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Modelling of Tidal Power with EasyJava Simulations

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WORK PLACEMENT REPORT

TYPE OF WORK PLACEMENT : (cochez la case correspondante)

☐ Rapport de parrainage ingénieurs
☐ Stage Découverte effectué en fin d'année P1, P2 ou I1 : ....
☐ Stage Scientifique & Technique (I2)
☐ Stage de Fin d'études (I3) : A dominante 'management' ? ☐Oui ☐Non
(I3) Présence du tuteur à déjeuner le jour de soutenance ? ☐Oui

AUTHOR : Baranger Pierre

DATES : 10/06/2012 au 30/08/2012

LEVEL OF CONFIDENTIALITY I2 / I3 :

☐ 0 (no conf.) ☐ 1 (low) ☐ 2 (high)

TITLE / SUBJECT

Modeling of tidal power on EJS

Company: University Polytechnic de Catalunya

Work supervisor: Yolanda BOLEA MONTE & Antoni GRAU

3. Thanks

I would like to thank UPC for having given me this opportunity and Jean-Charles Fournier for helping me find this internship. I would like to extend a special thanks to Antony GRAU and Yolanda BOLEA, my internship tutor, for being available anytime I needed them and for the effort and time they spent helping me.

4. Résumé

L'objectif de mon stage était de modéliser l'énergie marémotrice sur le logiciel EJS, une énergie et un logiciel que je ne connaissais pas. J'ai donc commencé par chercher des documents et à les étudier pour avoir un maximum d'informations sur les marées, leurs fonctionnement, la manière dont elles sont exploitées par l'Homme ainsi que des équations plus ou moins complexes pour les modéliser. J'ai ensuite appris à utiliser le logiciel EJS en étudiant des tutoriels et des vidéos sur internet ainsi qu'en étudiants des modèles créés par l'UPC, j'ai donc essayer de voir l'ensemble des possibilités du logiciel et regardé si les idées de modèles que j'avais étaient réalisable, après quelques essais et plusieurs croquis j'ai créé un modèle simple que j'ai petit à petit amélioré, j'ai aussi appris le langage html pour pouvoir mettre en page l'introduction de mon modèle sur internet. J'ai ensuite étudié des équations beaucoup plus complexes pour essayer de modéliser les marées autour du monde, mais ces équations encore à l'étude n'ont pas donné de résultats probants…

Mots clés : marrée, énergie marémotrice, EJS, simulation, recherche, UPC,

Abstract

The goal of my internship was to model tidal energy on the EJS software; Energy and software both of which were areas I was only aware of and had no real expertise in. I started by reading the vast literature on tidal energy and studying them to gather information and build the necessary foundation for modelling the same using equations. Then I learned how to use the EJS software by studying tutorials and videos on web and by studying UPC's models in order to explore the numerous possibilities offered by the software. This helped me analyse the feasibility of my approach and after a few tries and several sketches I created a simple model, which I progressively improved. I also learned html to position the model introduction page online. Although I was unable to successfully model the complex equations using EJS, it helped me get an insight and understand the complexities involved in modelling tidal energy.

Key words: tide, tidal power, EJS, simulation, research, UPC

5. Internship summary

Internship information :

- Place : Calle Jordi Girona, 31, 08034 Barcelona. South Campus.
- Internship dates : June 10 to August 31
- Purpose : Modeling of the tidal power on EJS
- Objective :
  - Find relevant literature and study the equations of tidal power.
  - Discover EJS (Easy Java Simulation), learn its working and the various possibilities offered by the software.
  - Develop a tidal power model on EJS with algebraic equations/ ODE in order to publish it on the UPC website.
  - (optional) Develop a sophisticated tidal power model on EJS with EDP.
- Difficulty: Discover a new software, find relevant and understandable equation, work independently, make successful research and study complicated equation which are not always modelizable.

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6. UPC description

The UPC (Universitat politécnica de catalunya) is a public institution dedicated to research and higher education, specialised in the fields of architecture, science and engineering. It's a university committed to excellence, a driver of economic and social change, an institution that's extremely well connected to the productive fabric.

In the 2010 call, the University strengthened its position as an International Campus of Excellence with the UPC Energy Campus project. These two knowledge ecosystems are aimed at promoting employability, social cohesion and regional economic development. By interacting with research centres, science and technology parks, companies and other agents, the UPC is seeking to become a hub that attracts talent and resources: students, researchers and scientific facilities.

According to the April edition of the SIR World Report, the UPC keeps its position as the first technical university at state level and has successfully moved up one place in the general ranking. The UPC is the third Catalan university and now the fourth Spanish scientific institution. In addition, the UPC is the first university in Spain in the field of engineering according to the I-UGR Ranking published in May 2013

UPC key figures:

Students:
29,407 bachelor's, first- and second-cycle students
2,476 master's degree students
2,937 doctoral degree students
2,963 continuing education students

Staff:
2,634 teaching and research staff members
1,480 administrative and service staff members

Localisation:
23 schools in 8 Catalan cities

Research:
42 departments
6 research institutes
194 research groups
16 specific research centres
19 TECNIO network research centres
17 associated research centres
78,266,782 € turnover for R&D projects (2011)

7. Internship report

The first part of my internship was to do a literature study to gather information on tides and understand how to transform tidal power into energy usable by humans. Then I had to study the equations for modeling tide behaviour: simple equations (ODE) and more complicated equations (EDP).

7.1 What tide it is?

For everyone, the Tides are the daily and regular oscillatory motion by which the mass of the ocean rises and falls alternately, so that the waters cover and leave alternately part of the coastline. This oscillation are mainly due to gravitational forces exerted by the Moon and the Sun and the rotation of the Earth. But this is not the only effect result of the same mechanisms. Thus, there are atmospheric tides, punctuated by the cycle of the moon, which are manifested by changes in air pressure, and earth tides, which are reflected in particular by rising and subsidence of the ground level of a range of a few centimetres, which also follow a lunar periodicity.

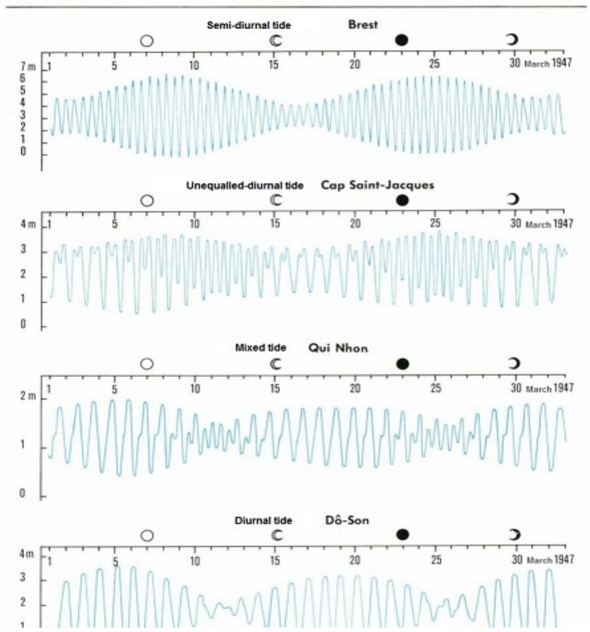


Fig 1: The four tide type.

There is different kind of tides around the world:

- Semi-diurnal tide: two almost equal high tides and two low tides each day.
- Diurnal tide: one high and one low tide each day.
- Unequalled-diurnal tide: semi-diurnal tide modulated by the diurnal tide.
- Mixed tide: two uneven tides a day, or sometimes one high and one low each day.

The times and amplitude of the tides at a locale are influenced by the alignment of the Sun and Moon, by the pattern of tides in the deep ocean, by the amphidromic systems of the oceans, and by the shape of the coastline and near-shore bathymetry.

Tide changes proceed via the following stages:

- Sea level rises over several hours, covering the intertidal zone called flood tide.
- The water rises to its highest level, reaching high tide.
- Sea level falls over several hours, revealing the intertidal zone called ebb tide.
- The water stops falling, reaching low tide.

In most locations, the largest constituent is the "principal lunar semi-diurnal". Its period is about 12 hours and 25.2 minutes, exactly half a tidal lunar day, which is the average time separating one lunar zenith from the next, and thus is the time required for the Earth to rotate once relative to the Moon. Simple tide clocks track this constituent. The lunar day is longer than the Earth day because the Moon orbits in the same direction the Earth spins.
The Moon orbits the Earth in the same direction as the Earth rotates on its axis, so it takes slightly more than a day (about 24 hours and 50 minutes) for the Moon to return to the same location in the sky. The moment of highest tide is not necessarily when the Moon is nearest to zenith or nadir, but the period of the forcing still determines the time between high tides.

