Use and example (OSX,BSD,LINUX)

Version 0.1 of the use and example pdf cover a brief introduction of the program and sections on how to use the program. The file pdf includes:

- Brief description.
- How to prepare the data files to obtain the wave pressure and velocity gradients.
- How to run the program.
- How to read the output.
- Things can be done with the output.

Description

Blacktern is a GPL program with a suite of libraries to calculate the velocity gradient caused by waves, the wave theories that are applied here are part of the Airy space (1st order) and Stokes space (2nd order) both at deep and transitional waters (at version 0.6b). It is expected that versos 0.7 will be able to calculate higher order of the Stokes space (3rd, 4th and 5th orders). Cnoidal wave theory it is not used here (Korteweeg de Vries space), this as wavelengths are limited to $\lambda/h>20$.

The program calculates the velocity gradient of the waves in the horizontal plane and vertical plane during certain time. The lengths of the calculations are as follows, the vertical velocity is measured until the bottom defined by the user, the horizontal velocities are calculated over a whole wavelength lenght and the time of the calculations is made during one interval of the wave movement (one period). More information about the process of calculations can be found in the how-to.pdf file.

Blacktern deliver and output of several files that have the wave velocity values and the pressure gradient below the water surface. This output is delivered in several departed files per each component, they can be merged with some knowledge on manipulation of lists. This will be addressed later in the last section of this file.

Blacktern has been compared against the analytical expressions using software as Mathematica and Matlab with a relative good agreement under the constrains of the theories used. Differences can arise still, this due to the phase of the waves used in other programs or a bad definition of the values of the wave properties.

Blacktern is given without any warranty and should not be used as the only tool to draw conclusions about the certainty of the values obtained. It is always a good practice to compare results between tools.

How to prepare the data

In order to use Blacktern two text files are need it, as an example these two files are provided with the Blacktern code in the same folder as the code. In order to understand how to prepare the files we will commit by now that these two files are included. The files need it are called **data.txt** and **pdata.txt**, the first contains the data of the wave trains and the second the sea parameters as temperature, salinity and atmospheric pressure.

We will explain how to structure the first file on Step A and how to structure the second on Step B.

Step A

I order to use Blacktern you will need wave data already processed, another tools will be added later. Blacktern uses two text files with extension .txt, the file must be composed solely by 5 rows that are separated by a space or tab space. The composition this file must have is:

- Wave period
- Wave height
- Δx
- Δy
- Δt

The structure will be:

```
T1     a1   Δx1   Δy1   Δt1

T2     a2   Δx2   Δy2   Δt2

T3     a3   Δx3   Δy3   Δt3

.

.

.

Tn     an   Δxn   Δyn   Δtn
```

Every Δ is given by the user, lets say that we want to calculate the velocity field meter by meter, each second of a swell of 1m amplitude and period of T=10.5s. Then our file will be composed as:

```
10.5 1    1    1    1
```

Now if we want to calculate three wave swells with periods 10.5, 12.3, 14.5 and amplitudes of 1.2m, 1.5m, 0.8m then our text file will be composed as:

```
10.5 1    1    1    1

12.5 1    1    1    1

14.5 1    1    1    1
```

Of course, each Δ can be different, but if all wave components belong to the same analysis it will be advised to keep them at same Δ.

Step B:

The second file to be used needs to define the sea conditions on temperature, salinity and atmospheric pressure. This file has to be stored at the same path as Blacktern, this file need to be called pdata and have a .txt extension. The structure of the file is the same for the wave components, this structure can bee seen below:

```
Temp Sal  Pressure
```

Temperature need to be given in celsius, Salinity un PSU and Pressure in atmospheres, the calculations use the method given by the UNESCO for water density. An example of this could be the one detailed below:

```
15   35   0.98
```

The density was included as the gradient pressure can be sensitive at the temperature/salinity of the place.

How to run the program

You can prepare your data as the instructions above or you can simply run the program with the provided data, in this section in order to explain how to run the program we will just use the data provided with the program.

First very important is that Blacktern and other programs work only on .nix alike operative systems, this includes: OSX(Apple), BSD, Linux, Solaris. It can run on Windows using CYWIN; however the process is tedious and has been avoided by the author as the platform requires more work.

