Volume 6, Issue 8, August 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Calculation of Potential Evapotranspiration Using Priestley-Taylor, Penman-Monteith and Thornthwaite Methodologies

Renan Nunes Steinck*, Lucas dos Anjos Varela, Breno Victor Lucrécio Branco, Viliam Cardoso da Silveira, Juliano Lucas Gonçalves
Departament of Computer Science Federal Institute of Santa Catarina, Lages, Brazil
Departament Meteorology, Federal University of Santa Maria, Brazil

Abstract— The evapotranspiration can be described as the amount of water evaporated and transpired by the soil and by the vegetation. The Potential Evapotranspiration (PET) concerns the amount of water, which would be utilized by an extensive land surface with lawn and without water restriction. The aim of this work is develop a software that calculates the PET through the Priestley-Taylor, Penman-Monteith and Thornthwaite methodology. This software will automate entire process of calculations, in this way will be possible stipulate the water demand for planting under certain periods of year, assisting rural producers.

Keywords— Agrometeorology. Evapotranspiration. Potential Evapotranspiration.

I. INTRODUCTION

The evapotranspiration is the way in which the water of the land surface passes to the atmosphere in the vapor state, having important role in the hydrologic cycle. This process involve the evaporation of the water in surfaces of free water (rivers, lakes, dams, oceans, etc.), of the soil and moist vegetation (which has been intercepted during a rain) and the transpiration of plants [1]. The Potential Evaporation (PET) is a crucial factor to consider for planting, once calculated, is possible stipulate the demand of water for a plantation in certain periods of year. But, the range of applications able to perform the calculation is quite small, and even smaller methodologies options, being necessary calculate through spreadsheets, which makes a slow and exhausting process.

Based on this problem, the aim here is to develop a software able to calculate the evapotranspiration in an agile and practice way, considering different methods. It is possible to compare the methods each other, and make comparisons between different locations. One of the objectives is to consolidate a database solid enough to provide a source of information for future projects. In general, the purpose of this work was to develop a free and accessible software to calculate potential evapotranspiration through the Priestley-Taylor, Penman-Monteith and Thornthwaite methods.

This project was developed using the MVC (Model-View-Controller) pattern, whose objective is to separate the business logic (Model), graphical interface (View) and the application (Controller). In this way, the application can be migrated to different platforms (web, mobile, etc.) without the need to change the business logic and application [2].

The choice of the above methodologies was based in the availability of the meteorological data. The data was assigned by climatological station of Pelotas. Based on the project proposal, the software was developed using a Java programming language, due to its great portability between systems, be free and have the possibility of using external libraries, and MySql database, a free software to non-commercial developments.

The meteorological data that we need to calculate the potential evapotranspiration by these three methods are: relative humidity, precipitation, solar radiation, insolation, maximum temperature, minimum temperature and mean wind speed in 2 meters.

II. METHODOLOGY AND DEVELOPMENT

On the section *A*, it is present the proposed methodologies and the data font used to calculate the potential evapotranspiration, also a brief explanation of the equations. On the section 3, it is discussed the application development.

A. Methodology to calculate the potential evapotranspiration

Although exists a lot of methodologies to calculate PET, it was decided to use in this work only 3. The choice was based on the meteorological data available on the moment.

Pristley-Taylor: Described by the following equation

$$PET=\frac{1{,}26*W*(R_n-G)}{2{,}45}$$

Being R_n the daily total liquid radiation, $(MJm-2_d-1)$, and, G is the daily total of heat on the soil, calculated by the following expression

$$G=0{,}38*(T_d-T_{-3d})$$

Wherein, T_d is the average temperature of the air on the day in question and, T_{-3d}, the average temperature of the air 3 days before. Besides that, W represents the dependent factor of temperature and psychometric coefficient, that is calculated through those equations:

$$W=0{,}407+(0{,}0145*T):(0°C<T<16°C)$$

$$W=0{,}483+(0{,}01*T):(16°C<T<32°C)$$

Penman-Monteith described by the following equation

$$PET=\frac{0{,}408*S*(R_n-G)+\frac{\gamma*900*U_2*(E_s-E_a)}{T+273}}{S+\gamma*(1+0{,}34*U_2)}$$