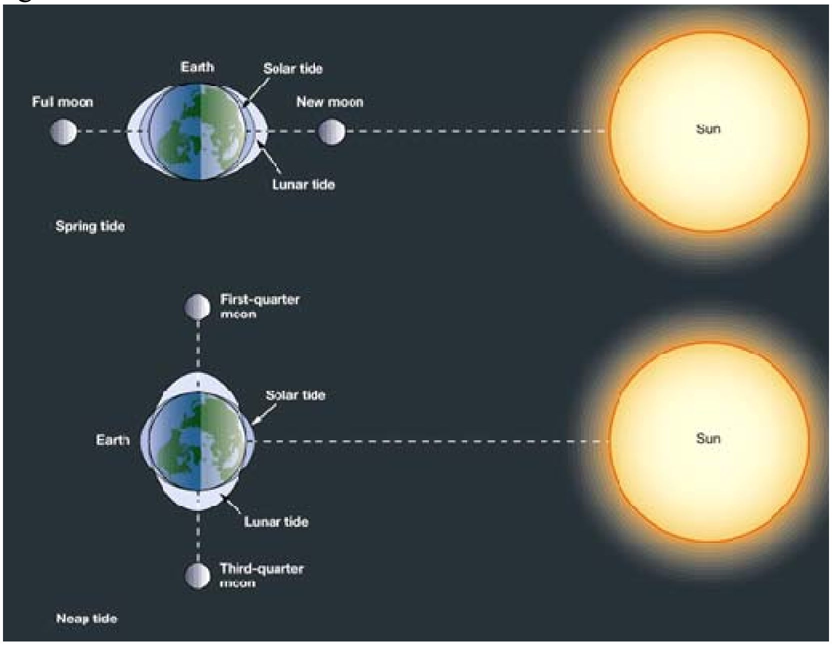


Fig 2: Astral influence on the water bulb.

Because the gravitational field created by the Moon weakens with distance from the Moon, it exerts a slightly stronger than average force on the side of the Earth facing the Moon, and a slightly weaker force on the opposite side. The Moon thus tends to "stretch" the Earth slightly along the line connecting the two bodies. The solid Earth deforms a bit, but ocean water, being fluid, is free to move much more in response to the tidal force, particularly horizontally. As the Earth rotates, the magnitude and direction of the tidal force at any particular point on the Earth's surface change constantly; although the ocean never reaches equilibrium the changing tidal force nonetheless causes rhythmic changes in sea surface height.

7.2 Tide modeling

I did a lot of research on modelling tide in order to study and understand the different kinds of complicated equations used for modelling. It has been difficult to find relevant documents and sometimes it was futile, because of the lack of explication or because EJS didn't allow us to use that kind of equations.

Although there are easy ways to determine the precise time and the tidal coefficient according to some previously measured constants, they are targeted at a specific tide and it is much more difficult to establish equations that models every kind of tide. Indeed tide modeling is a very complex subject and many scientific have studied the problem. In 1774 Laplace with his theory of tides put in equation the first hydrodynamic equations of motion tides, those equations are the basis of tidal research.

My first goal is to make a simple model of the tide behaviour and I chose to study the most common tides; the semi-diurnal one.

Simple tide model

Let's consider for example a semi-diurnal tide curve like the one in the following figure:

Fig 3: Bridgeport tide

We can see a periodic sinusoidal behaviour:

- To model it, let's start by the simple equation : $E_0(t) = \sin(t)$ (1)
- The tide period "TTidal" is approximately 12, 42 hours corresponding to half the moon period (it can change in terms of geography, elliptic orbits…) and the sin period is 2π.

  Let's fix the period: $E_1(t) = sin\ (\frac{2\pi}{TTidal}t)$ (2)

- We add the synchronisation period "Tsync" to select the tide state at the beginning of simulation.

  $E_3(t) = sin\ (\frac{2\pi}{12.27}(t + Tsync))$ (3)

- We add the average level water "tidalAverage"

  $E_4(t) = sin\left(\frac{2\pi}{12.27}(t + Tsync)\right) + tidalAverage$ (4)

- In the same way we create the range factor, we can see that the tide range is also sinusoidal, its period is approximately 420 hours called "TTidalRange". We add a synchronisation range period "TSyncRange" and a mean range value "tidalRange".
  $A(t) = tidalRange + \sin(\frac{2\pi}{TTidalRange}(t + TsyncRange))$ (5).

- The final equation is
  $E_5(t) = A(t) * sin\left(\frac{2\pi}{12.27}(t + Tsync)\right) + tidalAverage$ (6)

We can now represent all the semi-diurnal tide around the world by adjusting these variables.

7.3 Tidal energy

Tidal energy is one of the oldest forms of energy used by humans. Indeed, tide mills, in use on European coasts, date back to 787 A.D. Tide mills consisted of a storage pond, filled by the incoming (flood) tide through a sluice and emptied during the outgoing (ebb) tide through a water wheel. The tides turned waterwheels, producing mechanical power to mill grain and power was available for about two to three hours, usually twice a day.

On the Earth, the total energy flux of the tides is about 2 'TW, but only a very small fraction of this potential is used because the energy is spread around the world.

The amount of energy available from a tide varies approximately with the square of the tidal range. The energy available from a tidal power plant would therefore vary by a factor of four over a spring-neap tide cycle. Extraction of energy from the tides is considered to be practical only where it is concentrated in the form of large tides and geography provides suitable sites for tidal plant construction.

In the 1960's the first commercial-scale modern tidal power plant was built, at "La Rance", France. The hydro mechanical devices such as the paddlewheel and the overshot waterwheel have given way to highly-efficient bulb-type hydroelectric turbine/generator sets. The tidal barrage uses twenty-four 10-megawatt low-head bulb-type turbine generator sets.

The best way to use the tides is to harness the kinetic energy of a tide flow, or to use a basin to capture it.

The rise and fall of the sea level can power electric-generating equipment. The gearing of the equipment is tremendous to turn the very slow motion of the tide into enough displacement to produce energy. Tidal barrages, built across suitable estuaries, are designed to extract energy from the rise and fall of the tides, using turbines located in water passages in the barrages. The potential energy, due to the difference in water levels across the barrages, is converted into kinetic energy in the form of fast moving water passing through the turbines. This, in turn, is converted into rotational kinetic energy by the blades of the turbine, the spinning turbine then driving a generator to produce electricity.

The highest output is achieved from hydroelectric turbines by operating when the available head is highest. The available head is highest at extreme low tide and extreme high tide. These periods are roughly two hours in length, but there is relatively little change in water level during the half hour preceding and the half hour after each of the extreme lows and highs. By including these 30-minute "shoulder" periods, a 3-hour generation period is achieved twice per tidal cycle. Thus, one can effectively generate at optimum levels for roughly half of each tidal cycle. Unfortunately, tidal cycles do not correspond to daily cycles of demand for electricity.

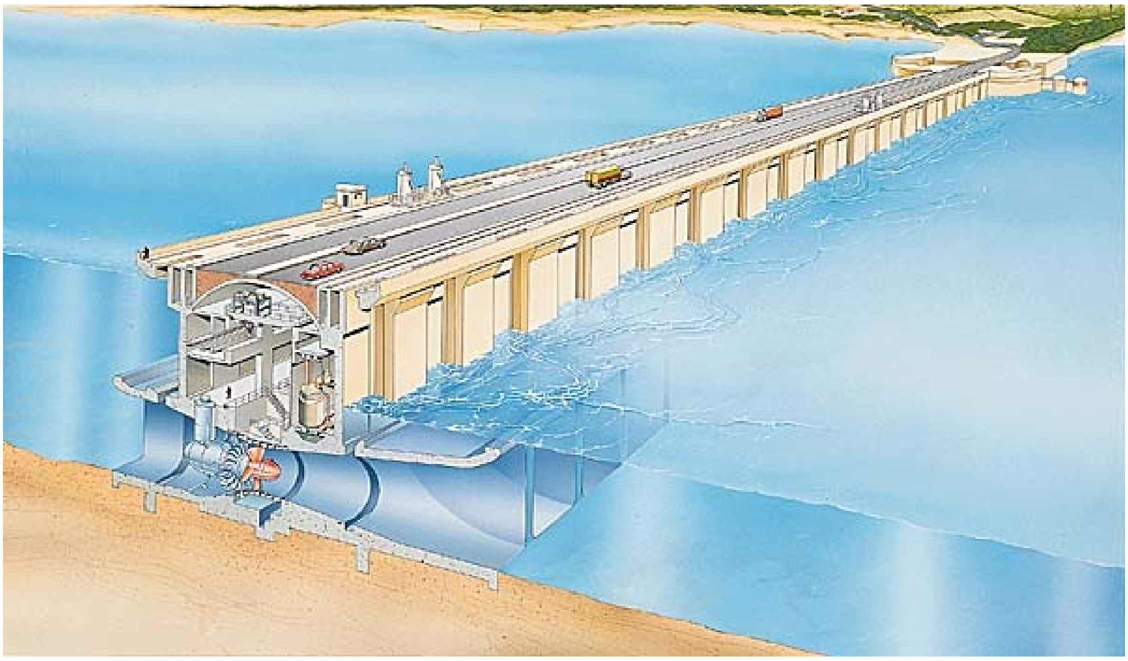


Fig 4: Dam and turbine illustration

A barrage or dam (as shown on the figure above) is typically used to convert tidal energy into electricity by forcing the water through turbines, activating a generator. The basic components of a barrage are turbines, sluice gates and, usually, slip locks, all linked to the shore with embankments. When the tides produce an adequate difference in the level of the water on opposite sides of the dam, the sluice gates are opened. The water then flows through the turbines. The turbines turn an electric generator to produce electricity.

Fig 5: Tidal fences illustration

Tidal fences look like giant turnstiles. They can reach across channels between small islands or across straits between the mainland and an island. The turnstiles spin via tidal currents typical of coastal waters. Some of these currents run at 5–8 knots (5.6–9 miles per hour) and generate as much energy as winds of much higher velocity. Because seawater has a much higher density than air, ocean currents carry significantly more energy than air currents (wind).
Tidal fences are composed of individual, vertical axis turbines which are mounted within the fence structure, known as a caisson, and they can be thought of as giant turn styles which completely block a channel, forcing all of the water through them as shown on the figure above.

