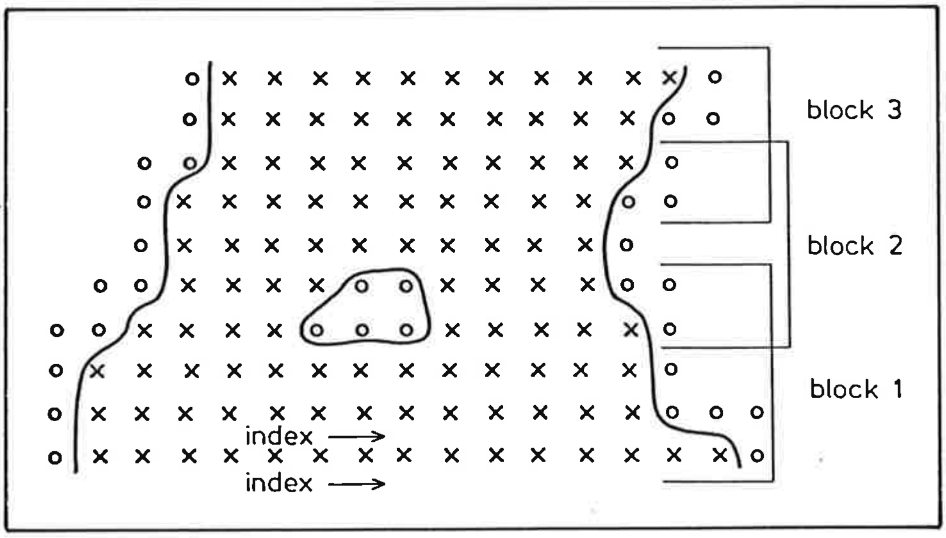

THE WAM WAVE MODEL SYSTEM

by

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THE W A M WAVE MODEL SYSTEM

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Contents.

1. Summary.

1.1 General Structure

The WAM model is a third generation wave model which integrates the wave transport equation without any restrictions on the shape of the spectrum. The source function STOT = SIN + SDS + SNL consists of the wind input term SIN, adapted from Snyder et al (1984), the discrete interaction parameterization of the nonlinear transfer SNL, from Hasselmann et al (1985) and a dissipation source function SDS, from Komen et al (1984).

The model runs on a latitude-longitude grid of arbitrary resolution, for any rectangular latitude - longitude region (including the full globe).

The spectrum is represented by 25 logarithmically spaced frequencies, with DELFR/FR = 0.1, extending from an arbitrarily chosen minimum FRMIN (e.g. 0.042 Hz) to a maximum frequency FRMAX = 9.8 * FRMIN (e.g. 0.41 Hz). The directional resolution is currently 30 degrees (a 15 degrees resolution model will shortly be available).

The WAM Wave Model System is available as a single combined sytem which can be run on a CRAY X-MP and a CYBER 205, and for deep and shallow water.

The model system consists of three major program parts:
1) a pre-processor
2) the WAM model
3) a post-processor

The WAM model runs on the back end (vector) computer. The post-processor runs on the front end, and the pre-processor is normally run on the back end computer, but can also be run on the front end. Plotting routines may be installed on either back end or front end. Conversion options from binary to formatted data are provided in case the link between front end and back end requires formatted data.

1.2 Pre-processor.

The pre-processor contains the following routines:

- PRESPEC:

This creates a JONSWAP spectrum with COS**2 directional distribution with specified mean direction and arbitrarily chosen five Jonswap parameters as initial spectrum for the wave field. It is uniform for the entire grid. This implies that, in practice, the model must be spun up for several days with real winds to obtain a realistic initial state. (It is planned to introduce an additional option in which the initial state is computed for each grid point from the local initial winds.)

- PREPROC:

Starting from a regional or global lat-long topographic data set, a blocked grid is created in the form required for the model. The grid points are collected into 1-d array blocks, and the model then runs through all grid points of a given block in an innermost vectorized loop. The routine generates the two way mapping relating (lat-long grid) <-> (model grid indices). The lat-long bathymetry and prescribed model output points are also transformed to the model grid. The routine further computes the model frequency array and great circle propagation parameters.

- PLOTGRI:

Plots the grid information data.

- PREWIND:

The prescribed 10 m winds, friction velocity or surface stresses (friction velocity squared) for a specified input grid (several options are available) are mapped into the model grid coordinates, interpolated in time and outputted on a separate file for each propagation time step or for each wind time step. These winds are then used as input to run the model.
(Details on time steps are given in section 3.3.)

- PLIWIND:

Plots original winds which are inputted into PREWIND. (Program has been tested only for special wind cases specified in the routine and in PREWIND. A generalization is in preparation.)

- PLOWIND:

Plots interpolated winds as outputted by PREWIND. (Interpolated winds are also plotted with the model output, see program POPRMAP.)

1.3 The WAM - Model:

The model can be integrated with independently chosen propagation, source term and wind input time steps. However,all time step ratios must be an integer or inverse integer. Also, the source term time step must be smaller than or equal to the other two time steps. (cf 3.3, 3.4)

Model output: (for plot formats,cf. 1.4)

1) At all grid points for specified output times :

   - significant wave height
   - mean wave direction
   - "mean frequency" (inverse of mean period)
   - friction velocity (magnitude and (wind) direction)
   - optional:
   - mean swell height and direction
   - mean windsea height (implicit,computed in post-processor from significant wave height and swell height.)
   - mean windsea direction.

2) Two dimensional wave spectra for selected grid points at specified output times.

1.4 Post-Processor :

This contains the following graphic output routines:

- POPRMAP:
Fields of wind or wave data are plotted for the model region as Custer diagrams with superimposed significant wave height isolines .

- POPRSPE:
Produces frequency-direction polar isoline plot of the 2-d spectrum at specified grid points and times.

All plotting routines are based on standard CALCOMP routines, with a few exceptions which are supplied as subroutines in the program package. However, depencies of CALCOMP software on different computer environments have to be taken into consideration. The programs have been tested at ECMWF and the Max Planck Institute in Hamburg. Specific adaptions for these two systems are indicated by comment lines: CECMW for ECMWF and CHAMB for Hamburg, respectively.

If the the post-processing is not carried out on the vector computer and the output data from the WAM model run have to be formatted for further processing, three formatting interface programs are available :

- SPECFO:
Formats the 2-d spectra for specified output points, together with the local significant wave height, wave direction, friction velocity and wind direction.

- MAPFO:
Formats all field data except wind sea and swell, i.e. the significant wave height, mean wave direction, friction velocity and wind direction, for the complete model region .

- SWEFO:
Formats the windsea and swell field data, i.e the swell significant height and mean swell direction and the windsea significant wave height and mean windsea direction, for the complete model region.

2. Communication between the sub-systems.

2.1 General structure

Fig.1. shows the structure of the WAM model system.
The encircled names represent programs, input and output file names are denoted as square boxes.

For a detailed description of input and output files, cf.section 3.

2.2 Pre-Processor

The output file names of the pre-processor PREPROC are composed of 4 letters denoting the COMMON blocks in the WAM model and three letters indicating the particular model application. (e.g. GLO for a global run,NOS for a North Sea run)

The three pre-processors PRESPEC, PREPROC and PREWIND are run with their specified input files (see detailed description below). The output files are saved and used as input files for the WAM model.

Normally, the three pre-processor programs are run on the back end vector computer and the output data are stored in binary format for the WAM model. However, the pre-processor output can also be read in directly to the post-processor (eg. for plotting the grid). Since the post-processor may require formatted data, the pre-processor output can be generated both as binary and as formatted data (for details cf. 3.2 and fig 1).

2.3 WAM Model

Data is fed into the WAM model as shown in Fig 1. Input data from tape 5 are written after the program listing (see detailed description below).

An integration can be run for the entire period as one full run or it can be split into several runs, starting with a first run followed by several restart runs.

If only part of an integration is to be carried out, to be followed by a restart run,tapes 7, 12, 20, 4, 47 must be saved for a regional run, and the same tapes together with the additional tapes 19, 22 for a global run.For a restart, these tapes are accessed as tape10, 13, 21, 4, 47 with additional tapes 19, 23, respectively, for a global run. (Input parameter for restart: see input data in detailed description of the WAM model below, and Fig 5.)

2.4. Post-Processor

The output from the model run consists of three files:

1) SPEYYMMDDHHMM contains the two dimensional spectra at specified times and output points (see fig 6. for details regarding CYBER 205 and CRAY). The file name specifies the date of the last (first on the CYBER 205) propagation time step of the model run (year/month/day/hour min/ cf. table 1

2) MAPYYMMDDHHMM contains the fields of significant wave height and direction, mean frequency, mean wave direction, friction velocity and stress (wind) direction at all grid points of the region at specified output times.