Where, R_n and G are the same already described above. $\gamma=0{,}063\,kPa\,°C^{-1}$ is the psychometric constant, T is the air mean temperature (daily) in Celsius $(°C)$. U_2 is the wind speed in 2 meters of the soil (ms^{-1}).

$$T=\frac{T_{max}+T_{min}}{2}$$

Es : is the saturated vapor pressure (kPa).

$$Es=\frac{Es^{T_{max}}+Es^{T_{min}}}{2}\quad Es^{T_{max}}=0{,}6108*e\frac{17{,}27*T_{max}}{247{,}3+T_{max}}\quad Es^{T_{min}}=0{,}6108*e\frac{17{,}27*T_{min}}{247{,}3+T_{min}}$$

E_a is the partial vapor pressure (kPa).

$$E_a=\frac{(UR*Es)}{100}$$

S is the curve declivity of vapor pressure.

$$S=\frac{(4098*Es)}{(T+237{,}2)^2}$$

Thornthwaite To calculate the PET by the Thornthwaite methodology, it is necessary to calculate first the standard pET (pET mm/month) through the empiric formula. This method correlate precipitation and the leakage with the variable of temperature, that allows the estimation of evapotranspiration [3].

$$pET=16*\left(\frac{10*Tn}{I}\right)^a\quad 0<Tn<26{,}5°C$$

$$pET=-415{,}85+32{,}24*Tn-0{,}43*Tn^2\quad Tn\geq 26{,}5°C$$

where Tn is the month average temperature in ºC, I is the index that express the level of heat available on the region. The value of I depends of annual temperature rhythm, in other words, integrates the thermic effect of every month and a is also an regional thermic index.

$$I=\sum_{n=1}^{12}(0{,}2*Tn)^{1{,}514}$$

The valor of a is calculated through the following formula

$$a=6{,}75*10-7*I3-7{,}71*10-5*I2+1{,}7912*10-2*I+0{,}49239$$

This value would be obtained for a default month with 30 days, and every day would have 12 hours of photoperiod, but, to obtain the correspondent ETP of the month is necessary to make a correction in function of the number of days and photoperiod of the month, as

$$PET=pET*CORRECTION$$

The correction is obtained through the formula bellow:

$$CORRECTION=\left(\frac{ND}{30}\right)*\left(\frac{N}{30}\right)$$

ND = The number of days in the month in question.

N = average photoperiod of the month.

In general, the value of N can be obtained per one correction table, where considers a value of the photoperiod of the day 15 has the average of the month. The N value varies with the month and the latitude of the location. Below is presented a correction table with base on the latitude.