Unlike barrage tidal power stations, tidal fences can also be used in unconfined basins, such as in the channel between the mainland and a nearby off shore island, or between two islands. As a result, tidal fences have much less impact on the environment, as they do not require flooding of the basin and are significantly cheaper to install. Tidal fences also have the advantage of being able to generate electricity once the initial modules are installed, rather than after complete installation as in the case of barrage technologies.

The tide is the only factor that affects the generating activity of a tidal power plant that is programmed to produce maximum output. The output at any given time can be accurately calculated as far in advance as is necessary.

Mode of operations and configuration :

Single-Action OutFlow (also called Ebb) Generation: Barrages can use either one basin or a combination of basins, and can operate by ebb, flood, or two-way generation, with or without pumping. The simplest method is ebb generation using a single basin. The basin is permitted to fill through sluices (gated openings). Generation takes place as the basin is emptied via turbines once the tide level has dropped sufficiently. There are two bursts of generation activity each day, beginning approximately three hours after high tide and lasting 4-6 hr. Output levels will only show slight variation from one fortnightly period to the next.

Flood Generation: An alternative method is flood generation, which provides power as the basin fills. The basin empties through sluices as the tide falls. This method is not as efficient as ebb generation since it involves using the basin between existing low tide level and slightly above normal midtide level, thus producing less energy. An advantage of this mode is that it facilitates the production of energy out of phase with a neighbouring ebb generation scheme, complementing its output and perhaps providing some firm capacity.

Two- Way Generation: Two-way generation is a combination of ebb and flood generation, generating as the basin both fills and empties, but with a smaller power output than for simple ebb generation (except at the highest of tide ranges) due to reduced range within the basin. There is a resultant reduction in efficiency with two-way generation since turbines and water flow cannot be optimized. Turbines designed to operate in both directions are more costly. Two-way generation, however, does produce electricity more regularly. Blocks of energy are produced in approximately 6-hr cycles, with smaller power output and a greater plant utilization factor. The more regular output requires less retiming to produce the same capacity.

7.4 Tide energy modeling

After studying the different ways to transform tide energy in electric energy, I chose to modelize a barrage with turbines to make my simple model.

Simple Tide model

The energy produced by a turbine into a dam depends on the water velocity on the turbine, we can use the Torricelli law: $vTurb = \sqrt{2 * g * dH}$.

"vTurb" represent the water velocity on the turbine;

"dH" represent the difference between the height water of the sea/ocean and the basin : $dH = |hSea - hBasin|$

The power availed by the turbine is $powerAvail = Cp * \rho * Q * dH$

"Q" represents the water flow on the turbine $Q = vTurb * A$

"A" represents the turbine area.

"Cp" represents the loss coefficient.

"p" represents the water density.

8. Easy Java Simulation

The second internship objective was self-training on the EJS software by studying tutorials and videos on web and by studying UPC's models in order to explore the numerous possibilities offered by the software.

8.1 UPC model example:

Energy Equivalent Traffic Noise Prediction:

The model is based on empirical equations developed to predict how the traffic can cause disturbance and danger for humans near traffic routes without suitable acoustic barriers. In order to predict the energy equivalent sound level, the shortest distance from the point to study to the route must be given, and both an estimation on traffic volumes for automobiles (up to four tires) and trucks (six or more tires) and the average traffic speed at each hour to study.

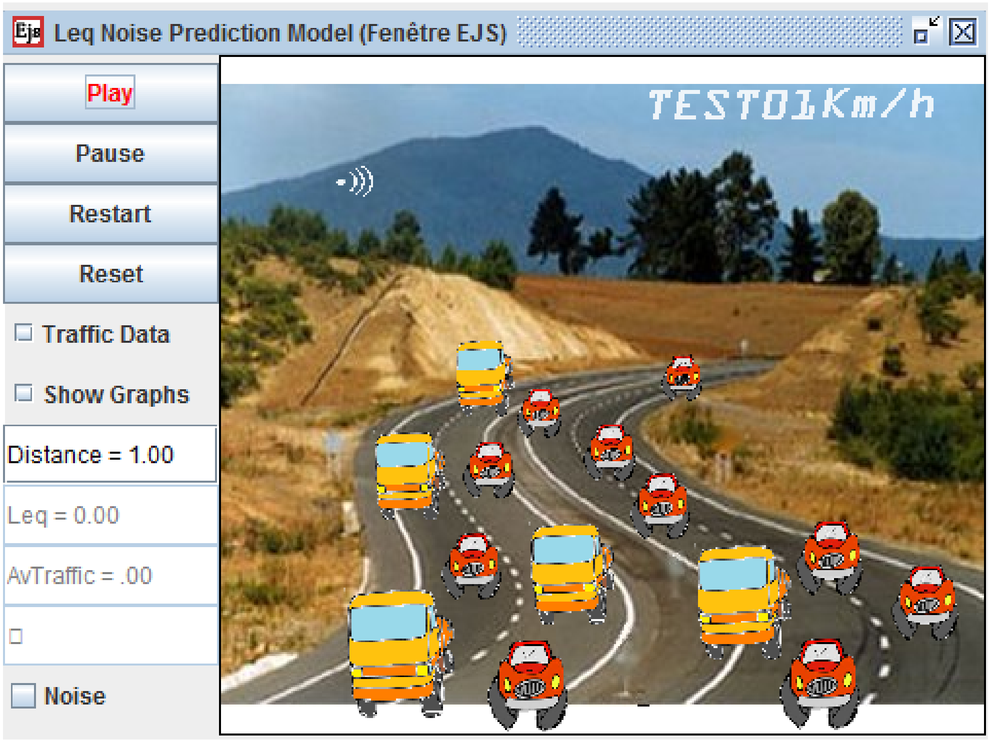


Fig 6: Traffic noise model

Wastewater secondary treatment:

This software is designed to simulate the behaviour of several variables during the application of a secondary treatment to a wastewater flow. In this case it is studied specifically the application of activated sludge treatment in a given sample plant. Note that even the model is designed having in mind a generic example of activated sludge treatment unit, it is entirely possible to modify any initial state or parameter value, the same as input function values, thus allowing user to describe any sludge treatment unit system.

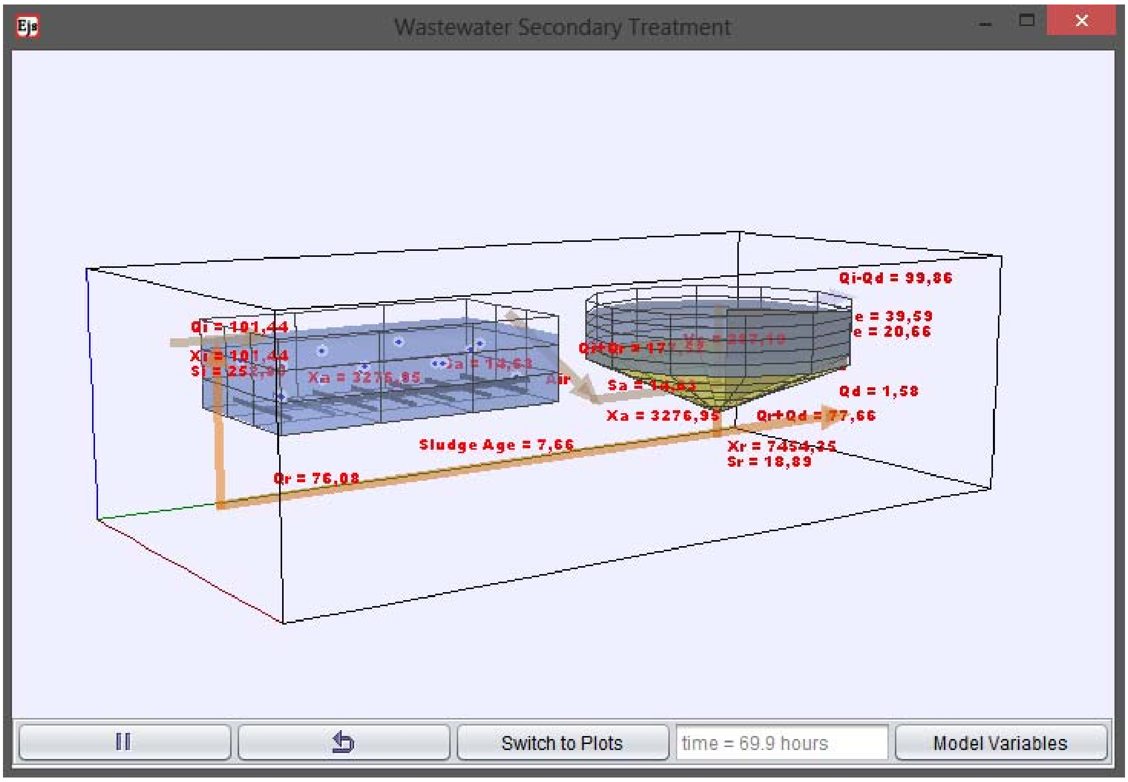


Fig 7: Wastewater secondary treatment model

It's a 3D simulation very complicated with lot of equations, it was a very good inspiration to make my own model.