3) SWEYYMMDDHHMM contains the fields of significant swell height and direction and significant windsea wave height and direction.

Again, if the plotting is to be carried out on a different machine than the vector machine, interface programs are provided for each of the output files to format the output data :SPECFO,MAPFO,SWEFO.

The plotting routines access several files indicated as broken boxes in fig.1.Some of the files are output files from the PREPROC run and can be read either as binary or as formatted data for plotting. Nearly all plotting software is based on CALCOMP subroutines. Exceptions are provided as separate subroutines.

3. WAM model system components:

3.1 - PRESPEC:

Purpose:
Initialization of wave field.

Interface:
*PROGRAM**PRESPEC(INPUT,OUTPUT,TAPE1,TAPE5 = INPUT,TAPE6 = OUTPUT)

TAPE1 - Logical unit for output of spectrum.
TAPE5 - Logical unit for input of JONSWAP parameters and mean wave direction.

Rec.no.	format	variable
1	I4	IAN: number of wave directions.
2	F10.8	FR(1): first frequency grid point.
3	5F10.5	ALFA, FM, GAMMA, SA, SB: JONSWAP parameters.
4	F10.5	THETAQ: mean wave direction.

TAPE6 - Logical unit for print output.

Method:
The spectrum is computed according to the JONSWAP formula with a COS**2 spreading function. The five JONSWAP parameters and the mean wave direction are read in and are taken as constant for the entire grid.

Externals:
SPR - Subprogram to compute COS**2 spreading function.

References:

HASSELMANN, K: ET AL, Measurements of Wind Wave Growth and Swell Decay during the JOINT NORTH SEA Wave Project (JONSWAP), Deutsche Hydrographische Zeitschrift A8, NO12, 95 PP.

3.2 - PREPROC:

Purpose:
Generate a blocked grid for the WAM wave model and compute the great circle propagation parameters, frequency grid points and other external parameters of the model.

Method:
A topographic data set on any lat-long grid for any given region containing the model rectangular box region is read in. Land is represented by negative or zero water depths. The model region is extracted and the topographic grid interpolated on to the model long-lat grid. Additional rectangular subregions can be specified seperately as land for the model run (e.g. lakes, fjords).
The current model does not handle open boundaries. Thus east and west boundaries have to be specified as land for each latitude segment of the model box region. If east and west boundaries are specified as ocean points, the model will regard the grid as periodic in the east-west direction for this latitude (e.g. southern part of globe). The program sets north and south boundaries to land automatically.
Longitudes run from 0 to 360 degree (not -180° to 180°), latitudes from -90° to +90°. The poles are exluded.

Block structure:
The grid points are collected into a one dimensional array, running through latitude lines from south to north. The blocking structure accepts only line segments with one western and one eastern boundary point for each latitude line, except for a specific two segment treatment of the Atlantic and Pacific Oceans in the global version of the model (cf. fig 2). Blocks are filled up latitude by latitude to maximally 512 elements. Land in the interior of a latitudinal segment (e.g. Australia) is accepted as part of the model region but marked as "island regions". Wave spectra for island points are then set to zero during the model integration (after the propagation time step). Blocks overlap over two latitude lines, in order to compute north-south advection terms.

Interface:
*PROGRAM PREPROC(INPUT,OUTPUT,TAPE1,TAPE2,TAPE4,TAPE5,TAPE6,
TAPE8,TAPE9,TAPE10)*

TAPE1 - Logical unit for input of topographic data given in the format:

```
DO 200 NLAT = 1, NLATEND
DO 100 NLONH = 1, ((NLONEND + 11) /12)
N1 = 12*(NLONH-1) + 1
N2 = 12*NLONH
READ (UNIT, '(12 (I5,A1))') (IA1 (I,NLAT), AX(I),
I = N1,N2)
100 CONTINUE
200 CONTINUE
DIMENSION IA1(360,115),AX(360)
```

AX(I) = E for elevation, = D for depression.
IA1(I, NLAT) is elevation or depression given in m.

TAPE5 - Input of input and output grid increments, region boundaries, long-lat coordinates for grid points where the 2-d spectrum is to be saved for certain output times. Input records and formats:

Rec.no.	format	variable
1.	8E10.3	XDELA:lat. increment of input grid. XDELO:lon. increment of input grid. XLAS :southern most lat. of input grid. XLAN :northern most lat. of input grid. XLOW :western most long. of input grid. XLOE :eastern most long. of input grid.
2.	2E10.3	XDELLA :lat. increment of output grid. XDELLO :long. increment of output grid.
3.	F10.8	FR(1) : first frequency grid point.
4.	I4	NPART : number of segments into which the region is divided. For example: the globe is divided into southern

		ocean,Pacific and Atlantic Ocean. This is not valid for nesting in general
5.	3I4	NOUTE(NP): number of ocean areas to be taken out of a segment by setting all gridpoints to land.For example lakes. (NP = 1, NPART)
6.	4E10.3,	XLATL(NP): southern most lat. of output grid. XLATH(NP): northern most lat. of output grid. ONGW(NP): western most long. of output grid. ONGE(NP): eastern most long. of output grid.
7.	4E10.3,I5	XOUTS(NP,I): southern most long. of area to be set to land (c.f. method above) XOUTN(NP,I): northern most long. of area to be set to land. XOUTW (NP, I): western most lat. of area to be set to land. XOUTE(NP,I): eastern most lat. of area to be set to land. NOUTD(NP,I): value of water depth for these grid points.Can be +9999 for land

Records 6. and 7. are repeated for NP = NPART times (I = 1, NOUTE (NP))

8.	I4	NGOUT: Number of output points for model run.
9.	8F8.2	OUTLAT(I),I = 1,NGOUT :lat. of output points.
10.	8f8.2	OUTLONG(I),I = 1,NGOUT :long. of output points.

11.	I4	IFORM:	= 1 -> output data are binary.
			= 2 -> output data are formatted
			= 3 -> output data are formatted and unformatted. (TAPE4, TAPE8 formatted, all others binary.)

TAPE2 - Logical unit for temporary storage of grid data.

TAPE4 - Logical unit for output of grid organisation and blocking data.(formatted)

TAPE40 - Same as tape 4 binary.

TAPE7 - Logical unit for output of a mapping from lat - long coordinates onto block and grid indices in a block.(formatted)

TAPE8 - Logical unit for general grid parameters (COMMON /CVAR/).(formatted)

TAPE80 - Same as tape8 binary.

TAPE9 - Logical unit for the bathymetry.

TAPE10 - Logical unit for frequency grid and group velocities.

TAPE6 - Logical unit for print output.

Externals.

In the order of their calls.

TOPOAR - Read topographic data set and extract region.

BOUNPT - Compute boundary points.

ARRANG - Interpolation to output grid.

BLOCK - Setting grid data on block indices. Next routine is called from BLOCK.

PARPROP - Computation of great circle and spectral parameters.

OUTDAT - Output of data to disk files. Next routine is called from OUTDAT.

MAP - Map Lat-Long <-> block number and index in block. Next 2 routines are called from MAP:

MIJLALO - Map index in a block and block number to lat-long.

MLALOIJ - Map lat-long to index in a block and block number.

3.3 - PREWIND :

Purpose:
Interpolates wind velocity and direction in space and time from a given input wind data grid to the model lat-long grid and wind time step.

The input grid may be either a polar stereographic grid or a long-lat grid.

Interface:
*PROGRAM**PREWIND

In the following, XXX stands for a run identifier (cf. fig.1)

Unit 3:
BLALXXX -Input data from PREPROC:
Lat-lon coordinates for required wind input.

Unit 5:
PREWXXX -General INPUT data .