Table 1: Correction Table

Lat.	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
5ºN	1,02	0,93	1,03	1,02	1,06	1,03	1,06	1,05	1,01	1,03	0,99	1,02
0º	1,04	1,04	1,04	1,01	1,04	1,01	1,04	1,04	1,01	1,04	1,01	1,04
5º S	1,06	0,95	1,04	1,00	1,02	0,99	1,02	1,03	1,00	1,05	1,03	1,06
10º	1,08	0,97	1,05	0,99	1,01	0,96	1,00	1,01	1,00	1,06	1,05	1,10
15º	1,12	0,98	1,05	0,98	0,98	0,94	0,97	1,00	1,00	1,07	1,07	1,12
20º	1,14	1,00	1,05	0,97	0,96	0,91	0,95	0,99	1,00	1,08	1,09	1,15
22º	1,14	1,00	1,05	0,97	0,95	0,90	0,94	0,99	1,00	1,09	1,10	1,16
23º	1,15	1,00	1,05	0,97	0,95	0,89	0,94	0,98	1,00	1,09	1,10	1,17
24º	1,16	1,01	1,05	0,96	0,94	0,89	0,93	0,98	1,00	1,10	1,11	1,17
25º	1,17	1,01	1,05	0,96	0,94	0,88	0,93	0,98	1,00	1,10	1,11	1,18
26º	1,17	1,01	1,05	0,96	0,94	0,87	0,92	0,98	1,00	1,10	1,11	1,18
27º	1,18	1,02	1,05	0,96	0,93	0,87	0,92	0,97	1,00	1,11	1,12	1,19
28º	1,19	1,02	1,06	0,95	0,93	0,86	0,91	0,97	1,00	1,11	1,13	1,20
29º	1,19	1,03	1,06	0,95	0,92	0,86	0,90	0,96	1,00	1,12	1,13	1,20
30º	1,20	1,03	1,06	0,95	0,92	0,85	0,90	0,96	1,00	1,12	1,14	1,21
31º	1,20	1,03	1,06	0,95	0,91	0,84	0,89	0,96	1,00	1,12	1,14	1,22
32º	1,21	1,03	1,06	0,95	0,91	0,84	0,89	0,95	1,00	1,12	1,15	1,23
33º	1,22	1,04	1,06	0,94	0,90	0,83	0,88	0,95	1,00	1,13	1,16	1,23
34º	1,22	1,04	1,06	0,94	0,89	0,82	0,87	0,94	1,00	1,13	1,16	1,24
35º	1,23	1,04	1,06	0,94	0,89	0,82	0,87	0,94	1,00	1,13	1,17	1,25

III. USED TECHNOLOGIES

In this section will be presented the used technologies in the development of the software. On the section *B* will be presented the JAVA language and a brief class diagram. The section *C* will be approached the data base, and finally, on the section 3,3 the used library to generate the charts, the JFreeChart.

B. Java

Is a free object oriented programming language, with an easy learning curve, multi-platform with a big community [4]. The object orientation is based on the use of classes, which in turn, are abstract forms and represents an object of the real world [5]. On the image bellow, is presented a part of the class modeling of the development. For an easier comprehension, part of the modeling was occulted. This diagram presents the relation of entities of the system, to explain its actions:

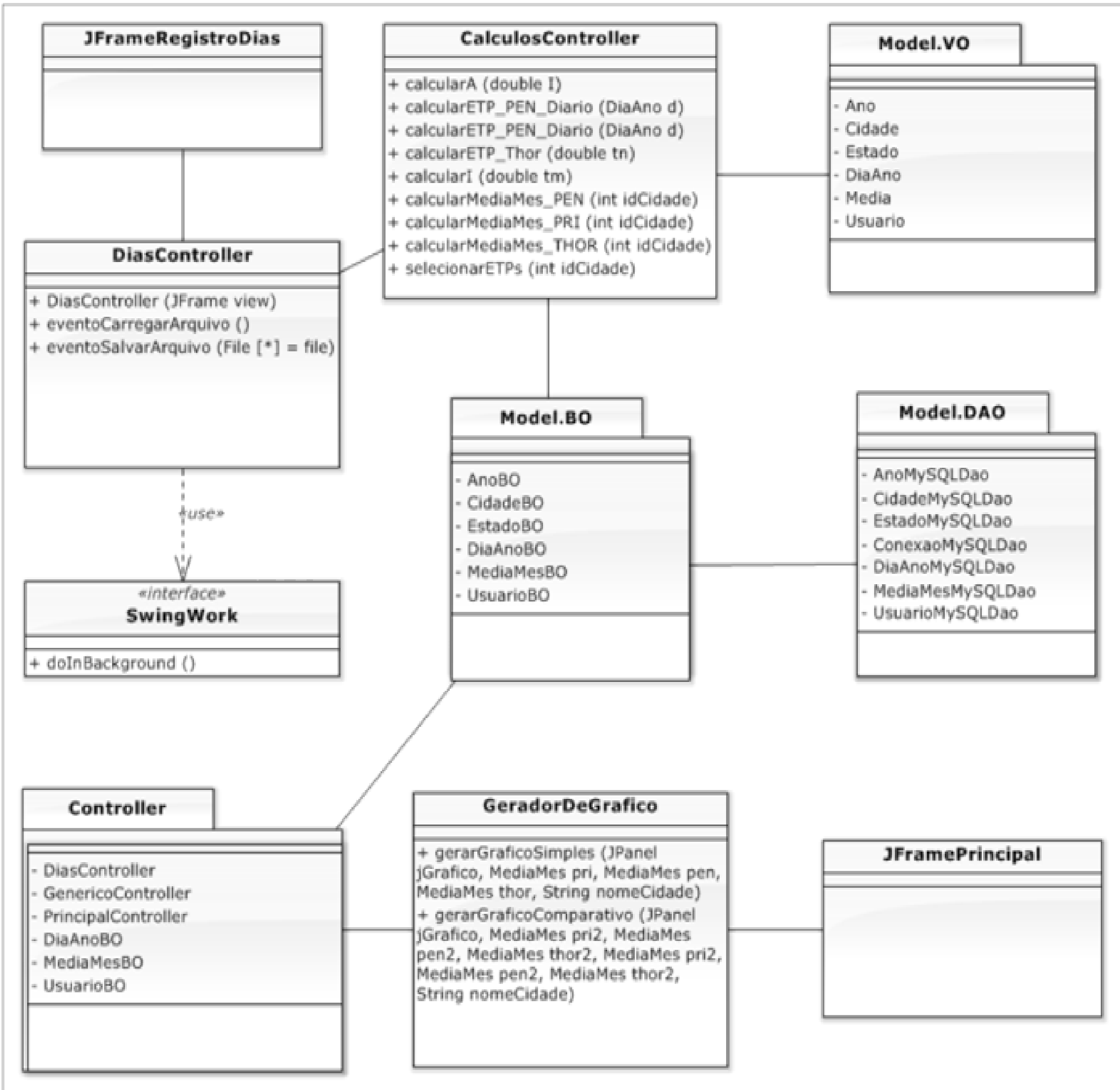

Figure 1 – Class Diagram

The class encharged to manipulate the file is DiasController". Once selected the file, the method "eventoCarregarArquivo" will be activated. In this event, it's made the selection of the file, filtering files of CSV format, and allowing the user to select multiple files at the same time. The "eventoSalvarArquivo" event will be encharged to create a new thread while the data is registered, making possible to use other function while the data is processed [6]. To do that, the library used was Javax SwingWork.

In the package ModelVO, the classes are designated to represent simple entities. Those entities are the days of the year, the calculated years, registered cities, etc. For the calculations, it was created a passive class to manipulate the values of the file, doing the calculus of PET daily, monthly, yearly, and the final average. Every methodology is calculated daily, except Thornthwaite. Because the need for accuracy of the values, it was used a type data of double-precision, Double.

Moreover, it's used communication classes (BO - Business Objects) to realize the intermedium between action classes and data access. This way, it guarantees the data integrity; allowing only one route of information, this way makes reuse and maintenance easier. The Model DAO is encharged of communication between software and the database, using prepared statement, ensuring the security of the software and the integrity of data. The data-base connection is made through conexaoMySQLDao, the rest of the classes of the package are encharged with the CRUD of the system.

Through the Controller package, it is possible to modularize the entire communication between the presentation and I/O. This way, it is possible to migrate for other platforms, like web and android, being necessary only to create new graphic interfaces. Lastly, the "GeradorDeGrafico" is responsible to create and present the chart with the result of the operations. This class uses JFreeChart, a library that will be discussed soon.

MySQL it is a server manager of database extremely popular due its performance, responsiveness to the community, easy interface for others softwares and gratuity for non-profit applications [7]. In the following figure, presents a disposal of database. Where the tables average months represents the final average of PET in millimeters. "Anos" receives the values of yearly averages of PET in millimeters. The table city and state were provided by IBGE, where contains every city and every state inside Brazilian territory. The table "dia_ano" is where the data are inserted through the files. The file reading is made through databases, with base on practicality and data integrity guarantee, was used the command "LOAD DATA INFILE", which allows reading files with CSV formats.