1.-Now the first thing will be to download the file BKT0_6.zip and decompress it.

2.-Now you will need to access the folder that was created by decompressing BKT0_6.

3.-Open a terminal inside the folder, or access the terminal on any operating system and navigate to the folder using the command **cd**. Let us say you access the terminal and now you was to navigate to the decompressed BKT0_6 in the folder Downloads, to do this you will open the terminal and type “cd /Downloads/BKT0_6”. It is important to say that the folder is called downloads in some versions of Linux/BSD so you will need to use “cd /downloads/BKT0_6”.

4.- Now you need to compile the program to link it with the libraries.

a) if you are using a Mac (OSX) device you will type: `gcc Blacktern0_6.c -L. -lprop -ldata -lcomp -lfields -o Blacktern0_6`
b) If you are using Linux/BSD/Solaris or other UNIX type: `gcc Blacktern0_6.c -L. -lprop -ldata -lcomp -lfields -o Blacktern0_6 -lm`

5.- Now Blacktern is compiled and you can run it by simply using again in the terminal the next command: `/Blacktern0_6 data.txt`

6.- The program will ask you for two variables, the depth of propagation of the wave systems and also the latitude of the buoy. Enter the values and press enter after each time you do it.

7.- If nothing bad happened, now you have a set of .txt files in the same folder with number from 0 to 3 that have the wave velocity gradient components (files named with an x) and the pressure gradient (files name with a p).

8.-If you want to alter the wave data and sea parameters, open the files data,txt and pdata.txt and modify them accordingly to your needs or data.

How to read the output

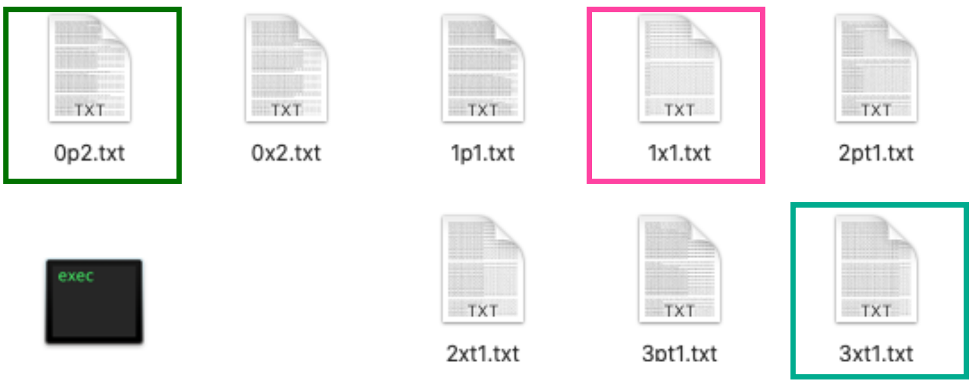
If Blacktern was able to run without any problem now you will have several txt files, I will explain how to read them.

The files name has the next structure:
[Wave spectra component][File type][Depth of propagation][Theory order].

The possible values for each one are:

Wave spectra: from 0 to n, were n is the maximum wave component numbers on the data.txt file. For the data.txt example it will be 0 to 4.
File type: p or x, if the file has a p is a file that contains he pressure gradient if the file has an x it contains the wave velocities.
Depth of propagation: t or no value, if the file has a t it means that the wave component is being propagated in a transitional water regime, if it has no letter then it is travelling into dee waters.
Theory order: 1 or 2, if the file has a 1 it means the wave has a solution that was approximated using Airy theory for its solution, if it has a 2 it means Stokes of 2nd order was used to approximate its solution.

An example can be seen below:



This is an actual screenshoot of the results after running Blacktern with the data provided as we mention in the last section. I am gonna interpret the data store in the files with the rules I mentioned before for the green, pink and cyan squares.

For: 0p2.txt
0:first wave component on the file.
p: contains the pressure field.
2: Its a wave approximated using the Stokes expansion at 2nd order.