User information on unit 5 is read in assuming that:

1. Every line starting with 'C' is a comment line
2. Line 1 is a comment line.
3. Input order of the items mentioned below is: Period, time steps, output files, selectors, formats
4. Data values are inserted at positions indicated by '-'

Example of input file TAPE 5:

```
      ------------------------------------------------------------------------------------------
C     **** PERIOD ***
C     NECESSARY SIDE CONDITION:
C       FIRST TIME EVALUATED IS FIRST TIME ON FILE > = START
C       LAST TIME EVALUATED IS LAST TIME ON FILE <  END
C
C *START*                  *END*
   CYYMMDDHHMM     YYMMDDHHMM
     83 0 1 01 00 00     83 01 05 06 00
C
C       ****TIME STEPS IN SECONDS****
C     IDTPRO  = WAM PROPAGATION TIMESTEP
C     IDTWO  = OUTPUT WIND TIMESTEP
C     IDTWI  = WIND TIMESTEP ON INPUT WIND FILE
C
C     ----------------      -------------------------------------------------------------------
C     DEMAND :          ALL RATIO'S ARE N OR 1/N AND N IS AN INTEGER
C     ----------------      -------------------------------------------------------------------
C
C     IDTPRO     IDTWO     IDTWI
C     ----------     ----------     ---------
      900          10800        10800
C
C     **** FILE IDENTIFICATION (NAME OF WIND OUTPUT) ***
C
C     CRAY: WXXYYMMDDHHMMKK    (15 CHARACTERS)
C     WXX                                     = REGION IDENTIFIER (XX)
C     YYMMDDHHMM                        = DATE-TIME GROUP
C     KK                                        = NUMBER OF WINDFIELDS ON THE FILE
C     C205:WXMDDHMM                   (8 CHARACTERS)
C
C     IDU    =    USER ID OF THE OUTPUT FILES
C     IT       =    INDICATOR FOR TEST OUTPUT FROM PREWIND
C                    IT< =0: NO TEST OUTPUT
C                    IT >0: TEST OUTPUT FOR BLOCKS WITH NUMBER < IT
C                    IT  = -5: FORMATTED WINDOUTPUT
```

```
C
C     WXX         IDU         IT
C     -------     -----       ---
      GKS         ZAM         3
C
C     **** SELECTOR FOR WINDS ON INPUT ***
C     IWISEL =    WINDFORMAT SELECTOR
C                 1 = BMO FORMAT
C                 2 = READING FORMAT RE-ARRANGED SOUTH TO NORTH
C                 3 = READING FORMAT NOT RE-ARRANGED
C                 4 = GLA - WIND
C                 >4 = OTHER WINDFILELD (SEE 'WINDS')
C     ICOMPU  = COMPUTER USED FOR RUNNING THE WINDPROGRAMM
C                 1 = CRAY READING ENGLAND
C                 2 = CRAY MUNICH GERMANY
C                 3 = CYBER 205
C
C IWISEL ICOMPU
      -      -
      1      3
C
C      ** SWITCH FOR BINARY OR FORMATTED READ OF INPUTWIND **
C           1 = BINARY
C           2 = FORMATTED
CIFORWI
C-
2
      ---------------------------------------------------------------------------
```

Unit 1:
WINDXXX -Input winds.

Possible input wind formats are:

1. BMO FORMAT
   19,5 m winds are given on a polar stereographic projection

2. READING FORMAT Rearranged:

ROW 1 + 2 southernmost latitude (U_*, V_*) (friction velocity) ROW 3 + 4 second latitude from the south etc. The last row is the nothernmost latitude.

3. READING FORMAT not rearranged:
ROW 1 + 2 northernmost latitude (U_*, V_*) (friction velocity)
ROW 3 + 4 southernmost latitude
ROW 5 + 6 second latitude from the north etc.

4. GLA-Wind stress components (formatted):
4 by 5 degree grid from south to north and from west to east on each latitude line.
Each windfield contains :
A) IY,IM,ID,IH,IMI ,FORMAT(3I2,2I2,2X)
B) USAT(NC,NR) ,FORMAT(12F6.2)
C) VSAT(NC,NR) ,FORMAT(12F6.2)

5. Other wind fields (binary or formatted):

formatted case:

rec. no	format	variable	
1	2I6	NCREAD	Number of Longitudes
		NRREAD	Number of Latitudes (for input wind field)
	4F10.3	RLATS	Southernmost Latitude
		RLATN	Northernmost Latitude
		RLLONL	Westernmost Latitude
		RLLONR	Easternmost Latutude (for input wind field)
	3I4	ICOORD	= 1 rectangular lon-lat wind grid
			= 2 polar stereographic projection (cf.1.)
		IPER	= 1 circular wind
			= 0 bounded lat-long wind grid
		ICODE	= 1 friction velocity
			= 2 wind stress

			= 3 U19.5 (is transformed to wind stress with Wu´s formula)
2	I10	IDATE	Date
3	9F8.3	U(N)	U-component
4	9F8.3	V(N)	V-component

(N runs from 1 to NC + NR)
(last three records are repeated until end of file is reached)
binary case: Data sequence as in formatted case.

Names of tape units:

UNIT *LOCAL FILE NAME* (= TO BE CONNECTED) AND *DESCRIPTION*

IUWND	-	WINDXXX	Input wind data
IULNLT	-	BLALXXX	Input of lat-long coordinates for each grid point of the model grid.
IUVELO	-	'WINDAN'	Output of friction velocity and wind direction
IUUSER	-	PREWXXX	General input data.
IUOUT	-	OUTPU	Print output.
IUSCR	-	SCRA--	Scratch units for all blocks (intermediate storage)

Method.

PREWIND relates the wave model grid to the wind grid and performs linear interpolation in space and time.

Interpolated winds are written on files. A new file is accessed for each propagation time step (if the wind time step is less than propagation time step) or for each wind time step (if the wind time step is greater than or equal to the propagation time step).

Structure of output files for different ratios of wind time step "DTOUTW" and propagation time step "DTPROP"

Note: All ratios must be integer, i.e 1, N, OR 1/N, where N = integer.

Cases:

1. DTOUTW = N*DTPROP

Wind file:

		File 1	File 2	File 3
RECORD NO	GEOGR. BLOCK	PROPAG.TIME T WXX(YYMMDD HHMM)01	T + DTOUTW WXX(YYMMDDH HMM)01	T + 2*DTOUTW WXX(YMMDDHH MM)01
1	1	WIND RECORD TIME T	T + DTOUTW	T + DTOUTW*2
2	2	T	T + DTOUTW	T + DTOUTW*2
3	3	T	T + DTOUTW	T + DTOUTW*2
	....	....	....	....
N	N	T	T + DTOUTW	T + DTOUTW*2

2. DTPROP = N*DTOUTW

Wind file:

		File 1	File 2	File 3
RECORD NO	GEOGR. BLOCK	PROPAG.TIME T WXX(YYMMDDHHMM) N	T + DTPROP WXX(YYMMDDHHMM) N	T + 2*DTPROP WXX(YMMDDHHMM) N
1	1	WIND RECORD TIME T	T + N*DTOUTW	T + 2N*DTOUTW
2		T + DTOUW	T + (N + 1)*DTOUTW	T + (2N + 1)*DTOUTW
.		....	....	....
.		....	....	....
N		T + (N-1)*DTOUW	T + (2N-1)*DTOUTW	T + (3N-1)*DTOUTW
N + 1	2	T	T + N*DTOUW	T + 2N*DTOUTW
N + 2		T + DTOUTW	T + (N + 1)*DTOUTW	T + (2N + 1)*DTOUTW
.		....	....	....
.		....	....	....
2*N		T + (N-1)*DTOUTW	T + (2N-1)*DTOUTW	T + (3N-1)*DTOUTW
.	3	....	....	....
.		....	....	....
.		....	....	....

Externals.

GETCOR - Reads geographical coordinates.
*NOTIM * - Interpolation in space .
*TIMIN * - Interpolation in time and space.
INUSER - Input of user input parameters.
*ERR * - Error handling regarding user input period and wind file period.
OUTBLO - SUBR. Called by NOTIM AND TIMIN,

Read/write results for one block from /to Scratch or result file.

*MEMO *	-	SUBR. Called by NOTIM AND TIMIN, saves result files dynamically either for CRAY, ECMWF (ICOMPU = 1) or CYBER 205 (ICOMPU = 3).
MEMOMU	-	SUBR. Called by NOTIM AND TIMIN, saves result files dynamically for CRAY, Munich (ICOMPU = 2).
GETWND	-	SUBR. Called by NOTIM AND TIMIN, reads and processes one windfield.
LINEAR	-	SUBR. Called by TIMIN, linear interpolation in time for all grid points of one block.
INCDAT	-	SUBR. Called by NOTIM AND TIMIN AND GETWND, increments date.
WAMWND	-	SUBR. Called by GETWND, computes wind velocity and direction for all grid points and all blocks.
BMOWND	-	SUBR. Called by GETWND, reads BMO u19.5-winds.
REAWND	-	SUBR. Called by GETWND, reads ECMWF friction velocity.
SATWND	-	SUBR. Called by GETWND, reads GLA-wind stress data.
WINDS	-	SUBR. Called by GETWND, reads arbitrary wind fields.
TRANSF	-	SUBR. Called by WAMWND, transforms WAM-Latitude/Longitude into grid coordinates of windfield.
*FRICT *	-	SUBR. Called by WAMWND, computes friction velocity for one grid point.
DIRECT	-	SUBR. Called by WAMWND, computes wind direction for one grid point.
LOCINT	-	SUBR. Called by WAMWND, locates WAM-grid point and interpolates wind onto WAM-grid.

