Documentation of *SWASHES* v1.03.00 (2016-01-29)

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Contents

1 Presentation of the *SWASHES* software

SWASHES is a library of Shallow Water Analytic Solutions for Hydraulic and Environmental Studies. A significant number of analytic solutions to the Shallow Water equations is described in a unified formalism. They encompass a wide variety of flow conditions (supercritical, subcritical, shock, etc.), in 1 or 2 space dimensions, with or without rain and soil friction, for transitory flow or steady state. The goal of this code is to help users of Shallow Water based models to easily find an adaptable benchmark library to validate numerical methods.

2 Software distribution

2.1 How to download *SWASHES* ?

The *SWASHES* software can be downloaded on the website `https://sourcesup.renater.fr/projects/swashes/`.

2.2 License

This software is distributed under CeCILL-V2 (GPL compatible) free software license. So, you are authorized to use the Software, without any limitation as to its fields of application.

If you make changes to *SWASHES* code, you are welcome to **contribute your changes to the main repository**, directly through the website (`https://sourcesup.renater.fr/projects/swashes/`) or by contacting its main developers (swashes.contact@listes.univ-orleans.fr). You may prefer to distribute yourself the *Modified Software*. In such a case, we ask you to **change its name** in order to avoid confusion between your software and the original one. In such a case, pay attention to the text that follows.

The license authorizes you to distribute the *Modified Software*, in source code or object code form, provided that said distribution complies with all the provisions of the *Agreement* and is accompanied by:

- a copy of the Agreement,
- a notice relating to the limitation of both the Licensor's warranty and liability,

and that, in the event that only the object code of the *Modified Software is redistributed*, you allows future users *access to the full source code of the Modified Software by indicating how to access it*, it being understood that the additional cost of acquiring the source code shall not exceed the cost of transferring the data.

For further explanation about this free software license, you should read the following links:

- `http://www.cecill.info/licences/Licence_CeCILL_V2-fr.html`
- `http://www.cecill.info/licences/Licence_CeCILL_V2-en.html`

2.3 Installation

Remark 1 *To windows' users: please, look at the application note entitled "Using Cygwin to compile and run* FullSWOF_1D, FullSWOF_2D *or* SWASHES *under windows".*

First unzip the archive of the software. When you are in the *SWASHES* directory, write the following lines:

```
make cleanall
make
```

and run the executable located in the *bin* directory:

```
bin/swashes PARAMETERS
```

