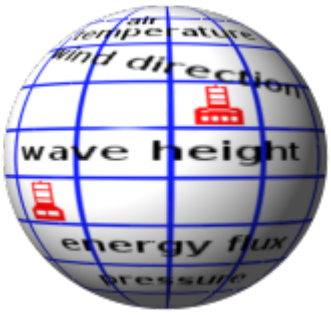

SPAMDA

Software for Pre-processing and Analysis of Meteorological DAta to build datasets.

SPAMDA 1.0v User manual

SPAMDA: Software for Pre-processing and Analysis of Meteorological DAta to build datasets.

This is the version 1.0 of the SPAMDA manual.

Authors:

Gómez-Orellana, A.M.; Fernández, J.C.; Dorado-Moreno, M.;

Gutiérrez, P.A.; Hervás-Martínez, C.

Building Suitable Datasets for Soft Computing and Machine Learning

Techniques from Meteorological Data Integration:

A Case Study for Predicting Significant Wave Height and Energy Flux.

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Contact information:

Antonio Manuel Gomez Orellana.
email: am.gomez@uco.es
Address: University of Córdoba, Department of Computer Science and Numerical Analysis, Rabanales Campus, AYRNA Research Group, Einstein Building, 3rd floor. Road Madrid-Cádiz, Km 396-A. 14071 - Córdoba (Spain)

Juan Carlos Fernández Caballero.
email: jfcaballero@uco.es
Address: University of Córdoba, Department of Computer Science and Numerical Analysis, Rabanales Campus, AYRNA Research Group, Einstein Building, 3rd floor. Road Madrid-Cádiz, Km 396-A. 14071 - Córdoba (Spain)

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1 Introduction to SPAMDA

1.1 SPAMDA description

SPAMDA is a software tool for creating datasets with meteorological data from two well-known sources of information, *National Data Buoy Center* (NDBC) [1] and *Reanalysis Project* (NNRP or R1) [2, 3].

The datasets created with SPAMDA will be ready to use as input for Machine Learning (ML) techniques in classification or regression prediction tasks, although the researchers may use them in the way they deem suitable. These datasets will contain one or more meteorological variables as inputs and another one as target (variable to predict). The format of the datasets will be *Attribute-Relation File Format* (ARFF) [4] that it is used by the well-known tool *Waikato Environment for Knowledge Analysis* (WEKA) [5], which provides a wide collection of ML algorithms. Besides, the datasets can also be generated in *Comma-Separated Values* (CSV) format, enabling the researchers to use others tools.

Some of the advantages that SPAMDA tool offers are briefly summarised below:

- The generation of datasets becomes a very easy and customizable task, by means of the selection of different input parameters.
- It makes the researcher focus on oceanic and atmospheric studies, without having to worry about mechanical tasks.
- It provides information about the quality and quantity of the data.
- It avoids possible researcher errors in the intermediate steps of the process of creation of the datasets.
- It includes different pre-processing tasks, such as normalisation and missing data recovery.

- It facilitates data management and well-organised storage of the datasets.
- Its modular design allows the implementation of new functional modules for managing meteorological data from others sources for renewable energy research.
- It includes an user-friendly GUI, facilitating and greatly simplifying data management, and it is integrated with the Explorer environment of WEKA.
- It is multi-platform, and it can be used on any computer with Java regardless of the operating system.

1.2 Meteorological data sources

The data provided by the above-mentioned sources of information used by SPAMDA is briefly described below:

- NDBC is a part of the *National Weather Service* (NWS). NDBC designs, develops, operates, and maintains a network of data collecting buoys (stations). The mission of the network is to collect real-time marine meteorological and oceanographic observations, such as wave height, dominant wave period, or wind speed and direction, among others.

  The buoys maintained by NDBC are deployed in the coastal and offshore waters around oceans and seas, and are equipped with assorted sensors which allow them to perform different measurements. The information collected by the buoys is available in NDBC web page [6], which is divided into different groups. One of them is the standard meteorological information of the historical data collected by each buoy, which can be downloaded as annual text files and whose format was adopted by NDBC since January 2007 [7]. These files contain hourly measurements per day from 00:50 to 23:50 UTC and from 23:50 31th Dec of the previous desired year to 22:50 31th Dec of the desired year. In Table 1.1 a comprehensive measurements descriptions and units of such information is provided.

Table 1.1: Measurements descriptions and units of each meteorological variable or attribute collected by the buoys.

Attribute	Units	Description
WDIR	degT	Wind direction (the direction the wind is coming from in degrees clockwise from true N) during the same period used for WSPD.
WSPD	m/s	Wind speed (m/s) averaged over an eight-minute period for buoys and a two-minute period for land stations. Reported Hourly.
GST	m/s	Peak 5 or 8 second gust speed (m/s) measured during the eight-minute or two-minute period.
WVHT	m	Significant wave height (meters) is calculated as the average of the highest one-third of all of the wave heights during the 20-minute sampling period.
DPD	sec	Dominant wave period (seconds) is the period with the maximum wave energy.
APD	sec	Average wave period (seconds) of all waves during the 20-minute period.
MWD	degT	The direction from which the waves at the dominant period (DPD) are coming. The units are degrees from true North, increasing clockwise, with North as 0 (zero) degrees and East as 90 degrees.
PRES	hPa	Sea level pressure (hPa). For C-MAN sites and Great Lakes buoys, the recorded pressure is reduced to sea level using the method described in NWS Technical Procedures Bulletin 291 (11/14/80).
ATMP	degC	Air temperature (Celsius).
WTMP	degC	Sea surface temperature (Celsius). For buoys the depth is referenced to the hull's waterline. For fixed platforms it varies with tide, but is referenced to, or near Mean Lower Low Water (MLLW).
DEWP	degC	Dewpoint temperature taken at the same height as the air temperature measurement.
VIS	nmi	Station visibility (nautical miles). Note that buoy stations are limited to reports from 0 to 1.6 nmi.
TIDE	ft	The water level in feet above or below Mean Lower Low Water (MLLW).