References :
Report on the development of the WAM wind program PREWIND,
Groenewoud, P., Delft Hydraulics Lab;December 1986
Wu, Y., 1982, Wind-stress coefficients over Sea Surface from Breeze to Hurricane, JGR, Vol 87.

PLOWIND and PLIWIND:
The documentation for these programs is the same as for program POPRMAP.

3.4 - WAMODEL:

Purpose.

Computation of the 2-d frequency-direction ocean wave spectrum for a given region and period for a given input wind field.

Method.

General structure :

The model has a rather different data organization from most other wave models. This is because a highly vectorized model is needed for efficient computations, but the source function itself, because of the scatter integral structure of the nonlinear transfer term, in its present form is non-vectorizable.Thus the loop structure has been inverted relative to normal wave models. Instead of computing the spectrum of a given grid point for all frequencies and directions, the spectral variables running over the inner loops and the grid points over outer loops, the grid points are collected in the WAModel into 1d- array blocks which are placed into the innermost loop. This requires a large central core space to store all spectra and source functions for a large array of grid points. For most vector computer installations, the complete model cannot be placed into core, so that an overlay structure is needed in which only one block of grid points is processed in the central memory at a time.

All components of the spectrum are computed prognostically using the spectral transport equation up to a variable cutoff frequency FML = MAX(4*FPM,2.5*FMEAN), where FPM is the Pierson Moskowitz Frequency and FMEAN is the " mean frequency " (inverse mean period). Beyond the prognostic cutoff, a diagnostic f^{**-4} tail is attached. The level of the tail is adjusted separately for each direction to match continuously the spectrum at the highest prognostic frequency for that direction.

Source functions :

The input and deep water dissipation source functions are taken from Komen et al (1984), the bottom friction source function from P. Janssen et al, (1985), the nonlinear transfer from the discrete interaction parametrization of Hasselmann et al (1985B)

Time steps and integration method:

The source function and the advection term are integrated on two different time step levels and with different methods. The wind time step can also be chosen independently of the source function and advection time step. However, the ratio of all three time steps to one another must be an integer and the source function time step must be the smallest (i.e. the other time steps cannot be smaller).

All time steps must be specified in the input files as integer values in seconds. However, for labelling and output time specifications, the time steps must in fact be an integer number of minutes (i.e. divisible by 60).

The source functions are integrated implicitly according to Hasselmann and Hasselmann (1985a). The functional derivatives of the individual source functions required for the solution of the implicit equation are computed within the source function subroutines. The source function time step is typically 20 min.

The advection is integrated by a first order upwind scheme, also according to Hasselmann and Hasselmann (1985a). For stability, the advection time step must be chosen to satisfy the CFL criterion, depending on the spatial grid resolution and the lowest model frequency.

Winds are read in every wind time step. If the wind time step is greater than the source term time step, DELTWIND/DELTSOURCE source term time steps are integrated with constant winds (i.e. the wind field is not interpolated down to the source term time resolution; if necessary this should be done in PREWIND).

In each block of grid points the computations are carried out from south to north from the second latitude to the one before the last. In order to compute the advective terms, the blocks overlap such that the last but one latitude then becomes the first latitude in the following block (fig 3).

To avoid a large I/O time in relation to the cpu time, the computations for time step Tn -> Tn + 1 for block IG are carried out while the wave spectra for time Tn of block IG + 1 are read in and the completed computations for block IG-1 are written out, in buffered form (cf. fig. 4).

Units for Input and output are swapped after each timestep (cf-fig 3). Because only tapes 7, 12, 20 are saved at the end of a run and tapes 10, 13,21 are the input units for the first propagation time step of the next restart run, the number of propagation time steps for a run, which is to be followed by a restart run, must be odd. The program reduces the ending date automatically by one propagation timestep if an even number of propagation time steps is specified.(The side condition on the number of propagation time steps will be removed in cycle 2)

Interface.

PROGRAM *WAMODEL (INPUT, OUTPUT, TAPE1, TAPE3, TAPE4, TAPE7, TAPE9, TAPE10, TAPE12, TAPE13, TAPE15, TAPE19, TAPE20, TAPE22, TAPE23, TAPE25, TAPE31, TAPE32, TAPE43, TAPE48, TAPE5 = INPUT, TAPE6 = OUTPUT)*

TAPE1 - Logical unit for input of single initial spectrum for special case of homogeneous wave field (output of PRESPEC).

TAPE3 - Logical unit for output of significant wave height,"mean frequency" and mean angle at all specified points. File is saved at end of run under the name : MAPYYMMDDHHMM (see wind file specification, Fig. 6),data can be formatted for transfer through a remote link with the program MAPFO.

*TAPE35 - Logical unit for output of mean swell wave height and direction, wind sea wave height.

TAPE5 - Logical unit for input of logistic data:

rec.no.	format	variable	
1	2A5,I2,I1	NREG1NREG2:	Model region. For example: NORTH SEA NREG1 = NORT NREG2 = H SEA
		ICOMPU	= 1 CRAY disposing files on front end disks = 2 CRAY disposing files on CRAY disks = 3 CYBER 205
		IDESHAL	= 1 deep water run = 2 shallow water run
2	2A3,	IWNAME:	identification characters for input windfile. (A2, A3 for CYBER 205)

		USERID:	user identification under which files are stored on disk.
3	3I4	ICASE:	= 1, advection scheme on globe is used, = 2, advection scheme on a cartesian grid is used.
		IRESTRT:	see Fig. 5
		ISWELL:	= 1 wind sea-swell separation = 2 no windsea- swell separation
4	I8	NPOP:	number of source term steps in a propagation time step
5	3I8	IDELT:	source term time step.
		IDELTWI:	wind time step.
		CIRC:	circumference of earth in km. (40.000 - can be set to a very large number for flat earth limit)
6	2I10	IBGNDT:	Starting date of integration run.
		IENDDT:	Ending date of run. (Program changes ending date by one propagation timestep if number of propagation time steps is not odd.)
7	2I8	NOUT:	Number of output dates.
		ITESOU:	= 1 Test output is created, = 2 no test output is created.
	7I10	IOUTIME(I),I = 1,NOUT : output dates.	

TAPE6 - Logical unit for print output.

TAPE15 - logical unit for grid blocking and organization data.Data is stored in initialization data block COMMON/UBUF/,- in addition to the grid data COMMON/UBUF/ contains great circle wave propagation and refraction data (ouput of PREPROC - TAPE4).

TAPE7 - Logical unit for input and output of spectra at all grid points,- TAPE 7 and 10 are used in alternate input - output functions.The functions interchanging after each time step,- one tape is used to read in the spectra at time TN,while the new spectra at TN + 1 are written onto the other tape. (FIG 3.)

TAPE9 - Logical unit for input of COMMON BLOCK GRIDPAR (output of PREPROC - TAPE8).

TAPE10 - see TAPE7.

TAPE12 - New spectra on second latitude of block IG is saved as new values for last latitude of previous block IG-1.This tape is swapped in the INPUT/OUTPUT mode (Fig 3.) with TAPE13 in analogy with TAPE7-TAPE10

TAPE13- see TAPE12.

TAPE20 - Latitude before last of block IG is saved for first latitude of following block IG + 1.This tape is swapped with tape21 in analogy to tapes 7 and 10 (Fig 3.).

TAPE21 - see TAPE20.

TAPE19 - Second latitude of first block of Atlantic ocean is saved for Atlantic sector of last latitude of last block of southern ocean (Fig 3.).

TAPE22 - Latitude before last of Atlantic sector of last block of southern ocean is saved for first latitude of first block of Atlantic ocean.This tape is swapped with TAPE23 as above.-(Note that Pacific sector of southern ocean continues directly into Pacific ocean).

TAPE23 - see TAPE22.

TAPE4 - Logical unit for input of grid point indices characterizing junction of adjacent blocks.

TAPE31 - Logical unit for wind input. Wind files containing all wind data required for a propagation time step period are accessed during an integration run under a name specifying the date of the first wind record on the file. A new wind file is accessed after each propagation time step (table 1). Structure of wind files, ratios of wind, propagation and source term time steps see table 2.

TAPE33 - Swapped with TAPE31.

TAPE32 - Logical unit for input of frequency array and group velocities.

TAPE47 - Logical unit for storing last wind field.

TAPE48 - Logical unit for output of spectra at certain grid points and given times. File is saved at end of run under the name : SPEYYMMDDHHMM (cf. table 1). Data can be formatted with the program SPECFO.

Externals.

BUFSIMI - Simulates a BUFFERIN statement by buffering in 12288 words 13 times for storing the full 2-d array (only used on CYBER 205)

BUFSIMO - Simulates a BUFFEROUT statement.

WAITSIM - Simulates an IF UNIT statement.