3 Input and output values

If you run the code with unsuitable parameters, the possible commands will be printed:

```
USE: swashes dimension type domain choice NumberCellx [NumberCelly]

Available solutions:
DIMENSION = 1
 ******* type = 0 Inclined plane ****************************************************
 - - - - domain = 1 L=10 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: supercritical flow
 - - - - domain = 2 L=20 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: transient solution
2: periodic wave
 ********* type = 1 Bumps ***********************************************************
 - - - - domain = 1 L=25 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: subcritical flow
2: transcritical without shock (sub- to super-critical)
3: transcritical with shock (sub- to super- to sub-critical)
4: lake at rest with an immersed bump
5: lake at rest with an emerged bump
 ******* type = 2 MacDonald *********************************************************
 - - - - domain = 1 Long channel: L=1000 m - - - - - - - - - - - - - - - - - - - - -
1: subcritical flow (Darcy-Weisbach)                  2: (Manning)
3: supercritical flow (Darcy-Weisbach)                4: (Manning)
5: sub- to super-critical flow (Darcy-Weisbach)       6: (Manning)
7: super- to sub-critical flow (Darcy-Weisbach)       8: (Manning)
 - - - - domain = 2 Short channel: L=100 m - - - - - - - - - - - - - - - - - - - - -
2: smooth transition and shock (Manning)
4: supercritical flow (Manning)
6: sub- to super-critical flow (Manning)
 - - - - domain = 3 Very long, undulating, periodic channel: L=5000m - - - - - - - -
2: subcritical flow (Manning)
 - - - - domain = 4 Long channel: L=1000m with rain - - - - - - - - - - - - - - - - -
1: subcritical flow (Darcy-Weisbach)                  2: (Manning)
```

```
3: supercritical flow (Darcy-Weisbach)                4: (Manning)
 - - - - domain = 5 Long channel: L=1000m with diffusion - - - - - - - - - - - - - - -
1: subcritical flow
2: supercritical flow
 ******* type = 3 Dam breaks ********************************************************
 - - - - domain = 1 L=10 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: dam break on a wet domain without friction (Stoker's solution)
2: dam break on a dry domain without friction (Ritter's solution)
3: dam break on a dry domain with friction (Dressler's solution)
 - - - - domain = 2 L=20 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: self-similar dam break on a flat bottom with a laminar friction
 ****** type 4 = Oscillations ********************************************************
 - - - - domain = 1 L=4 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: planar surface in a parabola without friction (Thacker's solution)
 - - - - domain = 2 L=10000 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: planar surface in a parabola with a linear friction (Sampson's solution)
 ****** type 5 = Bedload (Exner) ****************************************************
 - - - - domain = 1 L=15 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: Grass eq
2: Meyer-Peter & Muler eq

DIMENSION = 1.5 (pseudo 2D)
 ******* type = 1 MacDonald PSEUDO 2D ************************************************
 - - - - domain = 1 Rectangular short channel, shape B1: L=200 m - - - - - - - - - -
1: subcritical flow
2: supercritical flow
3: smooth transition
4: hydraulic jump
 - - - - domain = 2 Trapezoidal long channel, shape B2: L=400 m - - - - - - - - - - -
1: subcritical flow
2: smooth transition and hydraulic jump

DIMENSION = 2
 ****** type 1 = Oscillations ********************************************************
 - - - - domain = 1 L=l=4 m - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
1: radially-symmetrical paraboloid (Thacker's solution)
2: planar surface in a paraboloid (Thacker's solution)
-------------------------------------------------------------------------------------

(for more details, see
'SWASHES: a compilation of Shallow Water Analytic Solutions for Hydraulic and Environmental Studies',
   O. Delestre, C. Lucas, P.-A. Ksinant, F. Darboux, C. Laguerre, T.N.T. Vo, F. James, S. Cordier
   International Journal of Numerical Methods in Fluids, 2013, 72(3): 269-300.
   DOI: 10.1002/fld.3741 . URL: http://hal.archives-ouvertes.fr/hal-00628246
and other references listed in the documentation.
```

This means that you have to specify 5 or 6 parameters depending on the case you consider.

- ⋆ First, you have to give the **dimension** of the solution you want, that is:
  - 1 for one-dimensional cases,
  - 2 for two-dimensional cases,
  - and 1.5 for the pseudo 2d solutions developed by Mac Donald MacDonald [1996].
- ⋆ The second parameter is the **type** of the solution *i.e.* inclined plane, bumps, dam breaks, oscillations or Mac Donald's solutions.
- ⋆ Then, you must specify the **domain** you want for the solution, among those available for the type you chose.
- ⋆ To complete the choice of your solution, you must choose the value of the parameter **choice** corresponding to the configuration you want (sub- or super-critical, Manning or Darcy Weisbach friction coefficient for example).

⋆ Last, enter the **number of cells** for the discretization in space. If you run a two-dimensional case, don't forget to add the number of cells in the y direction.

Once you selected an existing solution, the result is printed in the terminal. As usual, you can redirect it in a file using the syntax of the following form:
`bin/swashes 1 1 1 1 100 > sol.dat`
Thus, the file `sol.dat` is created, with a summary of the parameters of the solution in the header, and the values of the solution in the file. More precisely, the file contains several columns with:

- the values of the discrete space $x_i = (i - 0.5)dx$ (and eventually y in two dimensions),
- the values of the water height h,
- the values of the velocity u (and eventually v, $\sqrt{u^2 + v^2}$ in two dimensions),
- the values of the bottom (the topography),
- the values of the flux $q = q_x = hu$ (and eventually $q_y = hv$, $\sqrt{q_x^2 + q_y^2}$ in two dimensions),
- the values of the free surface,
- and the values of the critical surface, that is the surface where the Froude number (defined by Fr$= u/\sqrt{gh}$) is equal to 1.