8.2 What EJS is ?

Easy Java Simulations or EJS, is a software tool written in Java to create interactive computer simulations in Java, mainly for teaching or learning purposes. EJS has been created by Francisco Esquembre and is part of the Open Source Physics project.

A computer simulation, is a computer program that tries to reproduce, for pedagogical or scientific purposes, a natural phenomenon through the visualization of the different states that it can have. Each of these states is described by a set of variables that change in time due to the iteration of a given algorithm.

EJS creates Java applications that are platform independent, or applets that can be visualized using any Web browser (and therefore distributed through the Internet), which read data across the net, and which can be controlled using scripts from within web pages.

It has been translated to different languages like English, Spanish, and Catalan.

How it works ?

On the first windows, we can see the three main aspects of the simulation: Description, Model, and View.

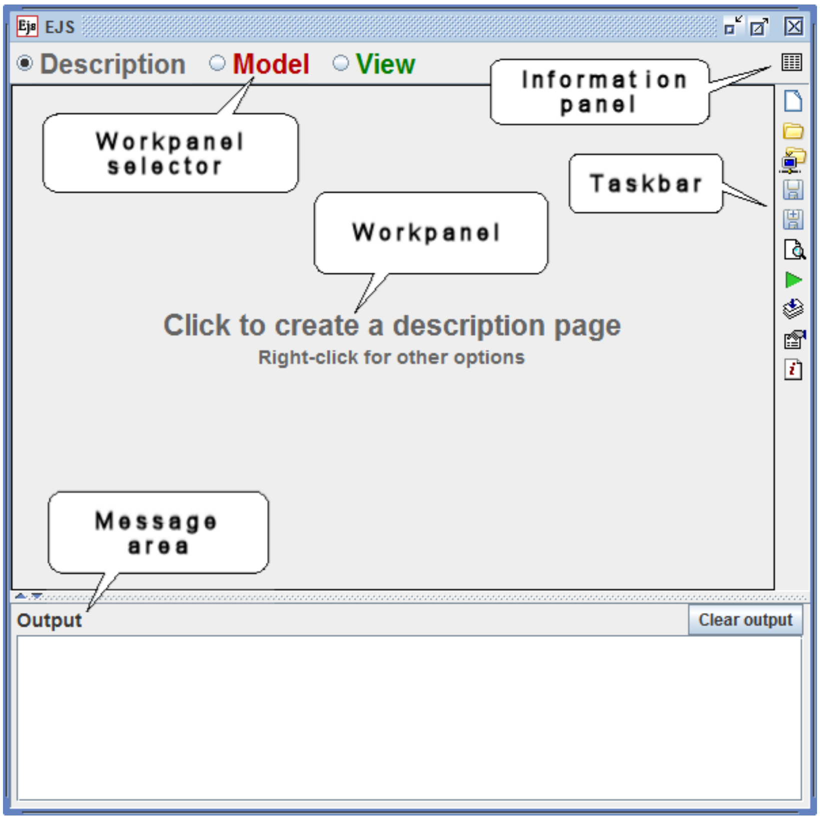


Fig 8: EJS main page

The first panel, Description, allows us to create and edit multimedia HTML-based narrative that describes the simulation. Each narrative page appears in a tab within the workpanel and right-clicking on the tab allows the user to edit the narrative or to import HTML files created with other tools.

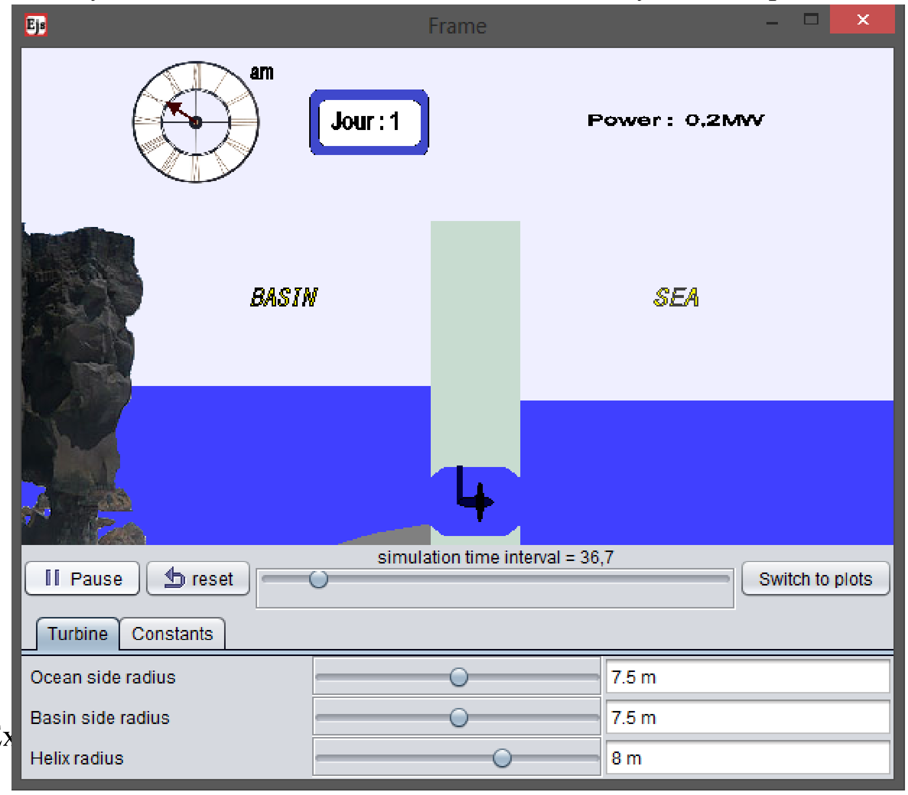
The second work panel, Model, is dedicated to the modeling process. We use this panel to create variables that describe the model of our simulation, to initialize these variables, and to write algorithms that describe how this model changes in time.

The third workpanel, View, is dedicated to the task of building the graphical user interface of the simulation, which allows final users to control the simulation and to display its output. We build the interface by selecting elements from palettes and adding them to the view's Tree of elements. For example, the Interface palette contains buttons, sliders, and input fields and the 2D Drawables palette contains elements to plot 2D data.

Simple tide model on EJS :

After exploring the software possibilities and the different tidal equations, I along with my internship tutor decided to represent tidal energy on a dam harnessed by a turbine.

So I started by doing a graphic sketch and analysing which variables would be interesting to modify in the simulation. After validation from my internship tutor, this is the result:



Ex

inning of the simulation

Fig 9: Simple tide model

- The blue dial indicates the number of days passed since the beginning of the simulation;
- "Power" indicates the instantaneous power produced by the turbine
- The control buttons, "play / pause" to start or pause the simulation, "reset" to restart.
- The slider called “Simulation time interval” allows to increase or decrease the time between each calculation so as to increase or decrease the speed of simulation.
- Turbine control panel allows to change the information on the radius of the turbine as the input or output of the turbine and the radius of the helix.

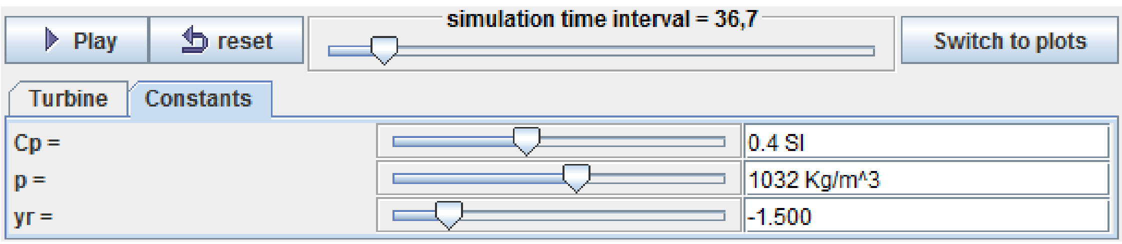


Fig 10: Constants panel

Constants control panel allows changing the calculation constants such as the power loss coefficient, the density of water (which changes according to the location), and the position of the turbine relative to the dam.

The buttons "switch to plots" allow change of view and observe the exploitable curves in the simulation.