- NNRP provides three-dimensional global reanalysis of numerous meteorological variables (e.g. air temperature, U/V-wind, relative humidity, pressure, etc.), which is available monthly, daily and every 6 hours at 00Z, 06Z, 12Z and 18Z from 1948 on a global 2.5° x 2.5° grid. Weather observations are from different sources, such as ships, satellites and radar, among others.

  The reanalysis data is available in NNRP web page [8], which are accessible through the different sections. Such data can be fully (a global 2.5° x 2.5° grid) or partially (only the desired reanalysis nodes or sub-grid) downloaded as *Network Common Data Form* (NetCDF) files [9], a special binary format for representing scientific data which provides a description of the file contents and also includes the spatial and temporal properties of the data. Each reanalysis file contains the values of a meteorological variable estimated by a mathematical model for each reanalysis node. For a better understanding, in Fig. 1.1 an approximate representation of a sub-grid containing six reanalysis nodes around the geographical localisation of a buoy (obtained from NDBC) is shown.

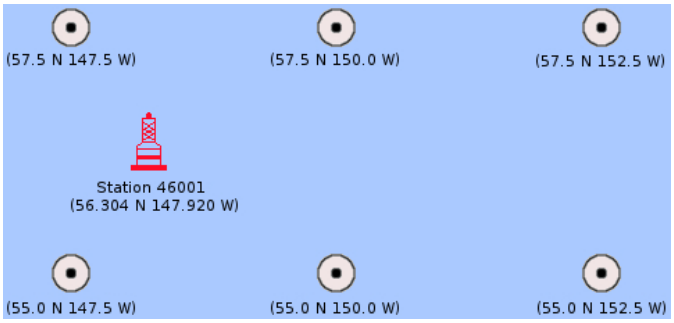

Figure 1.1: Example of a six sub-grid reanalysis nodes around the *Station 46001*.

With both sources of information SPAMDA will create datasets for prediction tasks. In this way, the input variables of the dataset will be one or more reanalysis variables from NNRP and one or more measurements from NDBC. The output variable of the dataset will be one measurement from NDBC. Note that the output variable cannot be used as input also.

2 Getting started

2.1 System requirements

SPAMDA has been developed in Java, therefore it is a multi-platform software tool. In this way, any computer having Java Virtual Machine (JVM) installed would be able to run the developed tool.

As SPAMDA has been compiled for Java JRE 1.8v, Java version 8 needs to be installed in the system, which can be downloaded from [10] choosing the correct distribution depending on the system platform.

2.2 Installing SPAMDA

The process of installation of SPAMDA is quite easy and it does not require administrator permissions to carry it out. The following sections describe how to perform the installation process according to the system platform.

2.2.1 Installing on Linux

To install SPAMDA on Linux follow the next steps:

- ***Step 1***: Download the SPAMDA software on the computer.
- ***Step 2***: Create a folder and copy the downloaded file inside it.
- ***Step 3***: Decompress the file.

After performing the above steps SPAMDA would be installed on the computer and ready to be run. Note that the process of installation creates all the folders and files

necessary inside the folder created in ***Step 2***. In Fig. 2.1 is represented an example of installation in the folder named "SPAMDA", which will contain the software tool.

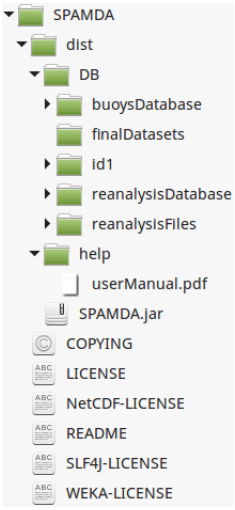

Figure 2.1: Content of the folder after installing SPAMDA (Linux).

Following, the structures of each folder and file created as a result of the installation are described:

- ***dist***: Contains the binary distribution of SPAMDA, which consist of:
  - ***DB***: Contains all the information managed by SPAMDA.
    - ***buoysDatabase***: Contains the database of the buoys.
    - ***finalDatasets***: It is used as a default folder to save the final datasets.
    - ***id1***: Contains the information of the buoy (annual text files, intermediate datasets, pre-processed datasets and matching configurations) entered as example.
    - ***reanalysisDatabase***: Contains the database of the reanalysis data.
    - ***reanalysisFiles***: Contains the reanalysis files entered through SPAMDA.
  - ***help***: Contains the user manual of SPAMDA.
    - ***userManual.pdf***: This is the user manual.
  - ***SPAMDA.jar***: This is the runnable file containing SPAMDA.
- ***COPYING***: This file contains a copy of the license of the GNU GENERAL PUBLIC LICENSE.
- ***LICENSE***: This file contains a copy of the license of SPAMDA.
- ***NetCDF-LICENSE***: This file contains a copy of the license of the Library NetCDF Java version 4.6.10