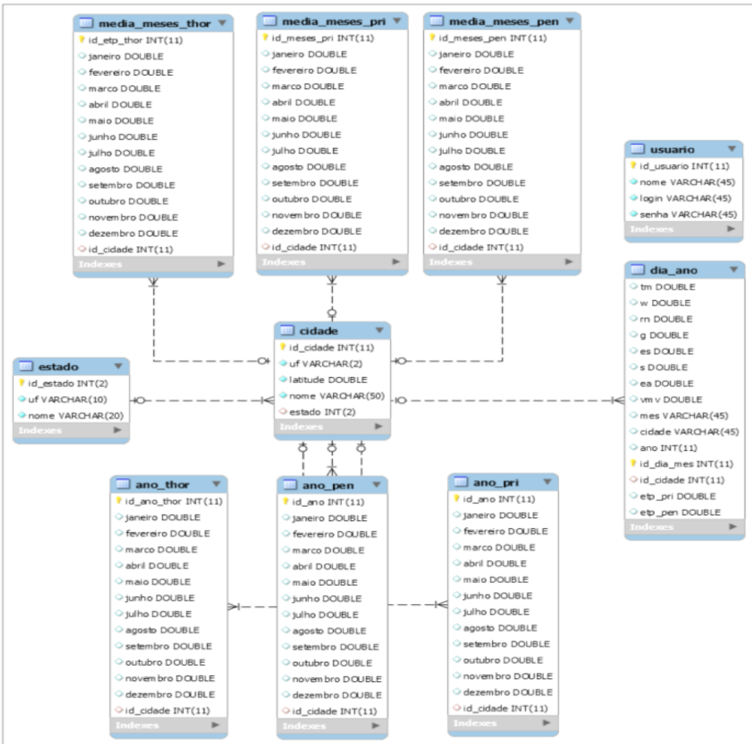

Figure 2 – Database Model

C. JFreeChart

It is a free library for Java applications, with a great diversity of types of normal and combinational charts [8]. Moreover, the charts created by this library have a lot of functions favorable for the application in question. The interactivity with the charts allow the user to change colors, increase or decrease zoom. Also, there is a option that allows the user to save the information in PDF format, or other image formats, and the possibility to print the chart.

The choice of the library was due the necessity of the final user, were the user is not obliged to open the application every time he needs to show the chart. Also, the diversity of visual changes and management options allows the chart to suit the user necessities.

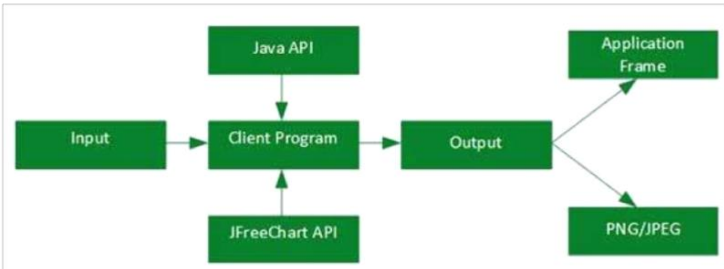

Figure 3 – Class Diagram for JFreeChart applications

IV. RESULTS

In this section will be presented the software windows. The application can be seen with more details in the images below, every screen will be explained for a better understanding. In the image 4, is presented the login screen. During the development, it was noticed the necessity of creating a filter of users, seen that every user can insert data, potentially harming the integrity of the results.