DISPACQ - Routine to dynamically fetch or dispose files. Note: In this routine
FETCH and DISPOSE belong to ICOMPU = 2
ACCESS and SAVE belong to ICOMPU = 1
Q5ATTACH and Q5DEFINE belong to ICOMPU = 3 (see variable ICOMPU in COMMON/SOURCE/)

FEMEAN - Computation of mean frequency at each grid point.

IMPLSCH - Implicit scheme for integration of source functions in time and input of winds.

INCDATE - Increase date.

NLWEIGT - Computation of index arrays and weights for the computation of the nonlinear transfer rate.

OUTGRID - Output of significant wave height, mean direction and mean frequency , friction velocity and wind direction at all active grid-points at specified times.

OUTINT - Storing blocks for following time step.

OUTSPP - Output of spectra,wave height,wave direction, u_* and wind direction at specified output points and times.

OUTP - Output of significant wave height,wave direction,mean frequency,friction velocity and wind direction at each grid point. (SUBROUTINE of OUTGRID).

PROPAG - Propagation scheme.

SEMEAN - Computation of total energy at each grid point.

SEPWISW - Computation of 2-d swell distribution.

SETSPEC - Set same initial spectrum F at each ocean grid point for homogeneous initial wave field,F = 0 on islands(for initial T = 0 only).

STHQ - Computation of mean wave direction at each grid point.

SDISSIP - Computation of dissipation source function and linear contribution of dissipation to functional matrix in implicit scheme.

SINPUT - Computation of input source function, and linear contribution of input source function to functional matrix in implicit scheme.

SNONLIN - Computation of nonlinear transfer rate and diagonal linear contribution of nonlinear source function to functional matrix.

SBOTTOM - Computes bottom dissipation source term and contribution to functional matrix.

Reference

Snyder, R.L., F.W. Dobson, J.A. Elliot, and R.B. Long, 1981: Array measurements of atmospheric pressure fluctuations above surface gravity waves. J.Fluid Mech. 102, 1-59.

Komen, G., S. Hasselmann and K. Hasselmann, 1984: On the existence of a fully developed wind sea spectrum. JPO.

Hasselmann, S., K. Hasselmann, J.H. Allender and T.P. Barnett, 1985: Improved methods of computing and parameterizing the nonlinear energy transfer in a gravity wave spectrum, JPO.

Hasselmann, S., K.Hasselmann, 1985: A global wave model, WAM report.

Janssen, P. and G.Komen, 1985: A shallow water extension of the 3-G WAM model, WAM report.

3.5 - POPRMAP:

PURPOSE.

This post-processing routine plots Custer diagrams of significant wave height and wave direction together with wave height isolines. It can also be applied to plot significant swell wave height and direction, windsea wave height and direction, or wind stress and direction (together with the corresponding isolines of the vector magnitudes).

Interface.

*PROGRAM POPRMAP (INPUT, OUTPUT, TAPE1, TAPE2, TAPE5 = INPUT, TAPE6)

TAPE1 - Logical unit for input from wave model : significant wave height, mean wave direction, mean frequency, friction velocity, wind (stress) direction.

TAPE8 - logical unit for input of mean swell wave height and direction.

TAPE2 - Logical unit for input of grid information data as outputted from PREPROC (tape4, tape40).

TAPE4 - Logical unit for general grid information as outputted from PREPROC (tape8, tape80).

TAPE3 - Logical unit for data mapping lat-long coordinates <-> block number and index in a block.Output from PREPROC (tape7)

TAPE5 - Input data:

rec.no.	format	variable	
1	7I5	MB :	= 1 plot is enlarged, = 2 else.
		NOGRID:	Leftern most longitude for plot: 0<NOGRID<360.
		NTIME:	number of time steps to be plotted.
		ITQ1,ITQ2:	all time steps between step ITQ1 and ITQ2 are plotted.
		IFORM:	= 1 model input is binary = 2 model input is formatted.
		ISWELL:	= 1 with swell evaluation, = 0 without swell evaluation.
2	E10.3	AMOWEP:	most western point just outside grid.
3	I5	NOP:	number of output points
4	2I5	NBLOCK(N), NIJ(N):	Block number of output point, index number of output point. (N = 1, NOP)

TAPE6 - Logical unit for print output.

Method.

All values for significant wave height and and friction velocity are normalized relative to the maximum value for the full set of plots. The normalized data are plotted as arrow (Custer) diagrams with superimposed vector magnitude isolines.

Externals.

TICK Marks at land boundaries.

NORTHS	Compute north-south extent of region
EASTWST	Compute the east-west extent of region to be plotted.
FISLIN	Plot contour lines for significant wave height.
TRAFO	Computes projection of indices onto plotmatrix (for isoline plot)

3.6 - POPRSPE:

Purpose:

This post-processing routine plots the wave spectrum as an (f, theta) polar isoline plot.

INTERFACE.

*PROGRAM POPRSPE (INPUT,OUTPUT,TAPE1,TAPE2,TAPE5,TAPE6)

TAPE1 - Logical unit number for input of block number,index number in a block of output grid points,date, significant wave height,mean wave direction,friction velocity,wind direction,2-d spectrum at specified points and times.

TAPE2 - Logical unit for mapping of long-lat coordinates <-> block number and grid index in a block, output of PREPROC (tape7).

TAPE5 - Logical unit for general input :

rec.no.	format	variable	
1	2I4	IFORM :	= 1 input is binary
			= 2 input is formatted.
		IGL:	Number of blocks in region.
2	F12.10	FR(1):	First frequency point
3	3I4	NOUTPT:	Number of output points.
		NOUTTM:	Number of output times
		IFBIG:	= 1: 9 spectra are plotted in each frame
			= 2: 4 spectra are plotted in each frame
			= 3: 1 spectrum is plotted.in each frame

TAPE6 - Logical unit for print output.

Externals.

TRAFO - Projection of spectral indices to plot coordinates for subroutine FISLIN.

PLOTP4 - Write information on plot.

FISLIN - Plot isolines.

4. Deep water and finite depth options.

The WAM-model can be run in either a deep water or a shallow water mode. The mode is set by the switch parameter IDESHAL (cf. 3.4). For details regarding deep and shallow water source functions, cf. Janssen and Komen, 1985, referenced in 3.4. In the present version of the model, the finite depth extends from 15m to 180m. Wave numbers and group velocities are precomputed for a 5m depth grid and then interpolated linearly to the correct water depth of each region grid point. Differences in the deep and the shallow water parts of the model are marked in the code by comment lines: CSHALLOW. (An extension to 1000m depth with logarithmic discretization is planned.)

5. Conversion between CRAY and CYBER 205 operation.

5.1 Changes in the source code.

This section applies only to the programs WAMODEL and PREWIND, which run on the back end. The model is designed to run on a CRAY and a CYBER 205 with only very minor changes in the code.

Details of the job control carried out during the model run depend on the specific vector machine (e.g. attaching and disposing files). This is done on the CYBER 205 via "Q5-functions" and on the CRAY through "CALL jcl-statements". The compilers are not compatible for this application. Therefore the "Q5-functions" have to be commented out in the CRAY version and the "CALL jcl-statements" in the CYBER 205 version.

The following changes in the FORTRAN source have to be made to switch between the CYBER 205 and the CRAY versions.

CYBER 205: Set ICOMPU = 3, activate 999x labels and comment out 888x, 777x labels (watch out for statement continuation lines !)

Set ICOMPU = 1, activate labels 888x, comment out labels 777x, 999x (CRAY X-MP in Reading)

Other CRAY X-MP computers (eg. Munich): Set ICOMPU = 2, activate labels 777x, comment out labels 888x, 999x.

5.2 Special CYBER 205 compiler.

The standard model runs on any CYBER 205 compiler. However, if a compiler is available that allows the user to control paging, the model execution time can be speeded up by a factor of 2. An update for this version of the model is available from the Max Planck Institute.

5.3 Half precision on a CYBER 205

The model can be run on the CYBER 205 in half precision mode. There is an update available from the Max Planck Institute for this feature.

5.4 Implementation on a CRAY 1.

The present model requires about 1.2 k words central memory. This exceeds the 1 MW memory of most CRAY 1 computers. However, by using parameter statements for the dimensions of the large spectral arrays FL1, FL2, FL3, the central memory requirements can easily be reduced. Parametrized array dimensions are planned as a general feature for cycle 2.

6. - Test runs for the WAM model:

All input files for the test runs are delivered with the model tape.

6.1 SWAMP case 2 (identifier for data sets 'XXX' = CAT)

Initial spectrum:	ALPHA = 0.018	FPEAK = 0.2	GAMMA = 3
	SIGMAA = 0.07	SIGMAB = 0.09	THETAQ = 0.