- ***README***: This file contains the instructions for getting started with SPAMDA.
- ***SLF4j-LICENSE***: This file contains a copy of the license of the Library SLF4J version 1.7.25
- ***WEKA-LICENSE***: This file contains a copy of the license of the Library WEKA version 3.8.1

After installing SPAMDA, and in order to run it, open the "dist" folder (as shown in Fig. 2.2) and type the following command on the command-line of the terminal:

```
java -jar SPAMDA.jar
```

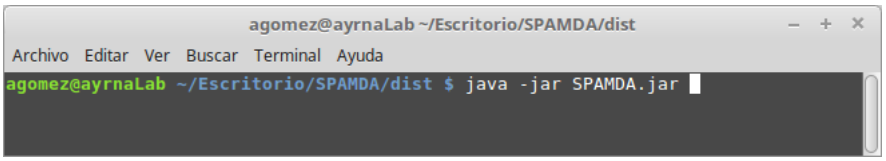

Figure 2.2: Running SPAMDA on Linux.

After executing such command, the main view of SPAMDA represented in Figure 2.3 will appear.

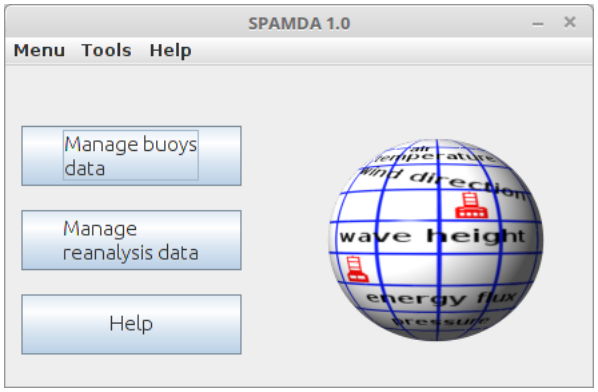

Figure 2.3: SPAMDA main view (Linux).

2.2.2 Installing on Windows

To install SPAMDA on Windows follow the next steps:

- ***Step 1***: Download the SPAMDA software on the computer.
- ***Step 2***: Create a folder and copy the downloaded file inside it.
- ***Step 3***: Decompress the file.

After performing the above steps SPAMDA would be installed on the computer and ready to be run. Note that the process of installation creates all the folders and files necessary inside the folder created in ***Step 2***. In Fig. 2.4 is represented an example of installation in the folder named "SPAMDA", which will contain the software tool.

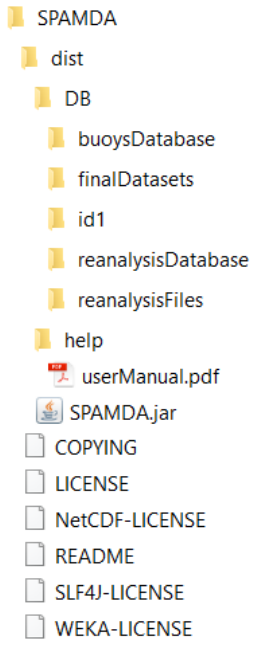

Figure 2.4: Content of the folder after installing SPAMDA (Windows).

Following, the structures of each folder and file created as a result of the installation are described:

- ***dist***: Contains the binary distribution of SPAMDA, which consist of:
  - ***DB***: Contains all the information managed by SPAMDA.
    - ***buoysDatabase***: Contains the database of the buoys.
    - ***finalDatasets***: It is used as a default folder to save the final datasets.
    - ***id1***: Contains the information of the buoy (annual text files, intermediate datasets, pre-processed datasets and matching configurations) entered as example.
    - ***reanalysisDatabase***: Contains the database of the reanalysis data.
    - ***reanalysisFiles***: Contains the reanalysis files entered through SPAMDA.
  - ***help***: Contains the user manual of SPAMDA.
    - ***userManual.pdf***: This is the user manual.
  - ***SPAMDA.jar***: This is the runnable file containing SPAMDA.
- ***COPYING***: This file contains a copy of the license of the GNU GENERAL PUBLIC LICENSE.

- ***LICENSE***: This file contains a copy of the license of SPAMDA.
- ***NetCDF-LICENSE***: This file contains a copy of the license of the Library NetCDF Java version 4.6.10
- ***README***: This file contains the instructions for getting started with SPAMDA.
- ***SLF4j-LICENSE***: This file contains a copy of the license of the Library SLF4J version 1.7.25
- ***WEKA-LICENSE***: This file contains a copy of the license of the Library WEKA version 3.8.1

After installing the software, and in order to run it, open the "dist" folder and double-click on the SPAMDA.jar file. Next, the main view of SPAMDA represented in figure 2.5 will appear.

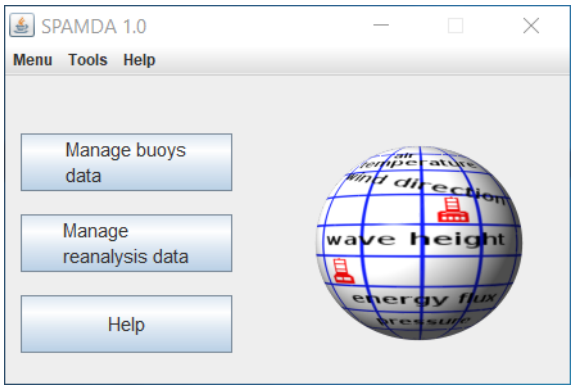

Figure 2.5: SPAMDA main view (Windows).