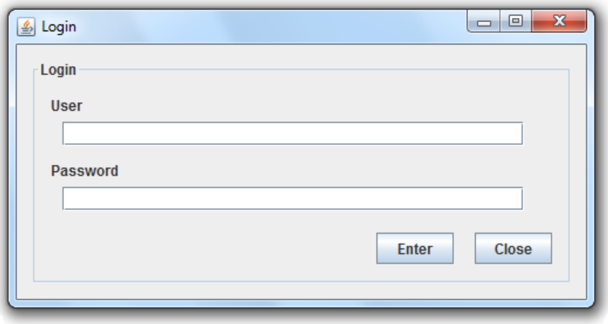

Figure 4 – Login screen

After the inserting login and password, the user is transfered to the main screen (figure 5). In this screen, it is possible to other screens, like "New Register", "New User", "Alter User", "Step by step" and "about". Also, it is possible to select the cities to print the charts in the screen. This screen allows the user to choose between simple (just one city) and comparative.

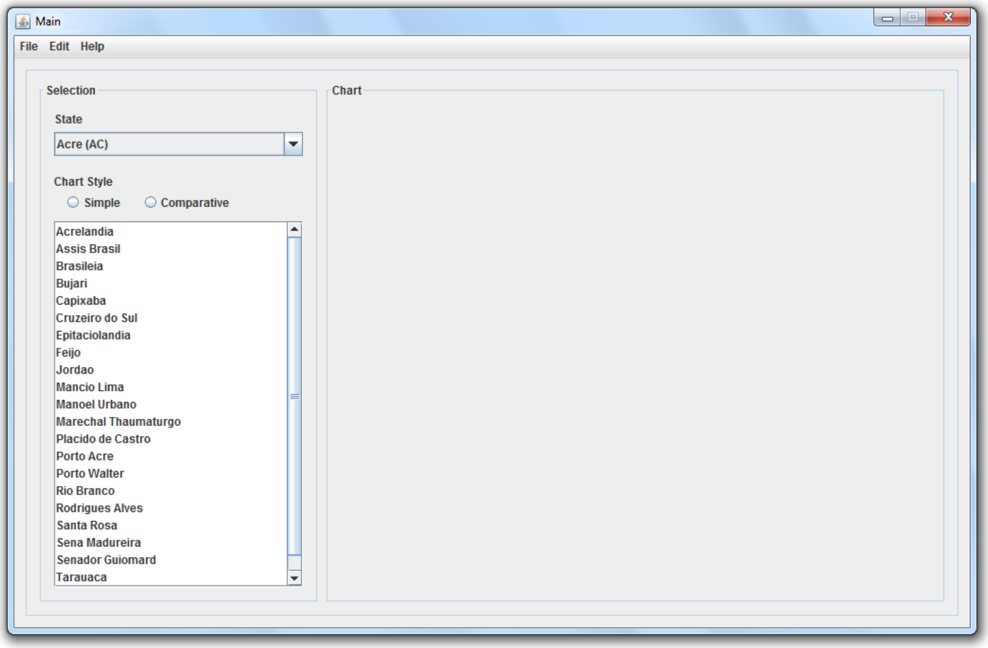

Figure 5 – Main screen

On the figure 6, is denoted the register screen. This screen is based in reading the file. Once the file is selected, it is possible to add the data in the database and to make the calculus (save button), remove the path of the file (remove button), and remove the path and go back to the main screen (cancel button), or keep the path and go back to the main screen (back).

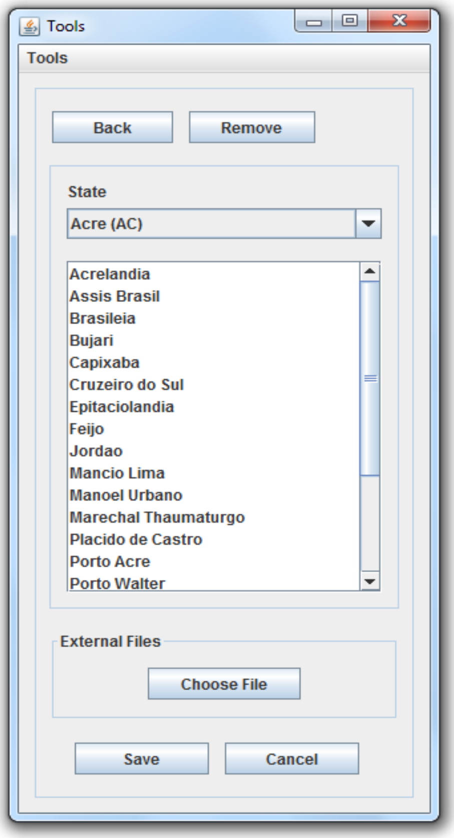

Figure 6 – Tools window

In the figure 7, it is shown the screen to create a user. To create a new user is needed to login with the admin account, and, in the figure 8, is presented the screen to alter an user.