Grid: 0.5 x 0.5 degree starting at 10 degree south. 4 blocks ,12 latitudes per block,41 grid points per latitude.(TOPOCAT,PRPICAT)

Propagation: Spherical and cartesian.

Time steps: Output: 10800 sec. (3 hours).
propag.: 1200 sec. (20 minutes)
source.: 1200 sec.(20 minutes)

Integration period. $1.78 * 10^5$ secs (48 hours).
Wind speed: 0.85 m/sec
Wind direction: 0. degree

In order to create a wind field for this test run in the required format for model input, a program CREWIN is included in the set of programs. Set the wind time step in the model to at least 360000 sec (in order to read in the wind data only once), and the starting date equal to the date of the wind file.

Water depth:
Deep water run
Shallow water runs: 180m,120m,15m (change topographic data set TOPOCAT accordingly)

Output for all runs is listed in table 3.

6.2 - WHIST storm 1. (identification 'XXX' = WNO)

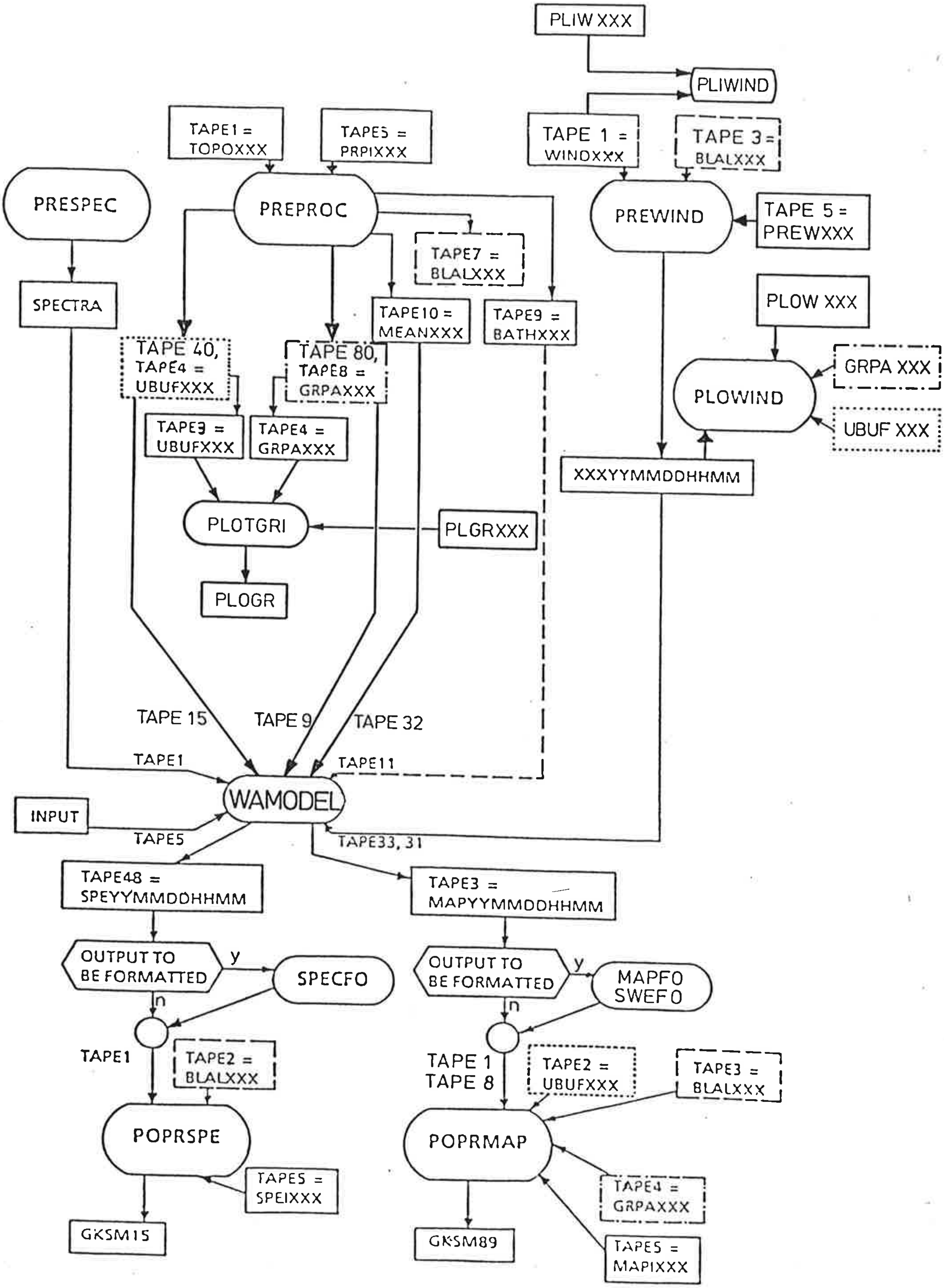
Initial spectrum:	As in first test case.
Grid geometry:	North sea grid (TOPOWNO,PRPIWNO) O.25 x 0.5 degree grid starting at -20.5 longitude and 10.5 latitude.
Wind data:	BMO winds in file WINDWNO.
Time step:	propagation: 900 sec source term: 900 sec wind: 10800 sec

Integration time: 83/01/01/00:00 to 83/01/05/00:00

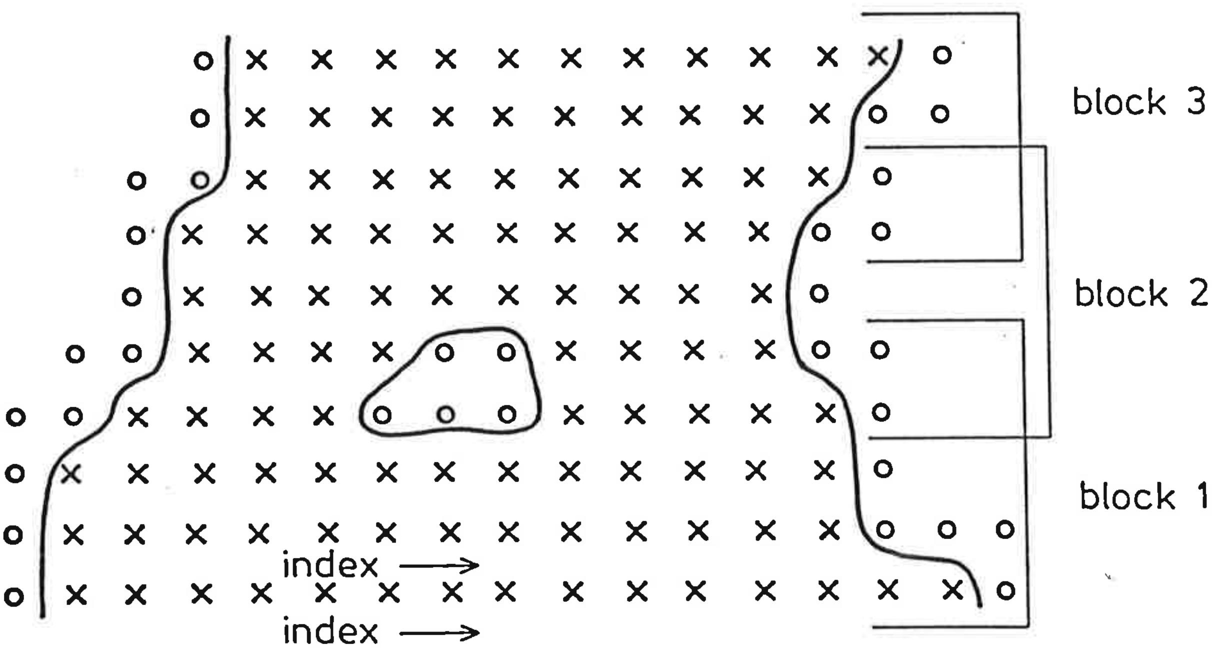
Output: Every 24 hours.
Results for the output points are shown in tables 4.

6.3 - Restart runs for SWAMP case 2. (Total integration time 48 hrs, cf, 6.1)

a. Integrate for 24 hours, save output files.
b. Restart, integrate for another 12 hours, save output files
c. Restart, integrate for another 12 hours. Results should be the same as for the full run.
   Note that run(a) actually cuts off at 23h 40min in order to acchieve an odd number of propagation time steps (cf. Section 3.4). The restart for run (b) has to be adjusted accordingly, i.e., it has to start after 23h 40min and has to integrate for 12h 40min. Since run (c) is the last restart of a run, (IRESTRT = 3) no files have to be saved in this case and the number of propagation time steps can be even.