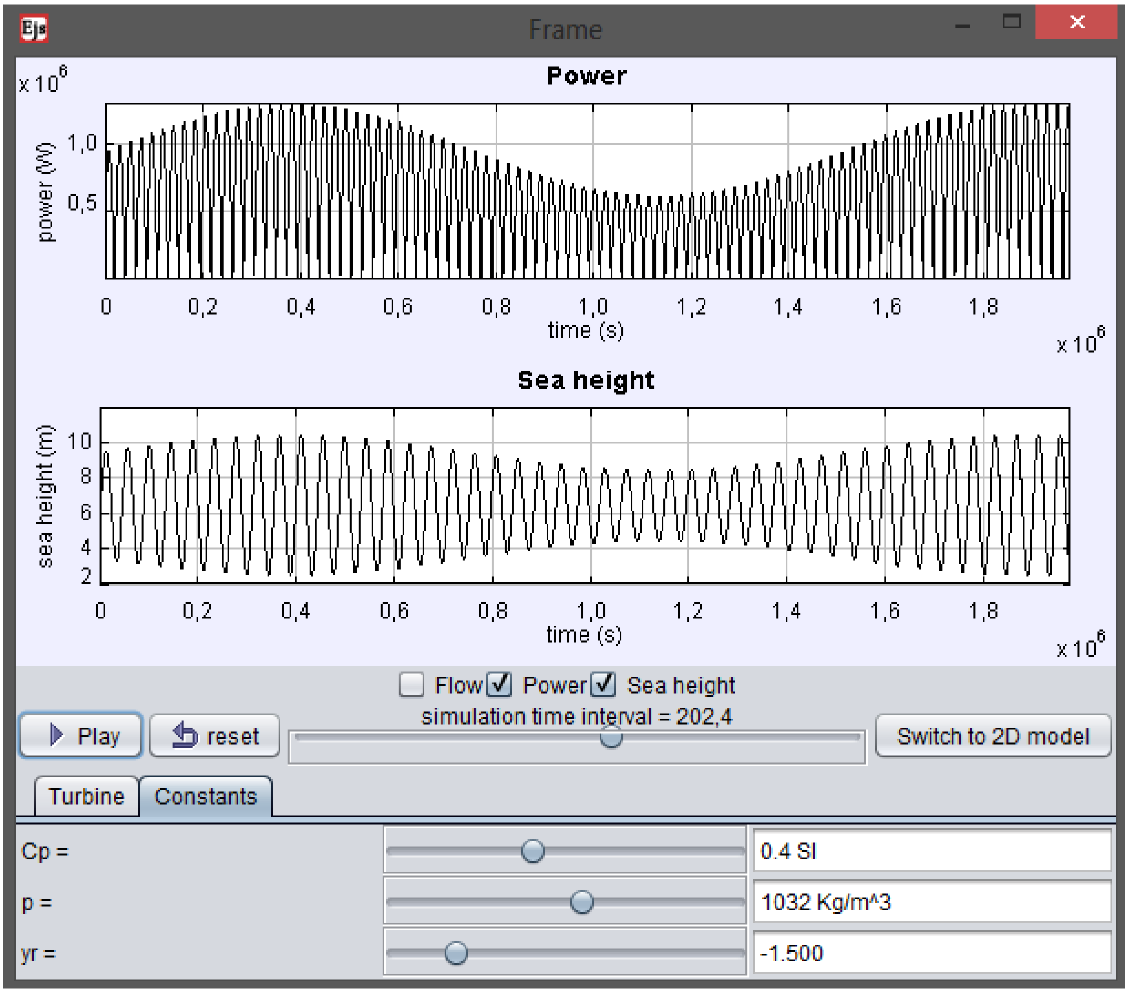


Fig 11: Plot view

Here we have the opportunity to observe the curves representing the tides and the power generated over time, as well as the water flow through the turbine. It's also possible to choose to observe one or more curves at the same time by selecting the appropriate fields. For example, only the sea level is shown in the following figure.

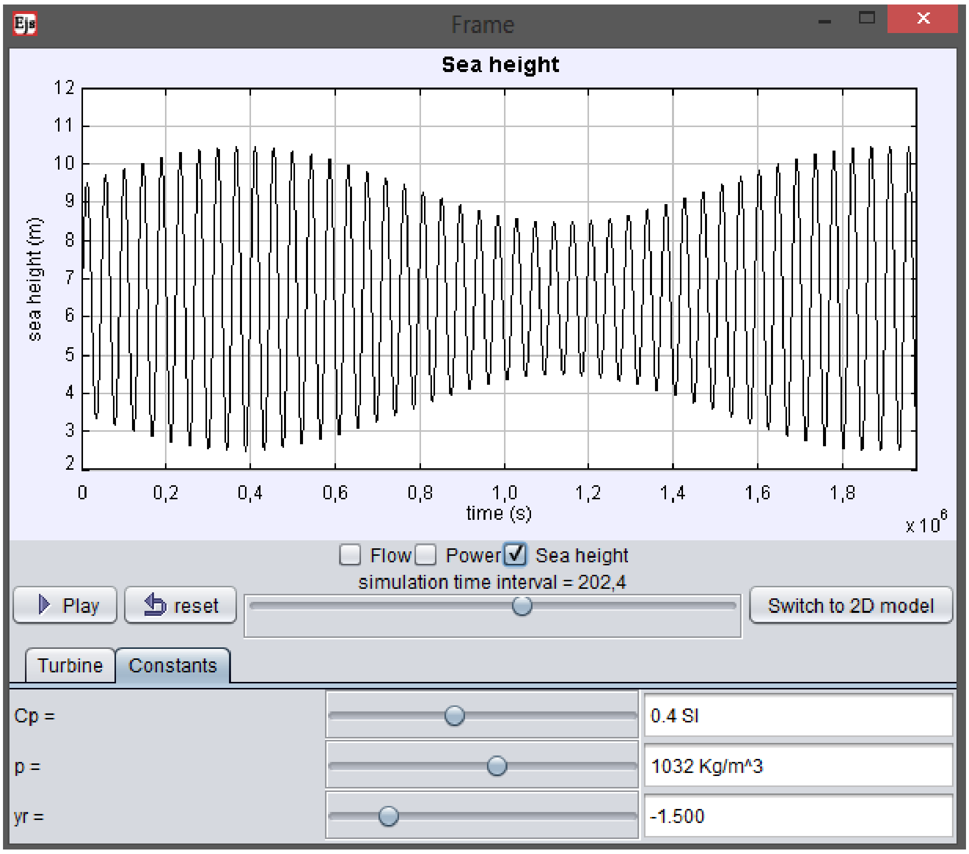


Fig 12: Sea height view

The model includes four pages of introduction explaining the tides and their modeling for that simulation, with an explanation of the different ways to convert this energy into electricity and its modeling in this model.

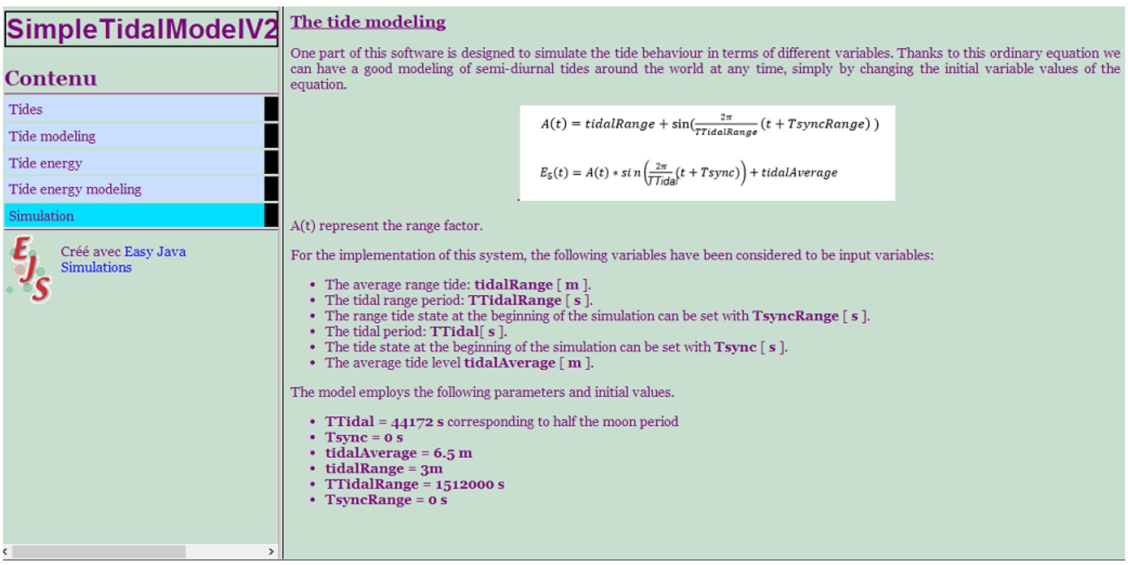


Fig 13: Introduction view

In order to make a good layout page, I had to make some html arrangements;

