

# GISPART Model Instructions

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## 1 Description

GISPART is a three-dimensional particle-tracking code designed to simulate the dispersion of contaminants in the Strait of Gibraltar. It is a simple, but robust, model that may be used for decision-making purposes since gives very fast response. It consists of two sub-models. First, a hydrodynamic module is run off-line. This provides the tidal constants and residuals that are required to reconstruct water movements in the model domain. Tidal constants and residuals are stored in files that are read by the dispersion module to

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compute advective transport. Once that the hydrodynamic module has been adequately calibrated and all information required by the dispersion computations is stored, it is not necessary to repeat the hydrodynamic calculations. Thus, the hydrodynamic sub-model is not provided, although some details about it are given below. More information on the technical aspects of the model can be seen in Periañez (in press).

## 1.1 Hydrodynamic sub-model

An important feature of the tidal flow in the Strait is that it can be considered, as a first approach, as barotropic (Mañanes et al., 1998; Tsimplis and Bryden, 2000). As a consequence, 2D depth-averaged models have already been applied to simulate surface tides in the Strait (see for instance Sánchez and Pascual, 1988; Tejedor et al., 1999).

The barotropic hydrodynamic equations are solved over the model domain using finite differences. Surface elevations are prescribed from observations along open boundaries and radiation conditions are used to determine the current component that is normal to the open boundary. A quadratic law for bottom friction is applied.

Hydrodynamic calculations are carried out separately for the two main tidal constituents,  $M_2$  and  $S_2$ . Thus, spring-neap tidal cycles can be simulated. Once a stable periodic solution is achieved, standard tidal analysis is carried out and residual transport is calculated for each constituent. Tidal constants (amplitudes and phases) for each point in the domain and residual transports for each tidal constituent are stored in files to be read by the dispersion code. Results from the hydrodynamic calculations have been validated through an extensive comparison of tidal amplitudes and phases and several current ellipse parameters with observations for 16 points in the domain.

## 1.2 Dispersion code

The dispersion of contaminants is calculated using a particle-tracking method. Essentially, the pollutant discharge is simulated by a number of discrete particles, each particle being equivalent to a number of units. Then the path followed by each particle is computed, turbulent diffusion being modelled as a three-dimensional random walk process. Decay of particles is also simulated using a Monte Carlo method (Periañez and Elliott, 2002). This process is relevant, for instance, in the case of radioactive contaminants, but can be representing other process like biodegradation of chemical pollutants. The density of

particles per water volume unit is finally computed to obtain contaminant concentrations over the Strait at the desired time. Both instantaneous and continuous releases can be simulated. It must be noted that the particle-tracking model is three-dimensional, while the hydrodynamic module provides depth-averaged currents. Thus, a current profile is generated from the depth-averaged currents at each location by the dispersion code (see for instance Pugh, 1987).

The effect of wind is included as usual in particle-tracking models. Thus, it is assumed that the water surface moves in the direction of wind at a speed equal to 3 % of the wind speed 10 m above the sea surface. This current decreases logarithmically to zero at a depth usually taken as 20 m (Pugh, 1987; Proctor et al., 1994; Elliott, 1986).

Date and time of the discharge (and duration in the case of continuous releases) must be specified since the fate of the release will depend on the tidal state when it took place. Thus, the appropriate phase of each tidal constituent at  $t = 0$  must be specified. The values used in this model correspond to the origin of time being January 1, 2003 at 0:15 hours Greenwich time.

## 2 Model installation

Copy all files included into the GISPART.RAR archive in any folder and the model is ready to run. Operating system must be MS-DOS or Windows. A Pentium II processor is enough to simulate dispersion over several days in a few (less than 5) minutes.

Data files required by the dispersion code are the following (these files must not be modified):

File name	Content
<b>depth</b>	Strait topography
<b>residual.dat</b>	average water circulation
<b>gm2.dat</b>	phases of the $M_2$ constituent
<b>gs2.dat</b>	phases of the $S_2$ constituent
<b>hm2.dat</b>	amplitudes of the $M_2$ constituent
<b>hs2.dat</b>	amplitudes of the $S_2$ constituent

The file **strait.bat** deletes files created during the previous model run and starts a new run by opening **strait.exe**. Additionally, files **contorno** and **film.plo** are used by GNU PLOT to make animations.