PLIW XXX
PLIWIND
TAPE1 = TOPOXXX
TAPE5 = PRPIXXX
TAPE 1 = WINDXXX
TAPE 3 = BLALXXX
PRESPEC
PREPROC
PREWIND
TAPE 5 = PREWXXX
TAPE7 = BLALXXX
SPECTRA
TAPE10 = MEANXXX
TAPE9 = BATHXXX
PLOW XXX
TAPE 40, TAPE4 = UBUFXXX
TAPE 80, TAPE8 = GRPAXXX
GRPA XXX
PLOWIND
UBUF XXX
TAPE3 = UBUFXXX
TAPE4 = GRPAXXX
XXXYYMMDDHHMM
PLOTGRI
PLGRXXX
PLOGR
TAPE 15
TAPE 9
TAPE 32
TAPE1
TAPE11
INPUT
WAMODEL
TAPE5
TAPE33, 31
TAPE48 = SPEYYMMDDHHMM
TAPE3 = MAPYYMMDDHHMM
OUTPUT TO BE FORMATTED
y
SPECFO
OUTPUT TO BE FORMATTED
y
MAPFO SWEFO
n
n
TAPE1
TAPE2 = BLALXXX
TAPE 1 TAPE 8
TAPE2 = UBUFXXX
TAPE3 = BLALXXX
POPRSPE
POPRMAP
TAPE5 = SPEIXXX
TAPE4 = GRPAXXX
GKSM15
GKSM89
TAPE5 = MAPIXXX

GRID STRUCTURE



$\circ\ :\ F(f, \Theta, t, \varphi, \lambda) = 0$

FIG.

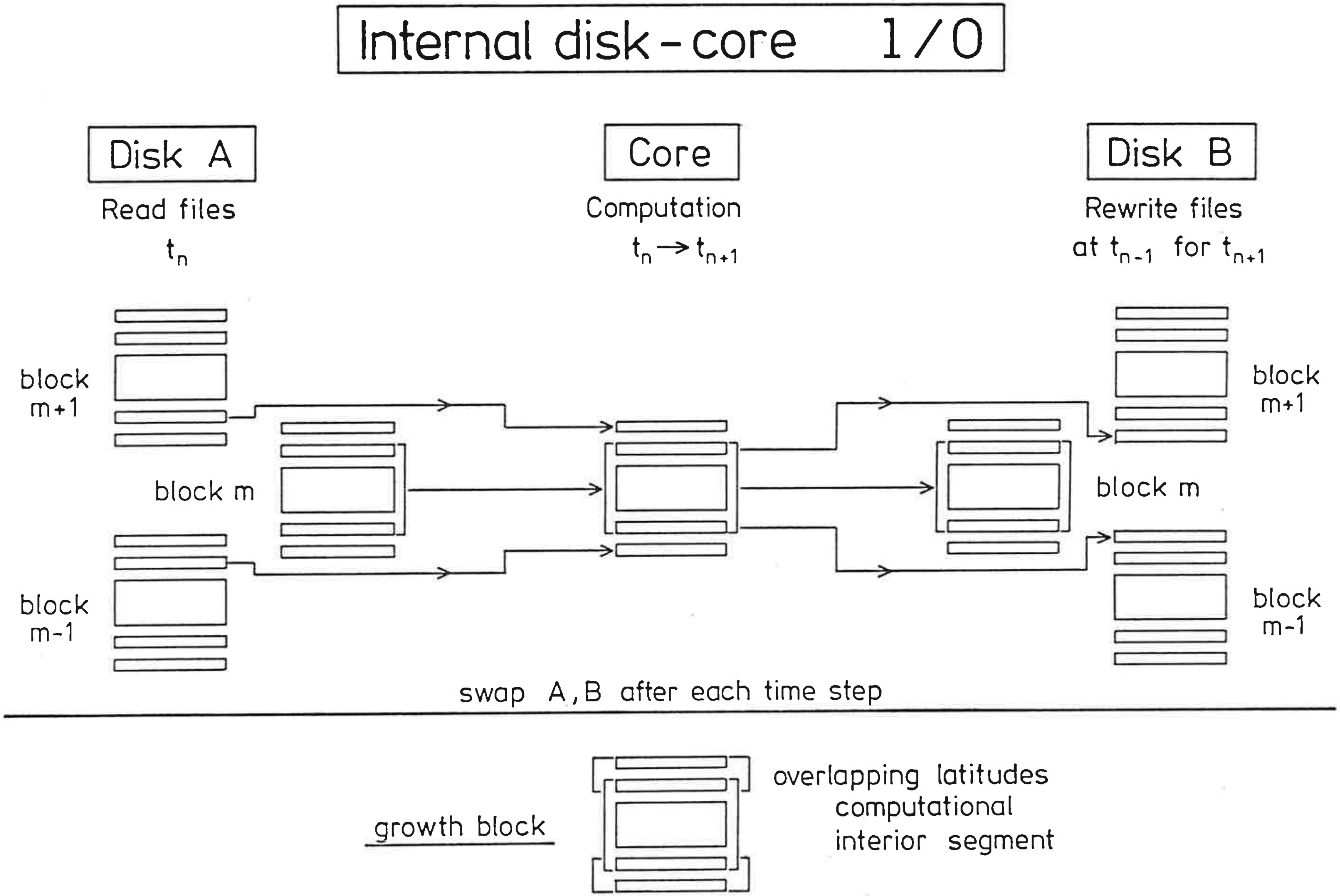

Internal disk-core I/O
Disk A
Read files
t_n
Core
Computation
$t_n \rightarrow t_{n+1}$
Disk B
Rewrite files
at t_{n-1} for t_{n+1}
block m+1
block m
block m-1
block m+1
block m
block m-1
swap A, B after each time step
growth block
overlapping latitudes
computational
interior segment

FIG 3

Buffered disk - core I/O of blocks of latitudes

problem: vectorization - input/output

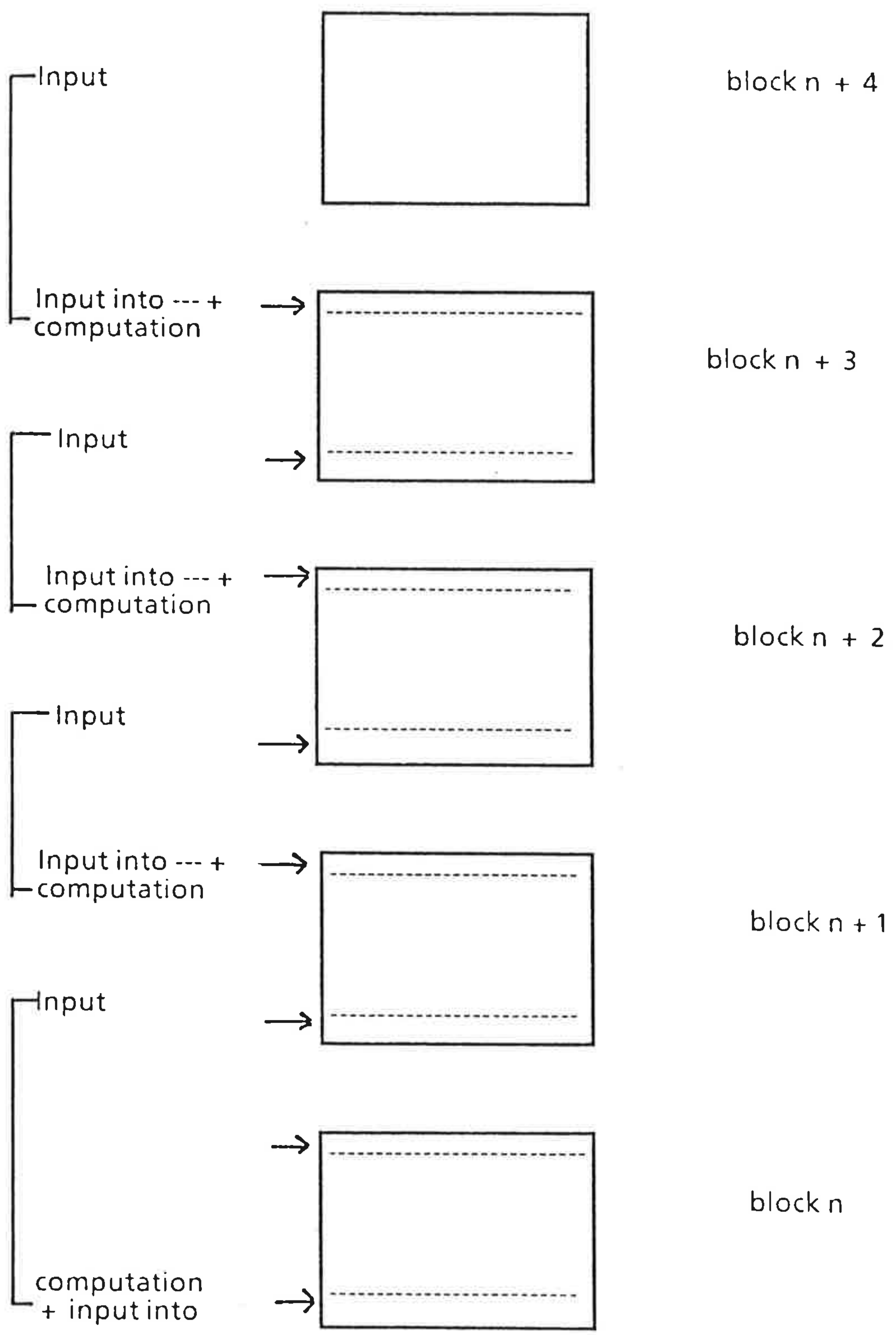


FIG 4

Restart of a model run

The total integration can be divided into a succession of separate integrations. This is controlled by a restart parameter.