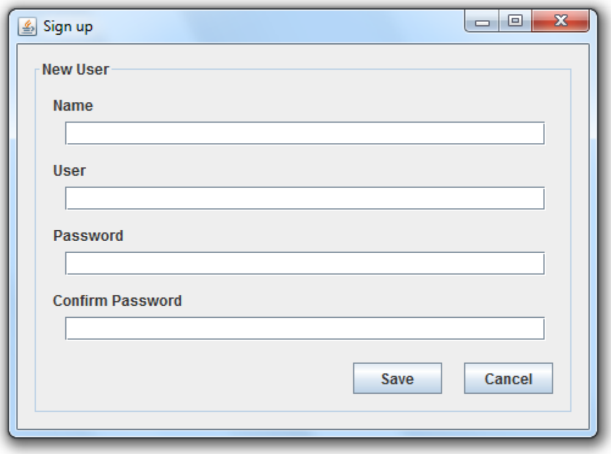

Figure 7 – Create User

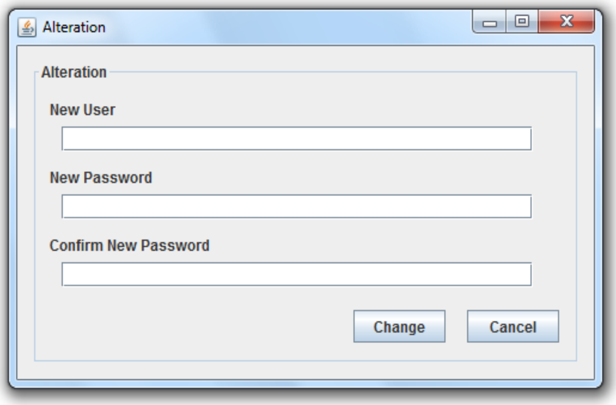

Figure 8 – Alter User

Finally, the figure 9 shows the main screen with the results of the calculation. Those values represent the evapotranspiration with the 3 methods for the city of Pelotas. For the city Picada Café was used stipulated values, only for the representation of a comparison between cities.