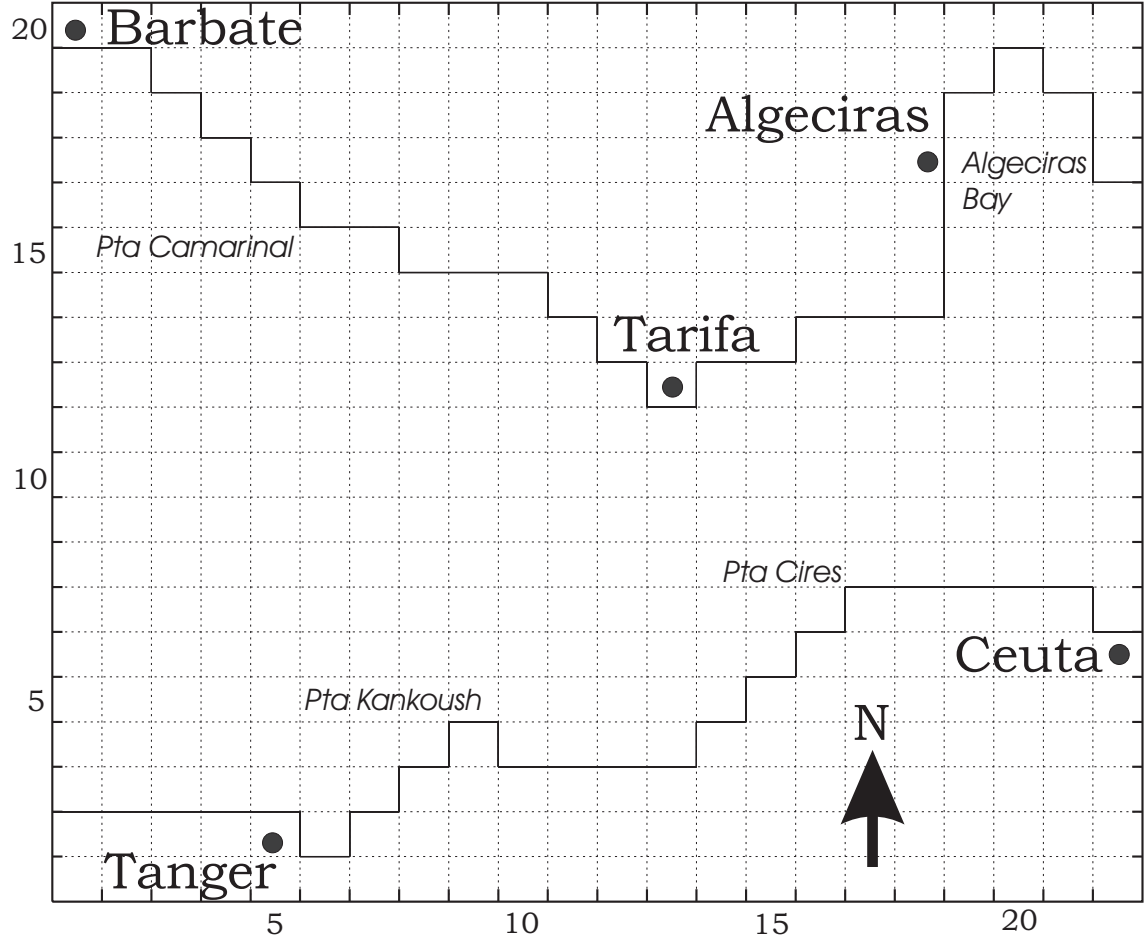


Figure 1: Computational grid. Each unit in the  $x$  and  $y$  axis correspond to 2500 m.

### 3 Running the model

The dispersion code is started opening the file `strait.bat`, as commented before. Data files are read and it is required that some information is introduced by the user. This information is the following:

- Release cell in grid coordinates  $(x, y)$ . A map of the model domain showing the computational grid is presented in Fig. 1. In this model version, it is assumed that the release occurs at the sea surface.
- Select between instantaneous/continuous release option.
- Wind speed.