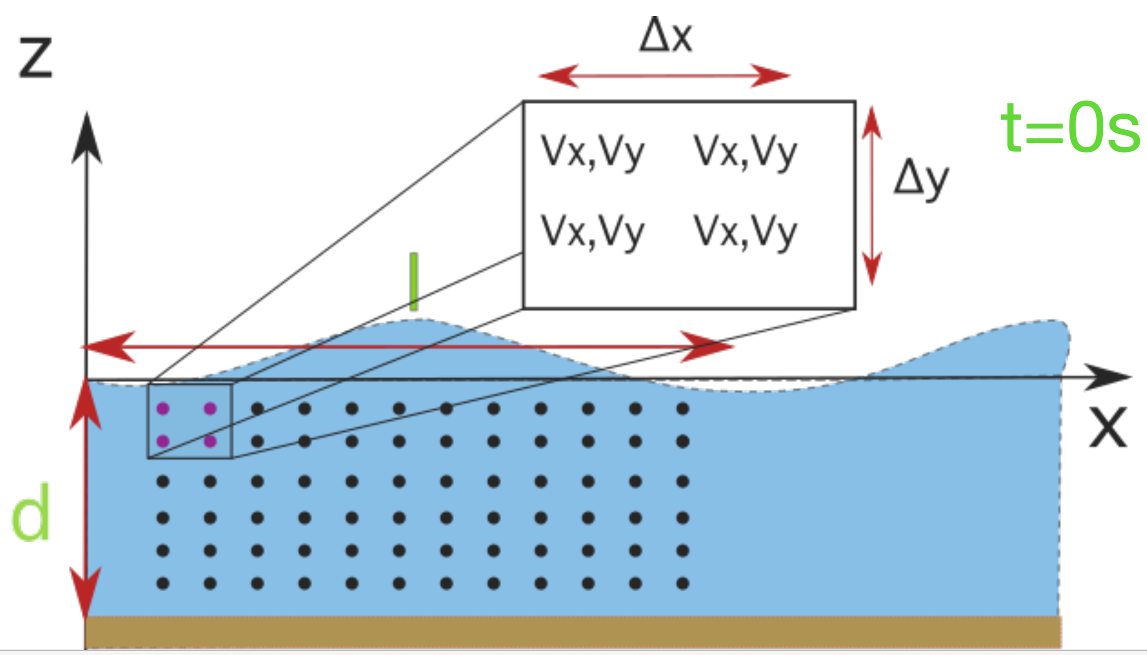
For: 1x1.txt
0:second wave component on the file.
p: contains the velocity field.
1: Its a wave approximated using the Airy theory.
For: 3xt1.txt

0: fourth wave component on the file.
p: contains the velocity field.
t: moves in transitional waters.
1: Its a wave approximated using the Airy theory.

The structure inside is the next one:

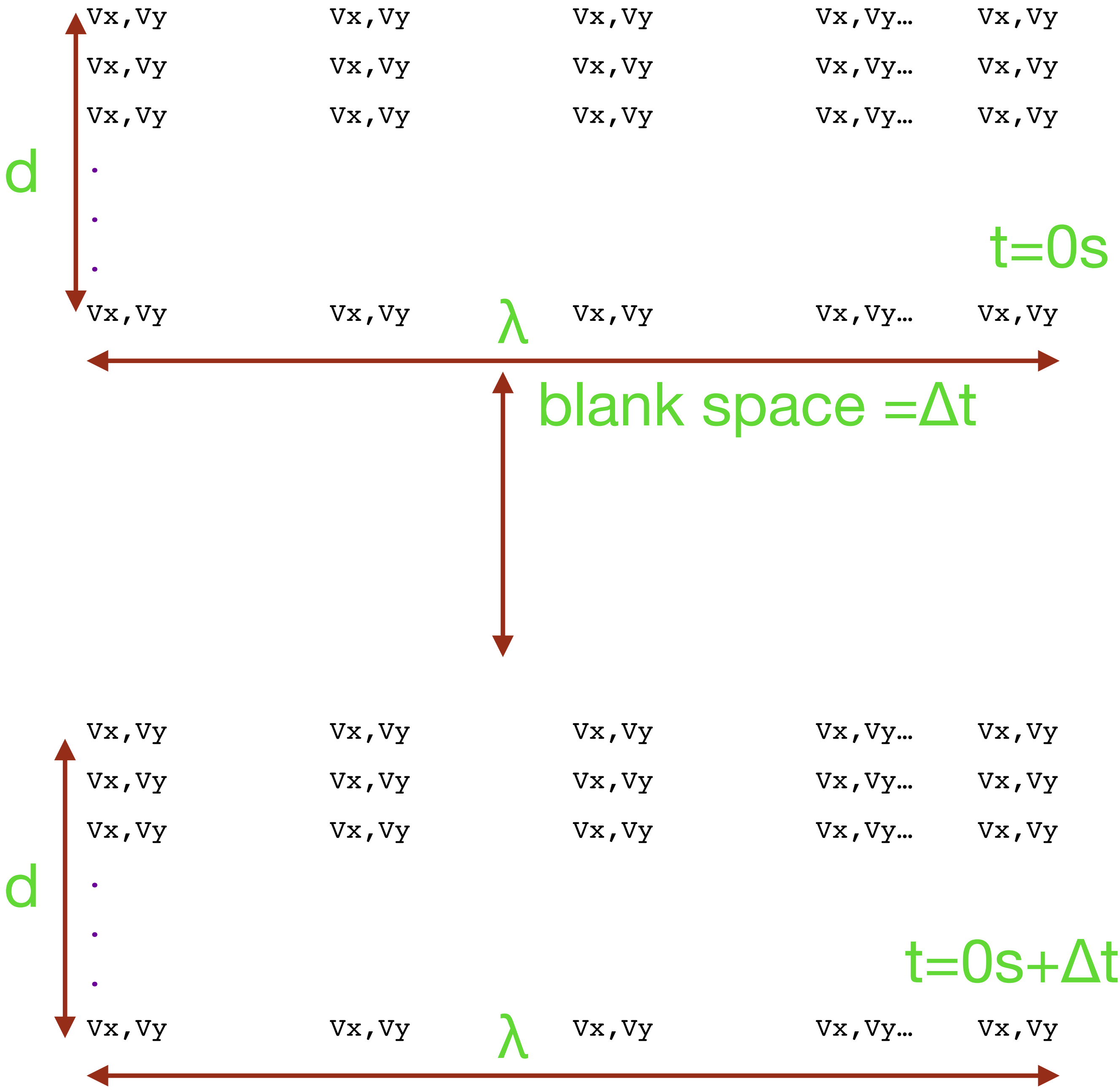
The output files will have and structure of columns and rows, where the pairs of data will represent the x,y velocity components. The components will be calculated in a length that goes from 0 to the maximum wavelength of the wave and from the mean water surface z=0 to the death where the wave is moving. The structure of the output and how it relates to the physical model can be seen in the figure below.