2.2.3 Installing on macOS

To install SPAMDA on macOS follow the next steps:

- ***Step 1***: Download the SPAMDA software on the computer.
- ***Step 2***: Create a folder and copy the downloaded file inside it.
- ***Step 3***: Decompress the file.

After performing the above steps SPAMDA would be installed on the computer and ready to be run. Note that the process of installation creates all the folders and files necessary inside the folder created in ***Step 2***. In Fig. 2.6 is represented an example of installation in the folder named "SPAMDA", which will contain the software tool.

Following, the structures of each folder and file created as a result of the installation are described:

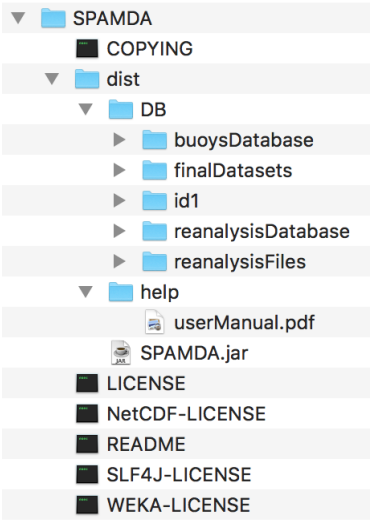

Figure 2.6: Content of the folder after installing SPAMDA (macOS).

- ***dist***: Contains the binary distribution of SPAMDA, which consist of:
  - ***DB***: Contains all the information managed by SPAMDA.
    - ***buoysDatabase***: Contains the database of the buoys.
    - ***finalDatasets***: It is used as a default folder to save the final datasets.
    - ***id1***: Contains the information of the buoy (annual text files, intermediate datasets, pre-processed datasets and matching configurations) entered as example.
    - ***reanalysisDatabase***: Contains the database of the reanalysis data.
    - ***reanalysisFiles***: Contains the reanalysis files entered through SPAMDA.
  - ***help***: Contains the user manual of SPAMDA.
    - ***userManual.pdf***: This is the user manual.
  - ***SPAMDA.jar***: This is the runnable file containing SPAMDA.
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- ***LICENSE***: This file contains a copy of the license of SPAMDA.
- ***NetCDF-LICENSE***: This file contains a copy of the license of the Library NetCDF Java version 4.6.10
- ***README***: This file contains the instructions for getting started with SPAMDA.
- ***SLF4j-LICENSE***: This file contains a copy of the license of the Library SLF4J version 1.7.25

- ***WEKA-LICENSE***: This file contains a copy of the license of the Library WEKA version 3.8.1

After installing the software, and in order to run it, open the "dist" folder and double-click on the SPAMDA.jar file. Next, the main view of SPAMDA represented in figure 2.7 will appear.

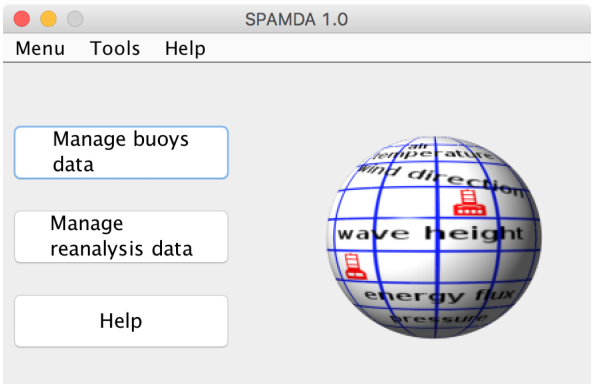

Figure 2.7: SPAMDA main view (macOS).

2.3 How to uninstall?

To uninstall SPAMDA just delete the folder in which the installation process was carried out.

Warning

This action will remove SPAMDA from your computer and any information entered in SPAMDA or generated by means of it will be lost.

3 Using SPAMDA

SPAMDA has been designed to greatly simplify all the steps involved in the creation of datasets with information from the sources mentioned in Section 1.2, thus the researcher can create as different datasets of the same meteorological data as needed, in a quick and efficient manner. For this purpose, SPAMDA manages three different types of datasets that are briefly introduced bellow:

- *Intermediate datasets*: Which will contain the meteorological observations from NDBC.

- *Pre-processed datasets*: Obtained as a result of pre-processing tasks performed on the intermediate datasets.

- *Final datasets*: Created by merging an intermediate or pre-processed dataset with the reanalysis data (referenced as matching process) and according to the needs of the study to perform (classification or regression).

SPAMDA consists of the following three main functional modules:

- ***Manage buoys data***

- ***Manage reanalysis data***

- ***Tools***

Such functional modules, which will be described in detail in the following sections, are accessible through the main view of SPAMDA represented in Fig. 3.1.