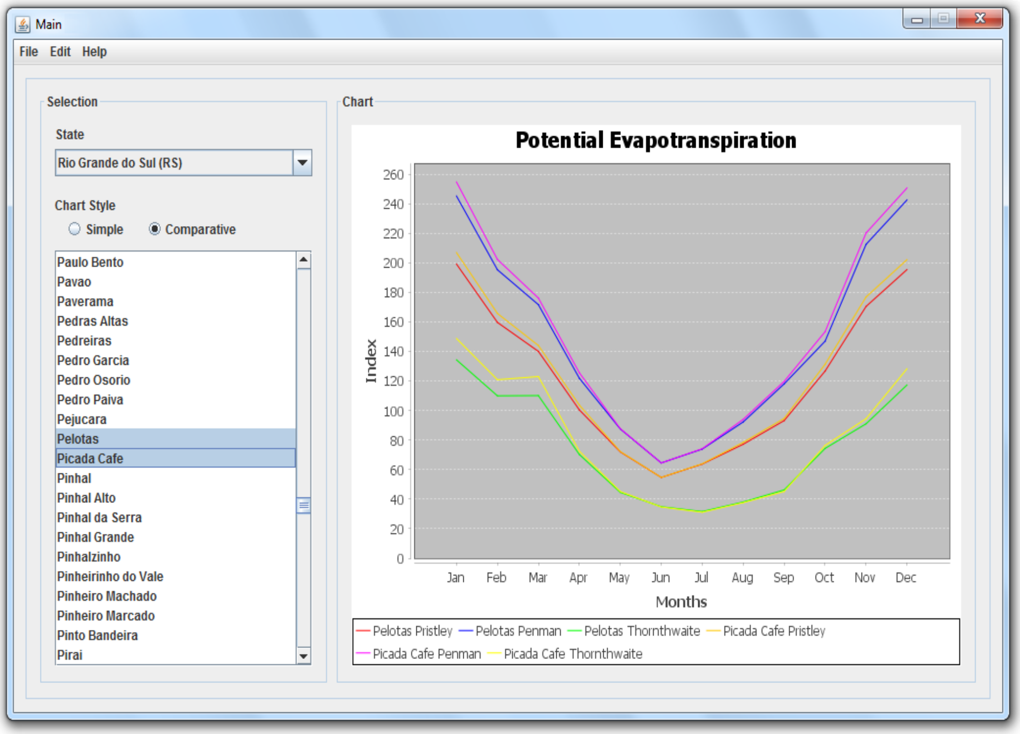

Figure 9 – Results

V. CONCLUSIONS

In this paper, initially, were described 3 methods to calculate the Potential Evapotranspiration (PET), the Priestley-Taylor, Penman-Monteith e Thornthwaite with the intention to study their behavior.

After this step, was described a free software using the Java Language, and the MySql has the database. The software allowed optimizing the process of calculating the PET. Also, the software allows the user to use any of the 3 methodologies described above.

Was demonstrated a convergence between the methods for the cities of Pelotas and Picada Café. Though there are differences between values, is possible notice a very similar curve on the mouths of higher and lower PET in all the three methodologies. Furthermore, is possible to see the relation between the average temperature of the month and it PET, ie, the months with higher temperature shows higher PET.

For future works, it is intended to add new functionalities to the software, like the calculus of Water Balance and the climate classification, being these calculus more long and complexes. Beyond that, there is the possibility of new versions for other platforms, like web and mobile.

ACKNOWLEDGMENT

We are thankful to the Federal Institute of Santa Catarina and National Counsel of Technological and Scientific Development (CNPq) for making this project possible with a report IFSC/Universal/CNPq/2015/2016 (financial support).

REFERENCES

[1] SENTELHAS, P. C.; ANGELOCCI, L. R. Climatológico Normal e Sequencial, de Cultura e para Manejo da Irrigação, Available at: <http://www.lce.esalq.usp.br/aulas/lce306/Aula9.pdf>. Accessed 22 february 2016.

[2] ALMEIDA, R. R. Model-View-Controller Disponível em: <http://www.dsc.ufcg.edu.br/~jacques/cursos/map/html/arqu/mvc/mvc.htm>. Accessed 17 february 2016.

[3] TUCCI. C. E. M.; DA SILVEIRA. A. I. I. Hidrologia: ciência e aplicação. EDITORA UFRGS.

[4] STEET DIRECTORY. Most Significant Advantages of Java Language Available at: <http://www.streetdirectory.com/travel_guide/114362/programming/most_significant_advantages_of_java_language.html>. Acesso em: Accessed 23 february 2016.

[5] RICARTE. I. L. M. O que é Classe? Available at: <http://www.iemss.org/sites/iemss2014/papers/iemss2014_submission_146.pdf>. Accessed 12 february 2016.

[6] ORACLE. Thread - Available at: <https://docs.oracle.com/javase/7/docs/api/java/lang/Thread.html>. Accessed 26 february 2016.

[7] ORACLE. Por que MySQL? - Available at: <http://www.oracle.com/br/products/mysql/index.html>. Accessed 22 march 2016.

[8] GILBERT. D. The JFreeChart Class Library - Available at: <http://ktipsntricks.com/data/ebooks/java/jfreechart-0.9.1-US-v1.pdf>. Accessed 25 february 2016.