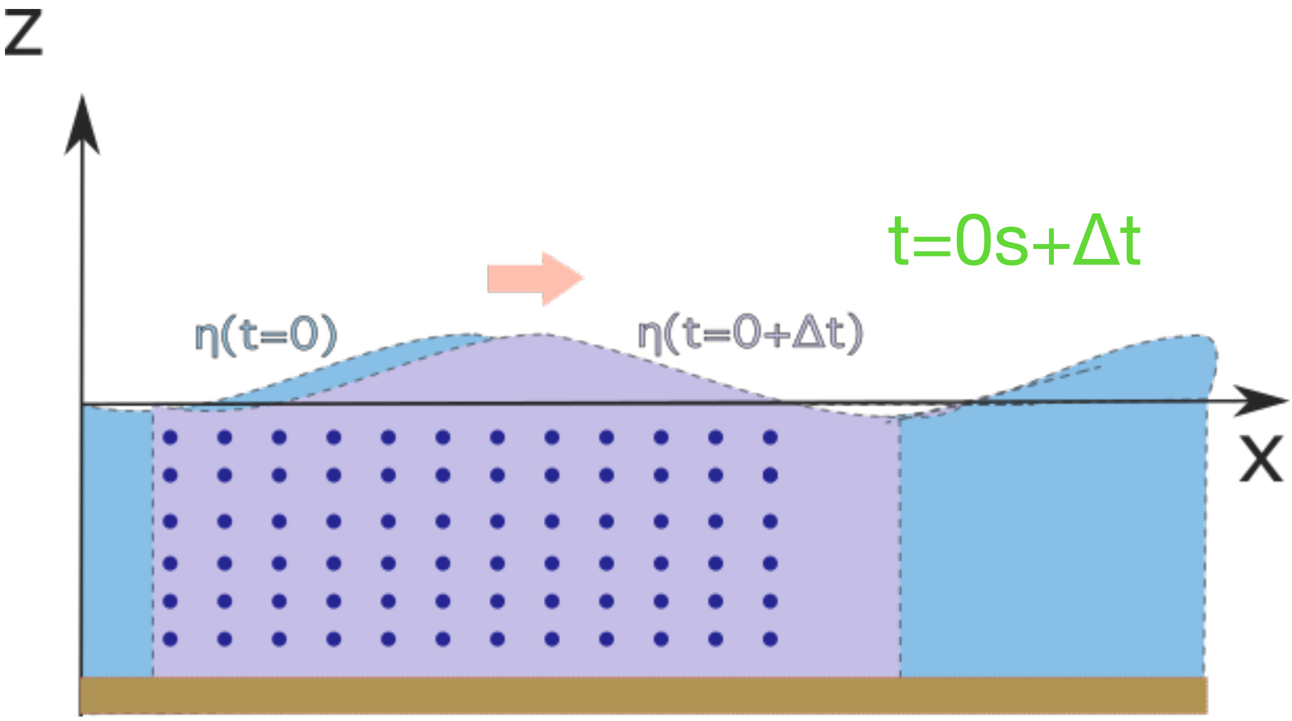
Vx,Vy	Vx,Vy	Vx,Vy	Vx,Vy…	Vx,Vy
Vx,Vy	Vx,Vy	Vx,Vy	Vx,Vy…	Vx,Vy
Vx,Vy	Vx,Vy	Vx,Vy	Vx,Vy…	Vx,Vy
.				
.				t=0s
.				
Vx,Vy	Vx,Vy	λ Vx,Vy	Vx,Vy…	Vx,Vy



Δx and Δy are given by the user in the wave data file, this will be mentioned in the next section

As the velocities are calculated from 0 to l and 0 to d, the variation on the velocities on time will be calculated next from 0 to the maximum period of the wave. The output file will have a jump with a blank space after calculating all instant velocities at t=0s, then will jump to t=0s+Δt. This will be repeated until a full wave period is completed, thus meaning that a full wave cycle passed over the area were we are calculating the instant velocities.





The new values for each point in the grid will correspond to the new flow velocity values as the waves moves over the defined area.

The same process will be repeated for the pressure gradient at the wave files containing a p instead of an x in its name. In some of these files pressure gradient could be negative below the surface, this is indicative of a trough.

In the final step, Blacktern will read the wave parameters as amplitude and period to calculate some spectral wave characteristics as:

- Wavelength of the given period at that depth.
- Frequency of the wave.
- Power density of the wave component at that wave height.
- Wave depth of interaction for deep water waves, thus telling us how far the Wakefield will reach in the water column.
- Maximum induced velocities by the waves in the surface, this as the maximum vectors on the z and z direction.

This data will be stored at a file called spectral.txt

Things that can be done with the output

Blacktern produces the gradients of velocity and pressure of the wave components given the wave parameters (wave height, wavelength). A screenshot of the output can be seen below for both:

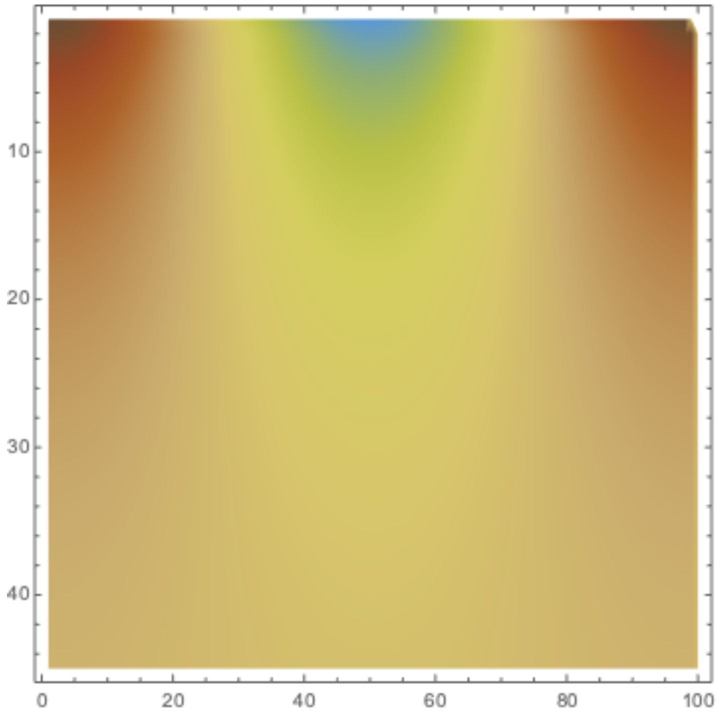
Vx(0)	Vy(0)	Vx(1)	Vy(1)	Vx(2)	Vy(2)	Vx(3)	Vy(3)	Vx(4)	Vy(4)	Vx(5)	Vy(5)	Vx(6)	Vy(6)	Vx(7)	Vy(7)	Vx(8)	Vy(8)	Vx(9)	Vy(9)	Vx(10)	Vy(10)	Vx(11)	Vy(11)	Vx(12)	Vy(12)
-0.314	0.000	0.289	-0.123	-0.218	-0.227	-0.111	-0.294	0.013	-0.314	0.135	-0.284	0.235	-0.208	0.298	-0.099	0.313	0.025	0.278	0.146	0.199	0.243	0.087	0.302	-0.038	0.312
-0.210	0.000	0.193	-0.082	-0.146	-0.151	-0.075	-0.196	0.008	-0.210	0.090	-0.190	0.157	-0.139	0.199	-0.066	0.210	0.017	0.186	0.098	0.133	0.163	0.058	0.202	-0.025	0.208
-0.141	0.000	0.129	-0.055	-0.097	-0.101	-0.050	-0.131	0.006	-0.140	0.060	-0.127	0.105	-0.093	0.133	-0.044	0.140	0.011	0.125	0.065	0.089	0.109	0.039	0.135	-0.017	0.139
-0.094	0.000	0.087	-0.037	-0.065	-0.067	-0.033	-0.087	0.004	-0.093	0.040	-0.085	0.071	-0.062	0.089	-0.030	0.094	0.008	0.083	0.043	0.060	0.072	0.026	0.090	-0.011	0.093
-0.063	0.000	0.058	-0.024	-0.044	-0.045	-0.022	-0.058	0.003	-0.062	0.027	-0.056	0.047	-0.041	0.060	-0.020	0.063	0.005	0.056	0.029	0.040	0.048	0.018	0.060	-0.008	0.062
-0.043	0.000	0.039	-0.016	-0.030	-0.030	-0.015	-0.039	0.002	-0.041	0.018	-0.037	0.032	-0.027	0.040	-0.013	0.043	0.003	0.038	0.019	0.027	0.032	0.012	0.040	-0.005	0.041
-0.029	0.000	0.027	-0.011	-0.020	-0.019	-0.010	-0.025	0.001	-0.027	0.012	-0.024	0.022	-0.018	0.028	-0.009	0.029	0.002	0.026	0.013	0.018	0.021	0.008	0.026	-0.004	0.027
-0.020	0.000	0.019	-0.007	-0.014	-0.012	-0.007	-0.016	0.001	-0.017	0.009	-0.015	0.015	-0.011	0.019	-0.005	0.020	0.001	0.018	0.008	0.013	0.013	0.006	0.016	-0.002	0.017
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-0.254	0.185	-0.306	0.070	-0.309	-0.055	-0.263	-0.172	-0.174	-0.261	-0.058	-0.309	0.068	-0.307	0.183	-0.256	0.268	-0.164	0.311	-0.045	0.304	0.080	0.248	0.193	0.153	0.275
-0.170	0.123	-0.205	0.047	-0.207	-0.037	-0.176	-0.115	-0.117	-0.175	-0.039	-0.206	0.045	-0.205	0.122	-0.171	0.179	-0.109	0.208	-0.030	0.203	0.054	0.166	0.129	0.102	0.183
-0.114	0.082	-0.137	0.031	-0.138	-0.025	-0.118	-0.077	-0.078	-0.117	-0.026	-0.138	0.030	-0.137	0.082	-0.114	0.120	-0.073	0.139	-0.020	0.136	0.036	0.111	0.086	0.068	0.123
-0.076	0.055	-0.092	0.021	-0.093	-0.016	-0.079	-0.051	-0.052	-0.078	-0.017	-0.092	0.020	-0.091	0.055	-0.076	0.080	-0.049	0.093	-0.014	0.091	0.024	0.074	0.057	0.046	0.082
-0.051	0.037	-0.062	0.014	-0.062	-0.011	-0.053	-0.034	-0.035	-0.052	-0.012	-0.061	0.014	-0.061	0.037	-0.051	0.054	-0.032	0.063	-0.009	0.061	0.016	0.050	0.038	0.031	0.054
-0.035	0.024	-0.042	0.009	-0.042	-0.007	-0.036	-0.023	-0.024	-0.034	-0.008	-0.040	0.009	-0.040	0.025	-0.034	0.036	-0.021	0.042	-0.006	0.041	0.011	0.034	0.025	0.021	0.036
-0.024	0.016	-0.028	0.006	-0.029	-0.005	-0.024	-0.015	-0.016	-0.022	-0.005	-0.026	0.006	-0.026	0.017	-0.022	0.025	-0.014	0.029	-0.004	0.028	0.007	0.023	0.017	0.014	0.024
-0.017	0.010	-0.020	0.004	-0.020	-0.003	-0.017	-0.009	-0.011	-0.014	-0.004	-0.017	0.004	-0.017	0.012	-0.014	0.017	-0.009	0.020	-0.002	0.020	0.004	0.016	0.010	0.010	0.015
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