- Wind direction.
- Date of release. It can be any time from January 1, 2003 on. Format must be day,month,year (for instance 25,3,2004).
- Time (UTC) of release in format hour,minute (for instance 22,45).
- Simulation time in days.
- Obtain the time evolution of  $NP$  (number of particles) at a given point (y/n)? If *yes* option is selected, it is required to introduce the grid coordinates of such point and the name of the file to write the information.
- Total amount of contaminant released. Units are arbitrary. The contaminant concentration over the domain computed at the end of the simulation from the density of particles per water volume unit is given in such arbitrary units per  $m^3$ .
- File name to write the integral of  $NP$  in each grid cell. This will be explained below.
- If the continuous release option was selected, it is required to introduce the discharge duration (hours) and the total quantity of contaminant released (again arbitrary units).

Calculations start (we can see on the screen the number of iterations). Results are written in several files described in the following section.

## 4 Model output

Several output files are generated. They are the following:

**conc.dat:** Contains the concentration of pollutants in arbitrary units per  $m^3$  at the end of the simulation in the format  $x, y, C$  where  $x$  and  $y$  are grid coordinates and  $C$  is concentration. These concentrations are obtained from the density of particles per water volume unit.

**foto1.dat to foto12.dat:** They contain the position of each particle at several times during the simulation in the format  $x, y, z$ , where  $z$  is particle depth below the sea surface. Thus, snap shots of particles can be drawn to study the evolution of the

discharge along time. In particular, 12 snaps shots at constant intervals during the simulation are provided. These files are used by GNUPLOT to make an animation of pollutant dispersion.

The following steps are required to make an animation:

1. Open GNUPLOT
2. Change to the directory where GISPART is located
3. Type: `load 'film.plo'`

A name must be given to the file where the integral of  $NP$  in each grid cell is written, as was said in Section 3. That integral,  $I_{i,j}$ , is defined as:

$$I_{i,j} = \int_0^T C_{i,j} dt$$

where  $C_{i,j}$  is number of particles at point  $i, j$  and  $T$  is the simulation time. Thus,  $I_{i,j}$  gives the area under the curve that represents the time evolution of the number of particles at point  $i, j$ . This quantity is calculated for each point in the model domain and all  $I_{i,j}$  are normalized to its maximum value. Thus, the magnitude  $P_{i,j}$  is obtained as:

$$P_{i,j} = \frac{I_{i,j}}{\max(I_{i,j})}$$

$P_{i,j}$ , that ranges between 0 and 1, may be mapped over the model domain and the map is used to define the areas of the Strait with a higher probability of being affected by contamination after an accident. It must be pointed out that  $P$  does not give any absolute probability of contamination, but it can merely be used to compare different points in the Strait. The areas with lower  $P$  values will have a higher probability of remaining un-affected than the areas of higher  $P$  values. A limitation of this approach is that points in which there is an intense peak with short temporal duration cannot be distinguished from points in which lower concentrations are obtained over longer times. Also,  $P$  does not give information about the magnitude of the peak, although this information can be obtained from the model.

The program `leo.exe`, also included in GISPART.RAR, makes the normalization of the integral  $I_{i,j}$ , thus calculating  $P_{i,j}$  and writing the result in a new file whose name must be provided. The fate of a pollutant discharge at a given point will depend on tidal state when

the release took place and on wind conditions. Thus, it would be interesting to simulate an accident at a given point occurring at different tidal states or with different wind conditions to have a more general view of the areas of the Strait with higher probability of being contaminated. Thus,  $P_{i,j}$  can be calculated for a single accident or for an arbitrary number of them. It is required to introduce the number of files to be read (containing the integral  $I_{i,j}$ ), their names and the name of the file where  $P_{i,j}$  is going to be written when running `leo.exe`.

In the file where the integral of  $NP$  is written, as well as in `conc.dat` and the file where  $P_{i,j}$  is written after running `leo.exe`, negative values are assigned to land cells so as to distinguish them from water cells where the corresponding quantity is zero. Maps can be drawn using GNUPLOT or, for instance, Golden Software SURFER.

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