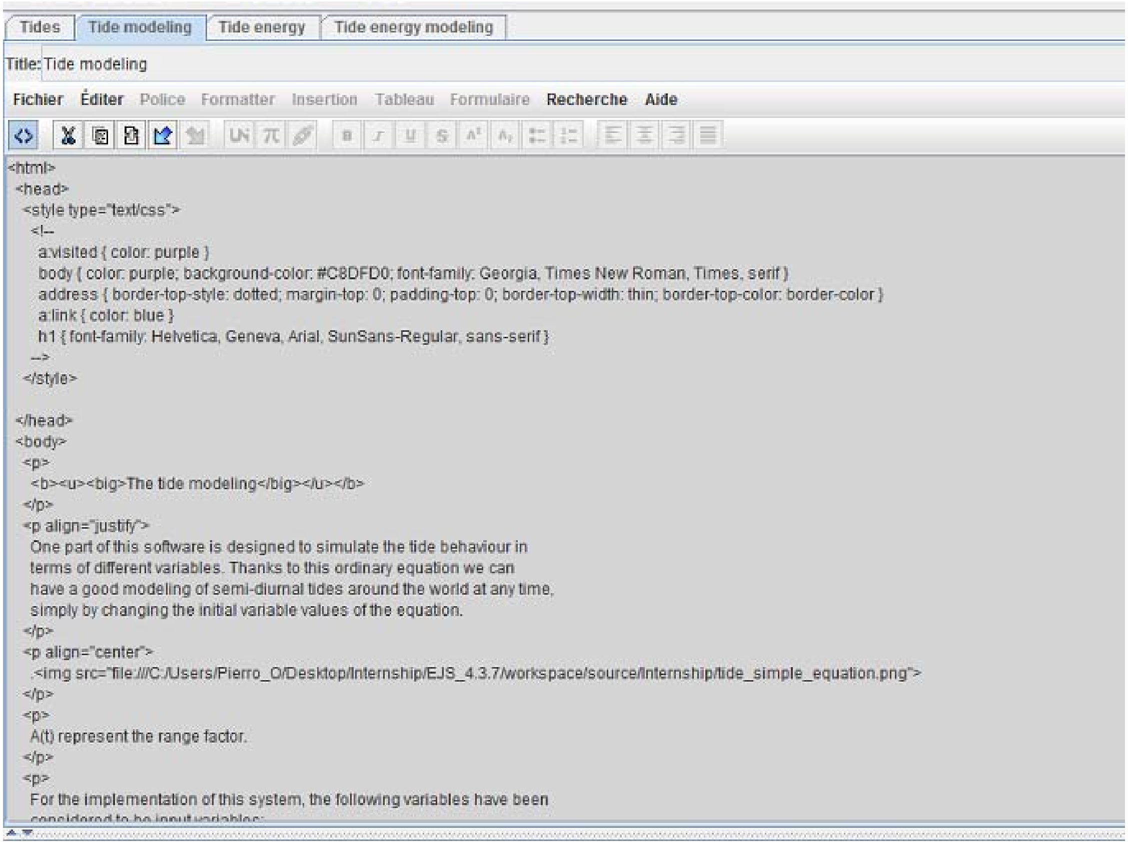


Fig 14: Html view

How to perform a simulation:

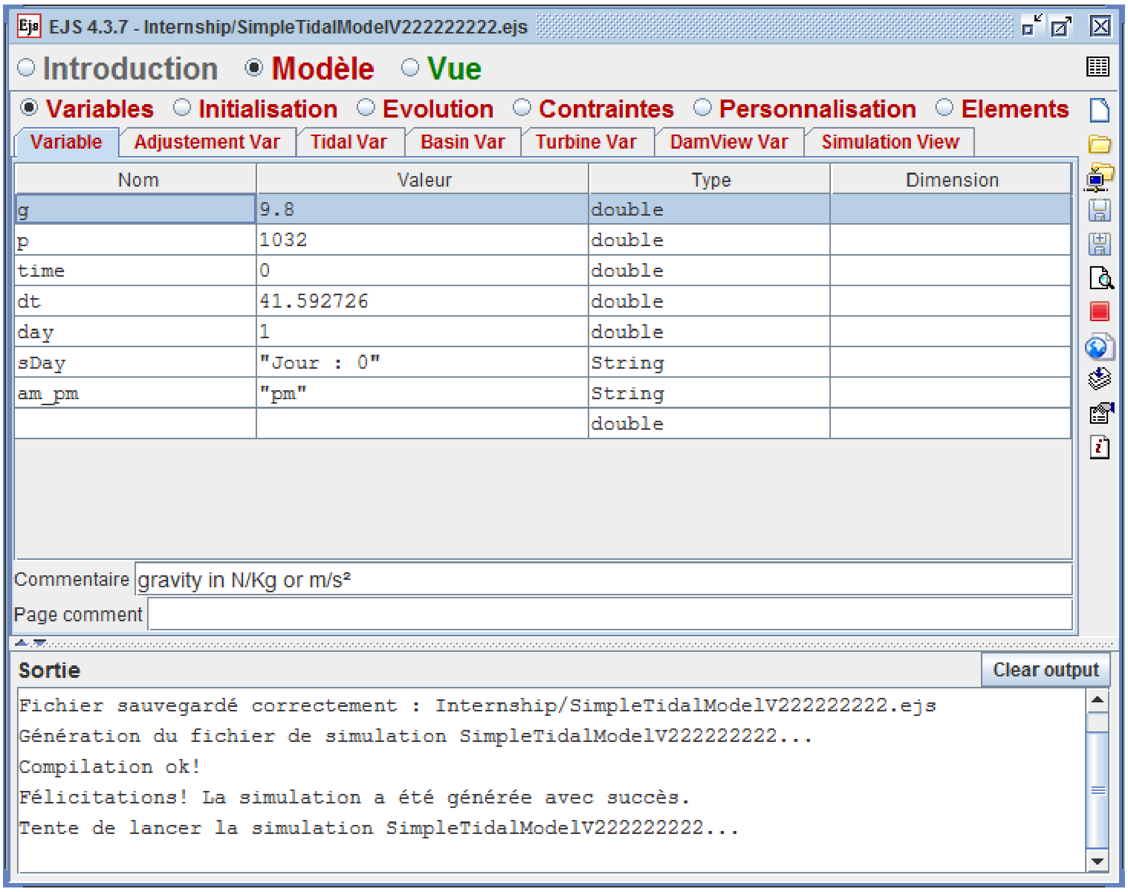


Fig 15: Variable panel view

All variables are declared in the variable menu, here I have different pages for better clarity and themes for each variable type. This menu allows us to create our variables, to give them an initial value and a type which is limited to integer / double / string / boolean with the possibility to comment the variable as shown in the figure above.

Initialisation panel :

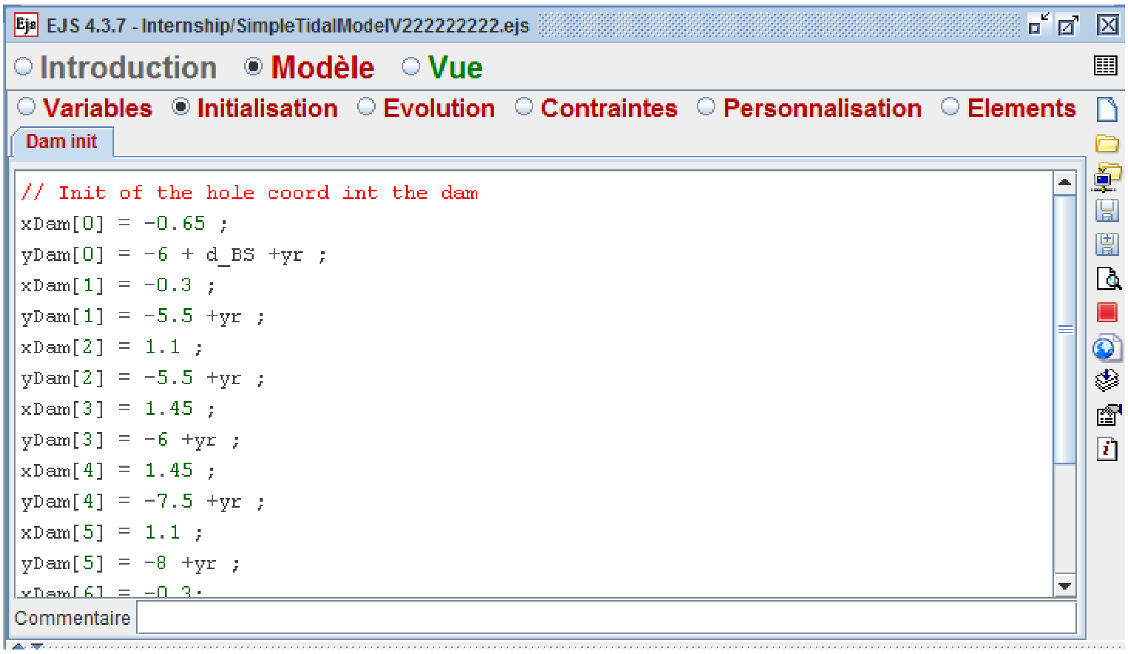


Fig 16: Initialisation panel view

This page allows to create initialisations that are a little more complex, like when a variable requires a preliminary calculation or depends on another variable before being initialized. The above figure shows initialization of a polygon used to represent a hole in the dam.

Evolution panel:

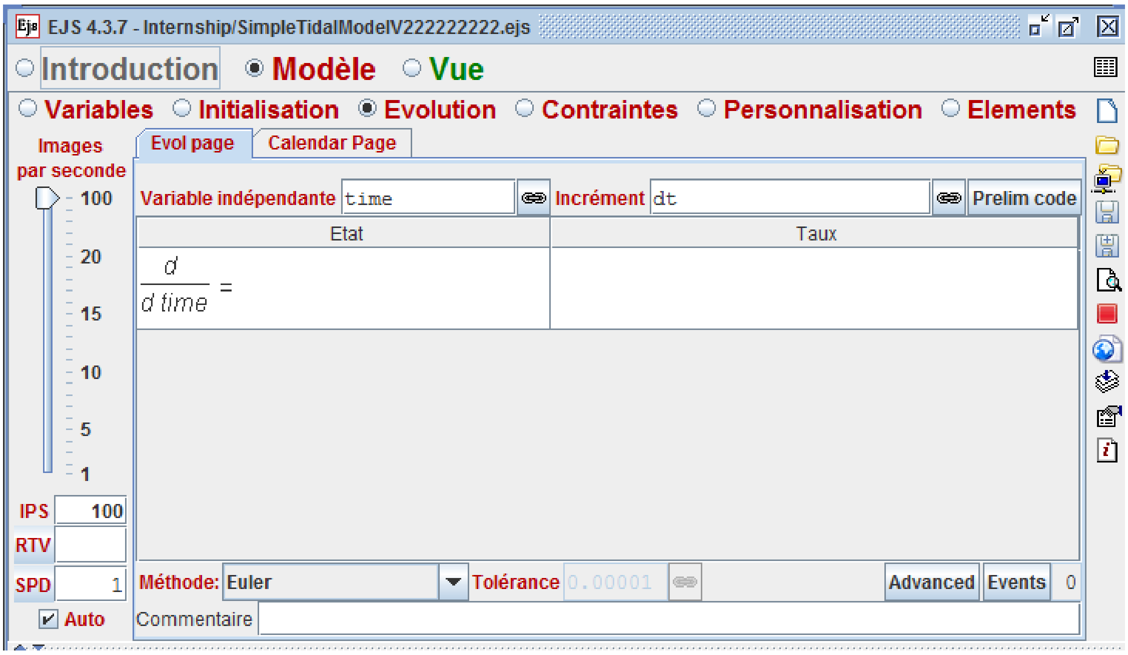


Fig 17: Evolution panel view

This option allows to specify the evolution of the simulation depending on the variable etc. ... you can put the differential equations which are solved by the software according to the resolution method chosen. It is also possible to write linear equation in a blank page.