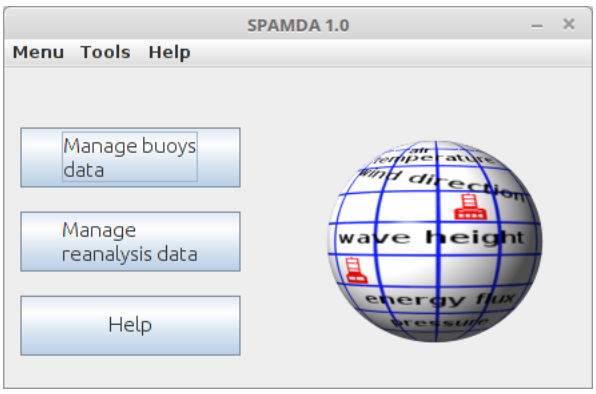

Figure 3.1: SPAMDA main view.

3.1 Manage buoys data

The aim of this module is to provide the features for the management and analysis of the information related to the buoys from NDBC, since such information is entered in SPAMDA until it is used by the researchers for conducting their studies. Such management and analysis involves:

- Entering and updating the information of each buoy.
- The creation of the intermediate datasets with the collected measurements.
- Pre-processing tasks for obtaining the pre-processed datasets.
- The matching process to merge the information from NDBC and NNRP.
- The creation of the final datasets accordingly to the ML technique to use.

The following sections describe the organisation of this module.

3.1.1 Buoys

The *Buoys* tab, which is represented in Fig. 3.2, allows the researchers to enter and update the information of each buoy. When entering a new buoy the following information, which can be obtained from NDBC, is requested:

- ***Station ID***: An alphanumeric identifier that allows the researchers to easily identify the buoy.
- ***Description***: A short description of the buoy.
- ***Latitude***: North or South geographical localisation (degrees) of the buoy.
- ***Longitude***: West or East geographical localisation (degrees) of the buoy.

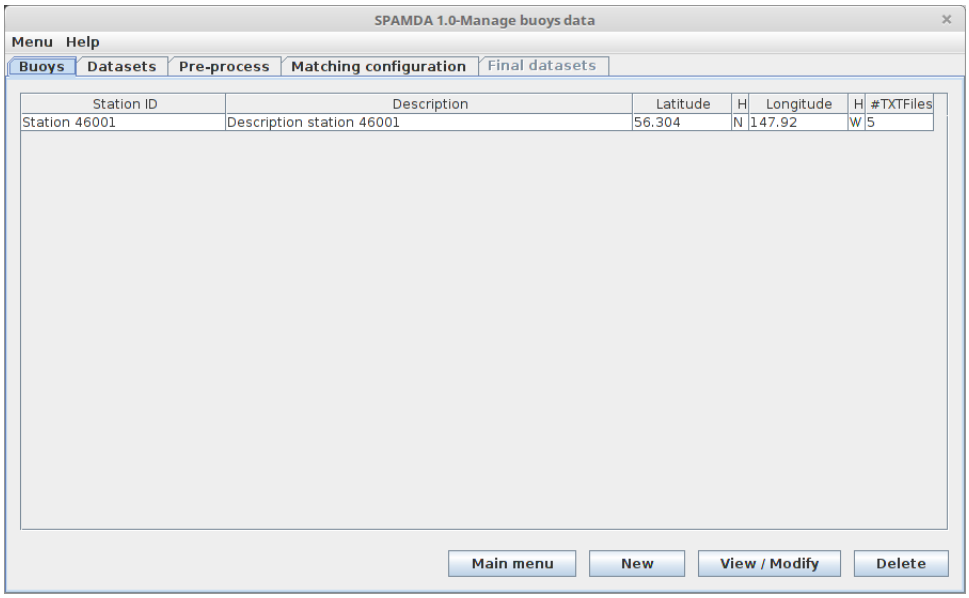

Figure 3.2: Tab *Buoys*.

- ***Measurements files***: The above-mentioned annual text files of the standard meteorological information collected by the buoy and downloaded from NDBC web page, which will be used for the creation of the intermediate datasets. The researchers will add to the buoy one file per year and as many as needed. Remember that such files are available in NDBC web page [6].

  To enter a new buoy follow the next steps:

- ***Step 1***: Click on the *New* button and the view represented in Fig. 3.3 will be displayed. (The remaining steps are related to such view).
- ***Step 2***: Type the required information about the buoy. To enter a new annual text file of the buoy click on the *Add file* button or click on the *Delete file* button to delete the selected one. By clicking on the *Clear* button it is possible to clean the form that request the information.
- ***Step 3***: Click on the *Save* button to insert the buoy.

In the same way, by clicking on the *View/Modify* button it is possible to view or modify the data relating to the selected buoy. To delete a buoy click on the *Delete* button.

Warning

Deleting a buoy will remove all the data related to the buoy.

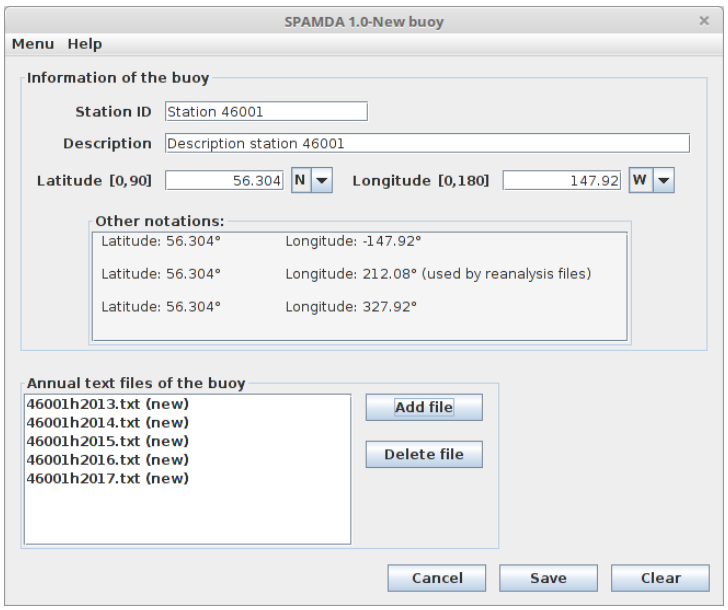

Figure 3.3: Entering a new buoy.