File showing the structure of a file that contains the velocity gradient, in green the columns with the horizontal velocity and purple the vertical velocity. The columns alternate each other, in red the gradient of the time t(0)+Δt.

P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)	P(12)	P(13)	P(14)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.
1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.
2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.
3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.
4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.
5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.
6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.
7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.
8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.188	983322.
1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.375	1966644.
2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.500	2949966.
3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.750	3933288.
4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.000	4916611.
5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.000	5899933.
6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.000	6883255.
7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.500	7866577.
8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.000	8849899.

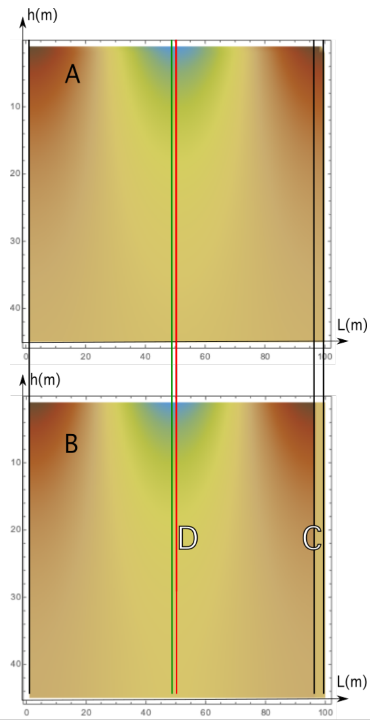
File showing the structure of a file that contains the pressure gradient. The white space in between shows the increment on time t(0)+Δt.

As the output generates arrays from surface 0 to depth hd, so the arrays can be used to create gradients maps on the wave oscillation or pressure. This can be used to visualise the effects of the wave components on the water column, this can be seen below for a simple wave component.



Horizontal wave velocity gradient for a wave at 45m depth.

The program can be used to compare two wave gradients t two different conditions such as, wave propagating over an even bottom or propagating over a bathymetry jump at 45m depth, this as shown below.



Horizontal wave velocity gradient for a wave at 45m depth, above as if the wave propagates from infinity at same depth hd=45m and below as if the wave jumped from 50m to 45m depth. The lines indicate the shift in the predicted frequency periods using wave propagation theory.

The gradient maps above were made by using Mathematica over the output of the files created by Blacktern, one could think that using Mathematica will be better as you can use the same tool to make this; however, the advantage go Blacktern is its speed. Blacktern can calculate over half million of vector velocities of a wave component moving at 100 meters depth, this calculating each 0.25m under less than 5s, this could be made faster if more optimisation is made over the code. Also Blacktern does not depend on any additional software as it is made on pure C, this without having any external dependency.