Constraints panel :

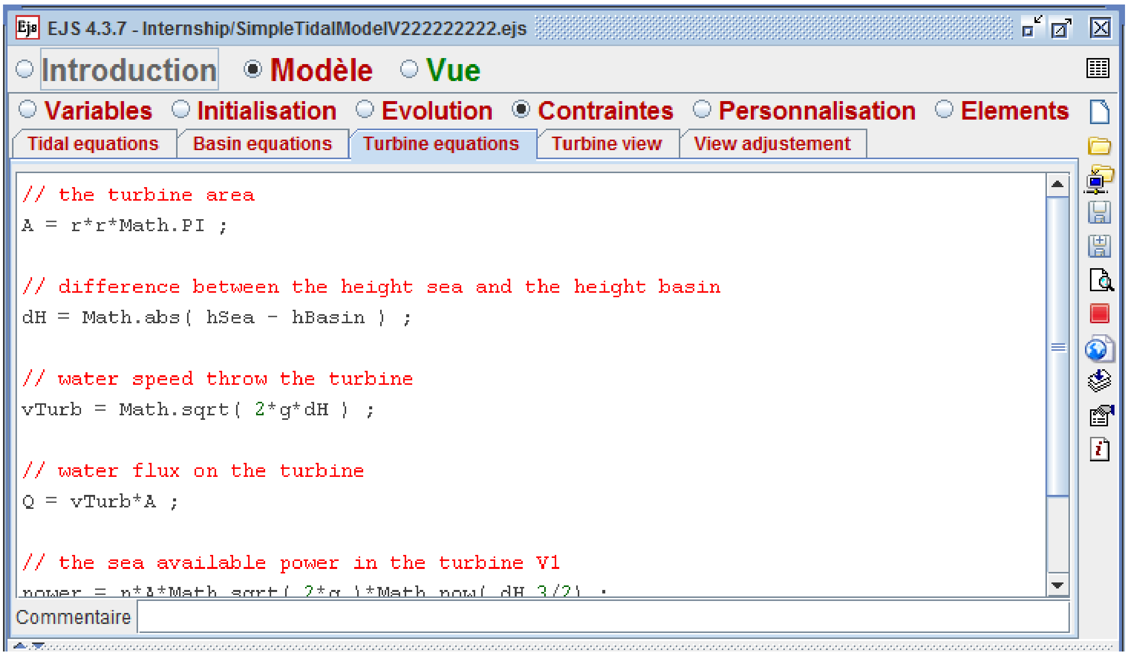


Fig 18: Constraints panel view

This panel works in the same way than the evolution page, but with the specification that we put the equations which can evolve in interaction user with the simulation.

Personalisation panel:

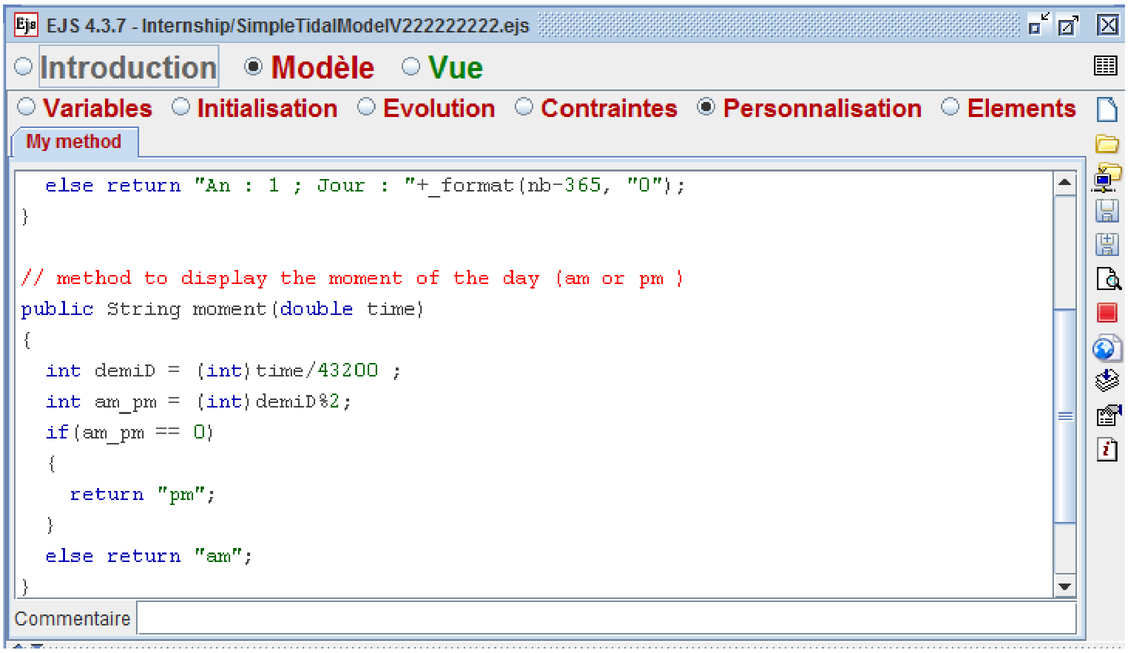


Fig 19: Personalisation panel view

This panel provide the possibility to create our own java method: for example in the figure above we can see a simple method which returns am or pm in functions of the time spend by the software.

The view panel :

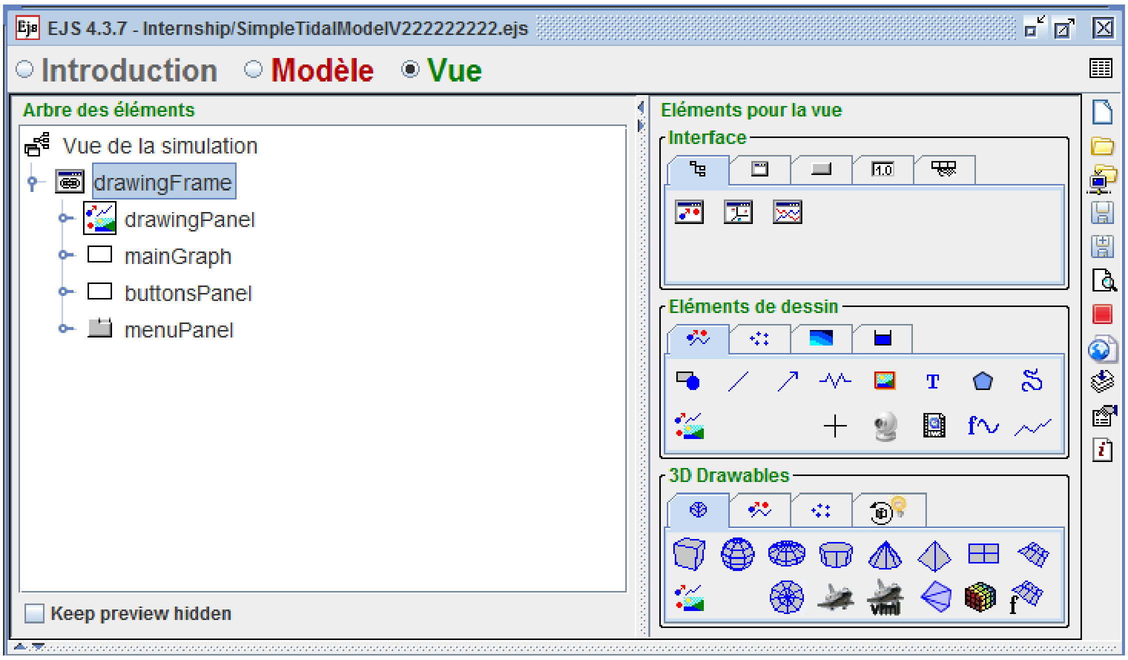


Fig 20: View Panel view

- "drawingPanel" includes all 2D element of the graphical view;
- "mainGraph" contains all the curves and the checkboxes to make the choice of curves that we want observed.
- "buttonsPanel" includes buttons to act on the pause / play simulation or to reset it, switch to plot ...
- "menuPanel" includes menu simulation