3.1.2 Datasets

The *Datasets* tab, which is represented in Fig. 3.4, allows the researchers to manage the intermediate datasets of each buoy, which are the baseline for their studies.

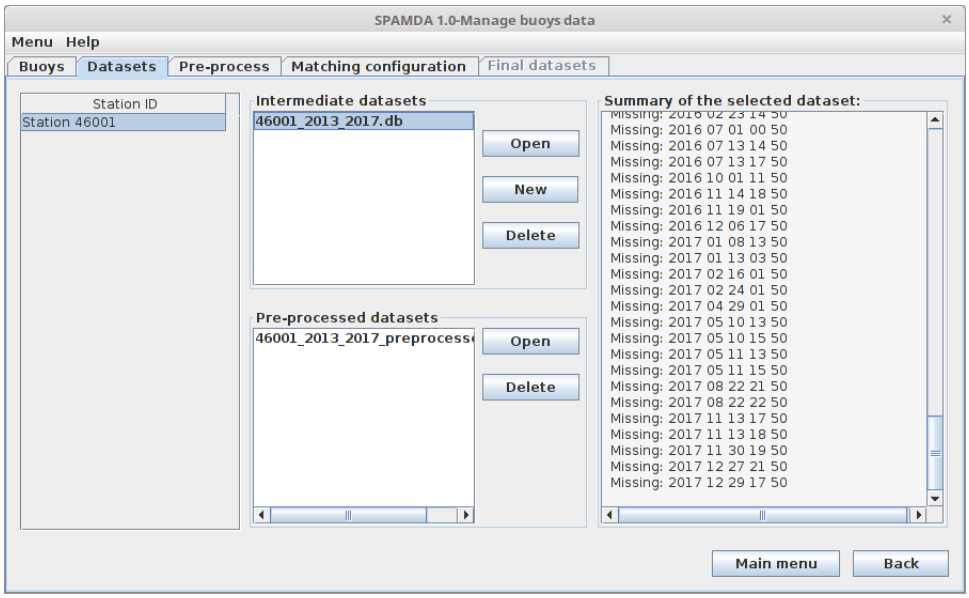

Figure 3.4: Tab *Datasets*.

Once a buoy has been entered it is possible to create intermediate datasets using one ore more annual text files (added previously), which contain the measurements collected by the buoy. Note that such measurements may be incomplete or recorded at a different time than the expected one due to the weather conditions in which the buoys have to operate.

SPAMDA has been designed to tackle such situation and it informs the researchers of any incidence found while reading the annual text files for creating the intermediate datasets.

When an intermediate dataset is created, it is associated with its corresponding buoy, enabling the researchers to identify which intermediate datasets belong to each buoy. Besides, a summary of the content of the intermediate dataset is also created, providing relevant information about its content such as number of instances, date of first and last measurement, annual text files included, missing and duplicated dates.

To proceed with the creation of an intermediate dataset follow the next steps:

- ***Step 1***: Select the desired buoy from the list shown on the left side.
- ***Step 2***: Click on the *New* button, then the view represented in Fig. 3.5 will be displayed. (The remaining steps are related to such view).

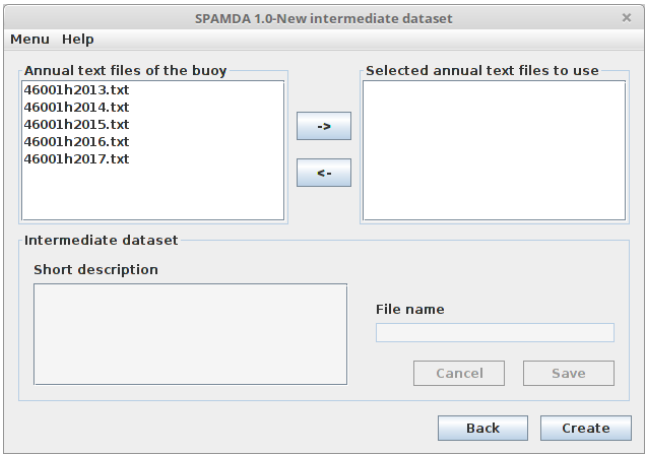

Figure 3.5: New intermediate dataset view.

- ***Step 3***: Select the annual text files to use by clicking on the $->$ button. To deselect a previously selected file click on the $<-$ button.
- ***Step 4***: When finished the selection click on the *Create* button.
- ***Step 5***: Type the description and the name of the intermediate dataset and click on the *Save* button to start the process of creation.

After that, SPAMDA will show the status of such process and the incidences that were found in the data, when it finished click on the *Ok* button. Note that the process can be cancelled by clicking on the *Cancel creation* button.