(Note that some of these values may not be available for each solution).

For more details, we refer to Delestre et al. [2013] where most of the solutions are detailled. For solutions on an inclined plane, one can read Delestre et al. [2012]. The swash solutions have been programmed by Noémie Gaveau during her training course (see Gaveau [2015]) from Carrier and Greenspan [1958]. Self-similar solutions have been added from Bodjona [2013] (see also *Self-similar_solutions.pdf* file in the *doc* folder and Huppert [1982]): note that these solutions are obtained from an approximation of the Shallow Water system and are not valid for small times.

Remark 2 (Bedload case) *If you consider bedload transport (with Exner equation) see Berthon et al. [2012], you will also save the (discrete) initial topography (and the initial free surface). The boundary conditions are the values on the boundaries (more precisely the mean value over the cells centered in $x = -dx/2$ and $x = L + dx/2$ respectively). Note that, to be validated through this solution, your code should not simulate a coupling between Shallow Water and Exner equations, but it must solve the whole system (on h, q and z_b), with no friction in the momentum equation.*

4 For developers: Doxygen

You may wish to add some functionalities to *SWASHES* to suits your needs. Always comment the files, at the beginning of the file, using Doxygen syntax (`www.doxygen.org/`). Then, you will be able to create the doxygen documentation of the whole code, with Doxygen 1.8.0.

HTML documentation. In order to generate the Doxygen html file, the **Doxygen_config_file_html** file is saved in the *doc* directory. To run Doxygen, from the *SWASHES* directory, use the command:
`doxygen doc/Doxygen_config_file_html`
Warning: Graphviz (`http://www.graphviz.org/`) must be in your PATH to generate HTML diagrams. If not, change the HAVE_DOT parameter of the Doxygen_config_file_html file. In the *doc/html/* directory, **index.html** is created.

PDF documentation. To generate the Doxygen LaTeX (pdf) file, you must use the **Doxygen_config_file_latex** file and compile the .tex file:

```
doxygen doc/Doxygen_config_file_latex
cd doc/latex
make
```

In the *doc/latex* directory, **refman.pdf** is created.

References

Christophe Berthon, Stéphane Cordier, Olivier Delestre, and Minh-Hoang Le. An analytical solution of the Shallow Water system coupled to the Exner equation. *C. R. Acad. Sci. Paris, Ser. I*, 350 (3–4):183–186, 2012. doi: 10.1016/j.crma.2012.01.007. URL `http://hal.archives-ouvertes.fr/hal-00648343`.

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G. F. Carrier and H. P. Greenspan. Water waves of finite amplitude on a sloping beach. *Journal of Fluid Mechanics*, 4:97–109, 1958. doi: 10.1017/S0022112058000331. URL `http://journals.cambridge.org/article_S0022112058000331`.

Olivier Delestre, Stéphane Cordier, Frédéric Darboux, and Francois James. A limitation of the hydrostatic reconstruction technique for Shallow Water equations. *Comptes Rendus Mathématique*, 350 (13-14):677–681, 2012. doi: 10.1016/J.crma.2012.08.004. URL `http://hal.archives-ouvertes.fr/hal-00710654`.

Olivier Delestre, Carine Lucas, Pierre-Antoine Ksinant, Frédéric Darboux, Christian Laguerre, Thi Ngoc Tuoi Vo, Francois James, and Stéphane Cordier. SWASHES: a compilation of shallow water analytic solutions for hydraulic and environmental studies. *International Journal of Numerical Methods in Fluids*, 72(3):269–300, May 2013. doi: 10.1002/fld.3741. URL `http://hal.archives-ouvertes.fr/hal-00628246`. See Annex on the HAL page for complementary results (with illustrations of each case).

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