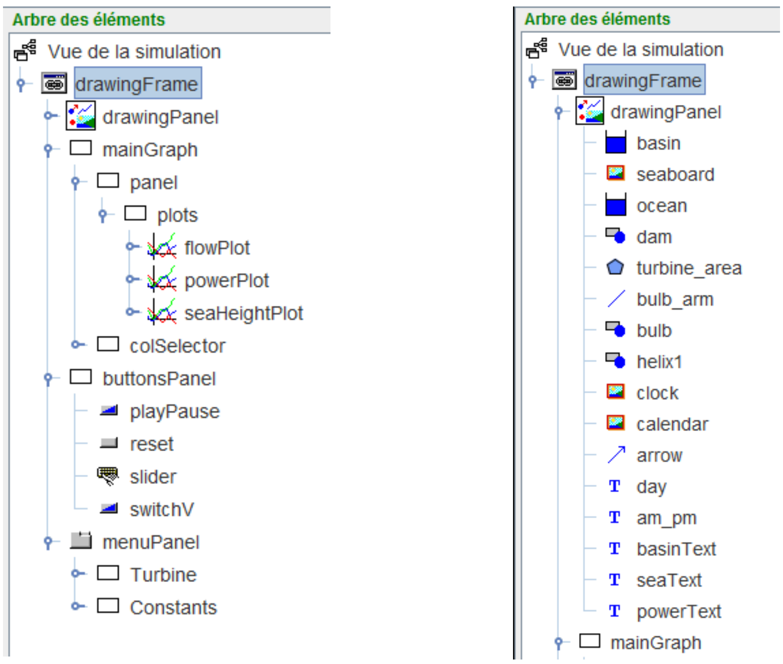


Fig 21: View panel details

Item adjusting:

Each element is then adjusted with its own window setting such as Variable Ocean shown in the figure below.

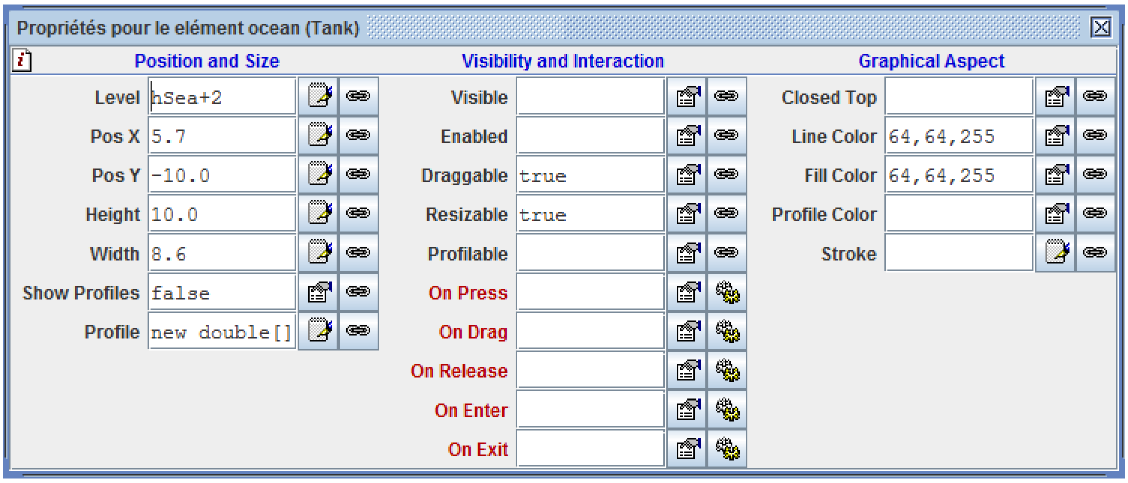


Fig 22: Item adjusting view

The "ocean" variable is an object of type "tank", the "level" parameter corresponding to the filling of the figure is associated with "hSea" (the variable that corresponds to the level of the ocean / sea). You can then choose its position in the window, width and thickness. It also supports other options like changing figure based on user actions on the simulation etc.

9. Complex tide model

To make the complex tide model, I had to study the equation of “On Charting Global Ocean Tides “a review article which highlights the three-century development of our scientific understanding of ocean tides.

I had to try to modelize the equations (28) (29) of the review.

Let’s write the most important equation

The harmonic decomposition of the equilibrium tides

$$\eta = \sum_{a=0} \eta_a\,(\lambda, \theta, t) \;\; (1)$$

With the following three major species of harmonic partial tides

Semidiurnal equilibrium tides:

$$\text{a} \;=\; 2 \;\; \eta = K * sin^2\,\theta * \cos(\sigma t + \;\chi + 2\,\lambda) \;\; (2)$$

Diurnal equilibrium tides:

$$a = 1 \;\; \eta = K * \sin\,(2\theta) * \cos(\sigma t + \;\chi + \;\lambda) \;\; (3)$$

Long-period equilibrium tides:

$$a = 0 \;\; \eta = K * (3 * \sin^2\theta - 2) * \cos(\sigma t + \;\chi) \;\; (4)$$

t: universal standard time, seconds
λ: east longitude
θ: colatitude
η: total or partial equilibrium tides, meters
K: amplitude of partial equilibrium tides, meters
σ: frequency of partial equilibrium tides, s^{-1}
χ: astronomical argument of partial equilibrium tide relative to Greenwich midnight

We can modelize every harmonic component of the equilibrium tide:

$$\eta = K(\theta) * \cos(\sigma t + \;\chi + v\lambda) \qquad v = 2{,}1{,}0 \qquad (5)$$

Which generated throught the ocean’s response a similar oceanic partial tide:

$$\varsigma = \xi(\lambda, \theta) * \cos(\sigma t + \;\chi - \delta(\lambda, \theta)) \qquad (6)$$

ξ: amplitude of the oceanic partial tides, meters

δ: retardation time of the oceanic tide ς , radian/°/time units

Elementary equation of Laplace Tidal equation:

$$U_t = \frac{GH}{R \sin\theta}(\eta - \varsigma)_\lambda + 2 * \Omega * V * \cos\theta \qquad (18a)$$

$$V_t = \frac{GH}{R}(\varsigma - \eta)_\theta - 2 * \Omega * U * \cos\theta \qquad (18b)$$

$$\varsigma_t + \frac{1}{Rsin\theta}(U_\lambda - (Vsin\theta)_\theta) = 0 \qquad (19)$$

R: earth radius equal to 0.637*10^4 m
Ω: earth angular velocity equal to 0.72722*10^-4 s^-1
H: ocean depth
(u,v): east north velocities
(U,V): H.(u,v).

Those equations can be extented to include additional terms representing secondary effects due to the terrestrial and oceanic tidal loads and lateral dissipation vector

$$U_t = \frac{GH}{R \sin\theta}(\eta - \hat{\eta} - \varsigma + \hat{\varsigma})_\lambda + 2 * \Omega * V * \cos\theta \; + A^\lambda + B^\lambda \qquad (28a)$$

$$V_t = \frac{GH}{R}(-\eta + \hat{\eta} + \varsigma - \hat{\varsigma})_\theta - 2 * \Omega * U * \cos\theta \; + A^\theta + B^\theta \qquad (28b)$$

$$R * sin\theta * \varsigma_t * U_\lambda \text{ - } (Vsin\theta)_\theta = 0 \qquad (29)$$

A^λ, A^θ : lateral dissipation vector
B^λ, B^θ: bottom friction vector
$\hat{\eta}, \hat{\varsigma}$:terrestrial and oceanic tidal-load potentials

All the terms of those equation are others complex equations, I had tried to understand it and make a modeling by simplifying them , but I didn't managed to have a good result ….

10. Conclusion

This internship was a very good experience, make it in a different country and in a big city like Barcelona was very nice, I have discovered the Spain culture, Barcelona and another way to live.

The internship subject was interesting, I don't work in environmental energy in my studies, so work on an unusual topic was rewarding. I have learned lot of things about tides and their harnessing by humans and I have discovered a new software.

Sometimes the work was very hard cause of complex equation that I didn't understand or because the research was unsuccessful but It was very great because I worked independently and I had to choose what I want to do, and the tutors were always here to help me.

11. Annexe

11.1 Internship CV

12. Bibliography

12.1 Paper, article and review :

- Tidal Power Energy by Zou FAN university of gävle
- Tidal Power by Thomas James HAMMSONS
- An Optimum Operation and Mathematical Model of Tidal Energy System at Red Sea Area by Faten H. Fahmy
- Back of the envelope tides calculations by Andy Ganse
- Wind Turbine Power Calculations by nPower

12.2 Website

- Étude numérique du comportement d'hydroliennes à axe horizontal : vers une modélisation d'un parc d'hydroliennes http://www.paralia.fr/jngcgc/12_90_mycek.pdf
- How Tides Work http://scienceblogs.com/startswithabang/2010/02/24/how-tides-work/
- Projet d'hydrologie marine http://hmf.enseeiht.fr/travaux/CD0001/travaux/optsee/hym/6/fon.htm
- Thèse : chapitre 5 les équations générales de la marée http://fabien.lefevre.free.fr/These_HTML/doc0005.htm
- Fiche technique des estuaires bretons http://fabien.lefevre.free.fr/These_HTML/doc0005.htm
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- The shape of the hydrosphere of earth http://www.sjsu.edu/faculty/watkins/hydrosphere.htm
- Cuantificacion de la erngia de una planta mareomotriz http://www.ejournal.unam.mx/ict/vol1102/ICT001100209.pdf
- Tide https://en.wikipedia.org/wiki/Tide
- La théorie des marrées http://archive.numdam.org/ARCHIVE/ASENS/ASENS_1923_3_40_/ASENS_1923_3_40__151_0/ASENS_1923_3_40__151_0.pdf