The view that shows the status of the process of creation of an intermediate dataset for the buoy identified as *Station 46001* using the annual text files of the years 2013, 2014, 2015, 2016 and 2017 is represented in Fig. 3.6.

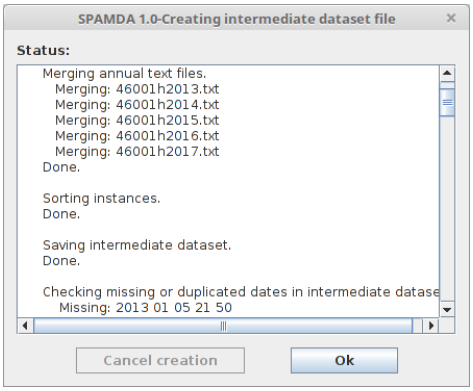

Figure 3.6: Status of the creation of the intermediate dataset.

As it is shown in Fig. 3.4 when a buoy is selected, the intermediate datasets belonging to it are displayed, similarly, if one of these intermediate datasets is selected, the pre-processed datasets (described in Section 3.1.3) obtained from it are displayed. Besides, on the right side the summary of the intermediate or pre-processed dataset selected is shown.

By clicking on the corresponding *Delete* button, the intermediate or pre-processed dataset selected will be removed.

Warning

Deleting an intermediate dataset will also remove all the pre-processed datasets belonging to it.

On the other hand, when clicking on the corresponding *Open* button the application will be redirected to the *Pre-process* tab (see Section 3.1.3) and the selected dataset (intermediate or pre-processed) will be opened for being pre-processed.

3.1.3 Pre-process

The *Pre-process* tab, which is represented in Fig. 3.7, allows to perform data pre-processing, which prepares the raw data (intermediate datasets) to be able to be treated correctly by ML algorithms. In this way, the quality of data can be improved prior to computational learning.

Once an intermediate dataset has been created it is possible to apply the necessary pre-processing tasks (filters) to enhance the data quality. In the *Statistical information* tab relevant data about each attribute of the opened dataset (the one is currently being pre-processed) such as number of instances with missing values, minimum and maximum values, mean and standard deviation is shown. Providing the researchers the capacity to evaluate the pre-processing being performed.

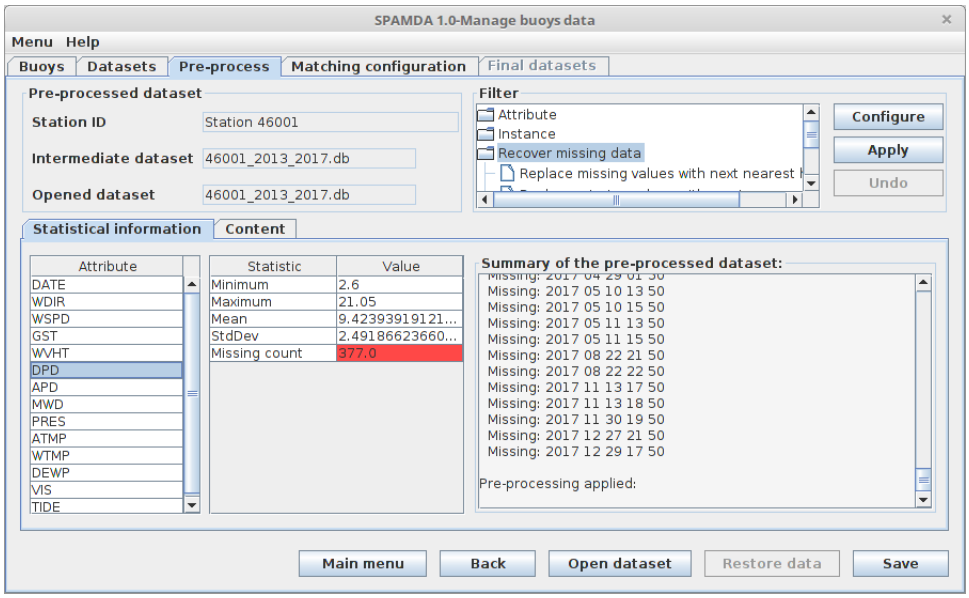

Figure 3.7: Tab *Pre-process*.

SPAMDA provides several configurable filters grouped in three categories, *Attribute*, *Instance* and *Recover missing data*:

- *Attribute*: All these filters can be applied to the attributes of the opened dataset.
  - *Normalize* [11]: This filter normalises all numeric values of each attribute. The resulting values are by default in [0,1] for the data used to compute the normalisation intervals.
  - *Remove* [12]: It removes an attribute or a range of them.
  - *RemoveByName* [13]: It allows to remove attributes based on a regular expression matched against their names.
  - *ReplaceMissingValues* [14]: For each attribute all the missing values will be replaced with its mean.
  - *ReplaceMissingWithUserConstant* [15]: This filter replaces all the missing values of the attributes with an user-supplied constant value.
- *Instance*: All these filters can be applied to the instances (hourly measurements) of the opened dataset.
  - *RemoveDuplicates* [16]: With this filter all duplicated instances are removed.
  - *RemoveWithValues* [17]: This filter removes all the instances that match on the attribute and value user-supplied.
  - *SubsetByExpression* [18]: It removes all the instances which don't match on a user-specified expression.