Restart parameter:

0 first run - no restart follows

initial spectrum uniform for entire region.

1 first run - restart follows

initial spectrum uniform for entire region, file from disk B has to be saved ⇒ number of propagation time steps has to be odd (automatic adjustment in model)

2 restart run -restart follows

input of former run, files saved as for 1

3 restart run - no restart follows

input of former run, no files saved.

Fig 5

Internal file name structure

Files handled in program
(attach, save)

CRAY:XXX YY MM DD HH MM CC

XXX = identifier:

MAP = mapping of entire region
SPE = 2-d spectra at given output points and times
GLO = global wind data
WNO North sea winds for WHIST studies
etc.

CDC 205: XX M DD H MI

XX	identifier	
M	1, 2,.....	, 9, A, B, C
DD	01, 02,.....	, 31 if H is am.
	51, 52,...	, 81 if H is pm.
H	1, 2,....	, 9 A, B, C
MI	01, 02,....	, 60

Table 1

Time steps

Δt_w: Wind time step - Δt_p: propagation time step
- Δt_s : source term integration time step:
- have to be integer ratios of each other
- given in full minutes
- Δt_w can be $\geqq$ or $<$ Δt_p
- $\Delta t_w < \Delta t_p \Rightarrow$ 1 wind file per propagation step
- $\Delta t_w > \Delta t_s \Rightarrow$ winds constant from $T_n^w{}_{-1/2}$ to $T_n^w{}_{+1/2}$
- $\Delta t_w < \Delta t_s$, $\Delta t_s < \Delta t_w$: structure of wind files:

	T_m^p	T_{m+1}^p	T_{m+2}^p
block 1	t^s_1 t^s_2 ⋮ t^s_n	t^s_{n+1} t^s_{n+2} ⋮	⋮
block 2	t^s_1 t^s_2 ⋮ t^s_n	t^s_{n+1} t^s_{n+2} ⋮	⋮
block 3	t^s_1 ⋮	t^s_{n+1} t^s_{n+2} ⋮	

Table 2

carth. prop, spherical prop, spherical propagation

	deep water		deep water		180 m		120 m		15 m	
	H_s	F_{mean}	H_s	F_{mean}	H_s	F_{mean}	H_s	F_{mean}	H_s	F_{mean}
X (°)										
0.5	4.02	0.1422	4.02	0.1422	4.02	0.1422	4.02	0.1422	3.12	0.1650
1	5.04	0.1272	5.04	0.1273	5.05	0.1273	5.04	0.1273	3.64	0.1512
1.5	5.66	0.1180	5.65	0.1180	5.66	0.1180	5.65	0.1182	3.86	0.1433
2	6.11	0.1127	6.10	0.1127	6.11	0.1127	6.10	0.1129	3.98	0.1392
2.5	6.45	0.1091	6.44	0.1091	6.45	0.1092	6.43	0.1094	4.05	0.1367
5.	7.41	0.0996	7.40	0.0997	7.40	0.0997	7.36	0.1001	4.18	0.1297
10	8.15	0.0932	8.15	0.0932	8.13	0.0935	8.06	0.0940	4.21	0.1286
20	8.53	0.09	8.55	0.0899	8.51	0.0903	8.48	0.0907	4.21	0.1285
T (h)										
3	3.27	0.1723	3.27	0.1723	3.27	0.1724	3.27	0.1724	3.13	0.1768
6	4.81	0.1373	4.82	0.1373	4.82	0.1373	4.82	0.1373	3.89	0.1480
12	6.41	0.1103	6.42	0.1103	6.43	0.1103	6.42	0.1103	4.11	0.1338
18	7.21	0.1015	7.22	0.1014	7.23	0.1014	7.22	0.1016	4.19	0.1297
24	7.71	0.0967	7.72	0.0966	7.73	0.0967	7.71	0.0969	4.21	0.1290
30	8.05	0.0939	8.06	0.0938	8.06	0.0940	8.04	0.0942	4.21	0 1290
36	8.28	0.0921	8.30	0.0920	8.29	0.0922	8.26	0.0925	4.21	0.1285
42	8.43	0.0908	8.45	0.0907	8.42	0.0909	8.39	0.0913	4.21	0.1291
48	8.53	0.09	8.55	0.0899	8.51	0.0903	8.48	0.0907	4.21	0.1285

Table 3

WHIST CASE 1 TEST RUN:

CRAY-XMP (CYBER 205 in parentheses, where last digit deviates)

OUTPUT POINT		DATE	HS	THETA	FMEAN	U_*	PHI
BLOCK	INDEX						
1	431	83/01/02/00/00	1.55	44°	0.1922	0.28	52°
2	152	- " -	1.63	51°	0.1862 (0.1858)	0.29	68°
2	306	- " -	1.83	42°	0.1813	0.37	91°
3	296	- " -	3.76	60°	0.1387 (0.1385)	0.57	62°
4	343	- " -	3.63	74°	0.1453	0.63	80°
6	304	- " -	3.21 (3.22)	47° (46°)	0.1211	0.25	110°
7	309	- " -	3.45	55°	0.1339	0.53	61°
7	360	- " -	3.44	52°	0.1339	0.53	56°
7	362	- " -	3.47	52°	0.1327	0.52	62°
10	95	- " -	3.87	55°	0.1147	0.36	76°
10	377	- " -	4.00	50°	0.1139	0.38	64°
1	431	83/01/03/00/00	0.82	92°	0.2499	0.34	3°
2	152	- " -	1.04	97°	0.2314	0.36	8°
2	306	- " -	1.30	54°	0.2429	0.50	20°
3	296	- " -	1.99	103°	0.1575	0.33	27°
4	343	- " -	2.25	77°	0.1695	0.51	8°
6	304	- " -	2.58	94°	0.1226	0.19	356°
7	309	- " -	4.52	94°	0.0903	0.39	11°
7	360	- " -	3.36	94°	0.1099	0.38	8°
7	362	- " -	3.38	97°	0.1107	0.36	12°
10	95	- " -	4.94	78°	0.0987	0.42	66°
10	377	- " -	5.46	75°	0.1016	0.53	63°

Table 4a

OUTPUT POINT		DATE	HS	THETA	FMEAN	U*	PHI
BLOCK	INDEX						
1	431	83/01/04/00/00	2.52	52°	0.1752	0.58	49°
2	152	- " -	2.45 (2.46)	53°	0.1738 (0.1733)	0.55	50°
2	306	-" -	2.40	40°	0.1749	0.53	51°
3	296	- " -	2.77	60°	0.1492 (0.1491)	0.44	63°
4	343	- " -	2.58	33° (32°)	0.1518 (0.1517)	0.45	39°
6	304	- " -	3.57	56°	0.1170 (0.1169)	0.37	16°
7	309	- " -	5 49	68°	0.1063	0.56	44°
7	360	- " -	5.38	63°	0.1070	0.57	46°
7	362	- " -	5.67	62°	0.1042	0.54	39°
10	95	- " -	6.49	29°	0.1120	1.03	14°
10	377	- " -	6 65	-2°	0.1149	1.14	335°
1	431	83/01/05/00/00	1.31	126°	0.1703 (0.1702)	0.0	0°
2	152	- " -	1.60	121° (122°)	0.1706 (0 1705)	0.28	86°
2	306	- " -	1.80 (1.79)	110° (109°)	0 1834	0.39	76°
3	296	- " -	3.49 (3.50)	109°	0.1460 (0.1459)	0 66	120°
4	343	- " -	2.97	110°	0.1533	0.53	91°
6	304	- " -	3.27	104°	0.1274	0.37	102°
7	309	- " -	4.12	93°	0.1046	0.38	49°
7	360	- " -	3 84	87°	0.1100	0.37	46°
7	362	- " -	3 78	90°	0.1121	0.38	56°
10	95	-" -	7.70	61°	0.975	0.86	55°
10	377	- " -	5.87	61°	0.1116	0.77	61°

Table 4b