- *Recover missing data*: All these filters can be applied to the instances of the opened dataset.
  - *Replace missing values with next nearest hour*: The missing values of each attribute are replaced with the next nearest non missing value.
  - *Replace missing values with previous nearest hour*: This filter replaces the missing values of each attribute with the previous nearest non missing value.
  - *Replace missing values with next n hours mean*: The missing values of each attribute are replaced with the next n nearest (configurable) non missing values mean. Note that these values may not coincide with the next n hours.
  - *Replace missing values with previous n hours mean*: This filter replaces the missing values of each attribute with the previous n nearest non missing values mean. Note that these values may not coincide with the previous n hours.
  - *Replace missing values with symmetric n hours mean*: The missing values of each attribute are replaced with the n previous and n next non missing values mean. Note that these values may not coincide with the symmetric n hours.

Once the pre-processing has been performed it is possible to save the resulting dataset, which will be referenced as a pre-processed dataset in SPAMDA. Besides, a pre-processed dataset can be also pre-processed again enabling the researchers to resume such task at any other time.

To apply a filter follow the next steps:

- ***Step 1***: Open the desired intermediate or pre-processed dataset by clicking on either the *Open dataset* button or the corresponding *Open* button of tab *Datasets*.
- ***Step 2***: Select one of the available filters.
- ***Step 3***: Configure the filter if necessary by clicking on the *Configure* button.
- ***Step 4***: Apply the filter by clicking on the *Apply* button.

As shown in Fig. 3.7 the pre-processing tasks performed on the opened dataset are displayed on the right side. SPAMDA allows the researchers to undo the last filter applied (*Undo* button) or to restore the initial content of the dataset (*Restore data* button).

To create a pre-processed dataset follow the next steps:

- ***Step 1***: Click on the *Save* button, then the view represented in Fig. 3.8 will be displayed. (The remaining step is related to such view).
- ***Step 2***: Type the description and the name of the pre-processed dataset and click on the *Save* button.

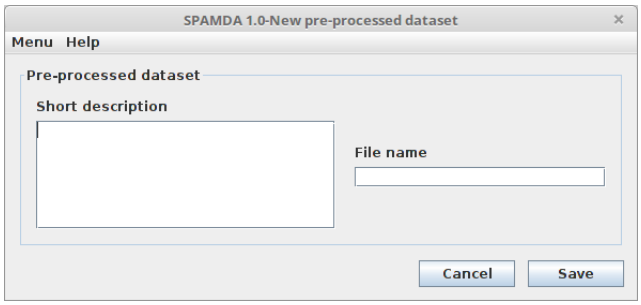

Figure 3.8: New pre-processed dataset view.

When saving the pre-processed dataset it will be associated with its corresponding intermediate dataset.

Moreover, it is also possible to visualise the content of the opened dataset, enabling the researchers to easily identify if any of the instances is missing, duplicated, incomplete (missing values) or was recorded at a different time than the expected one, as mentioned in Section 3.1.2. To proceed with such action click on the *Content* tab and use the buttons > and < to check the possible affected instances as it is shown in Fig. 3.9.

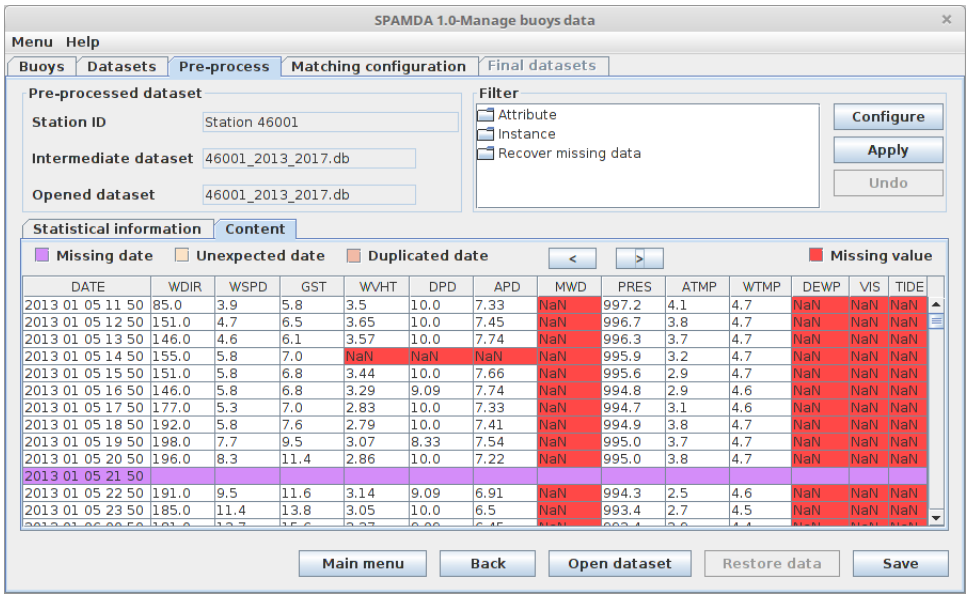

Figure 3.9: Visualising the content of the opened dataset.

3.1.4 Matching configuration

The *Matching configuration* tab, which is represented in Fig. 3.10, allows the researchers to customise the parameters of the matching process, which is necessary to carry out in order to merge and format the data provided by the two sources of information described in Section 1.2.

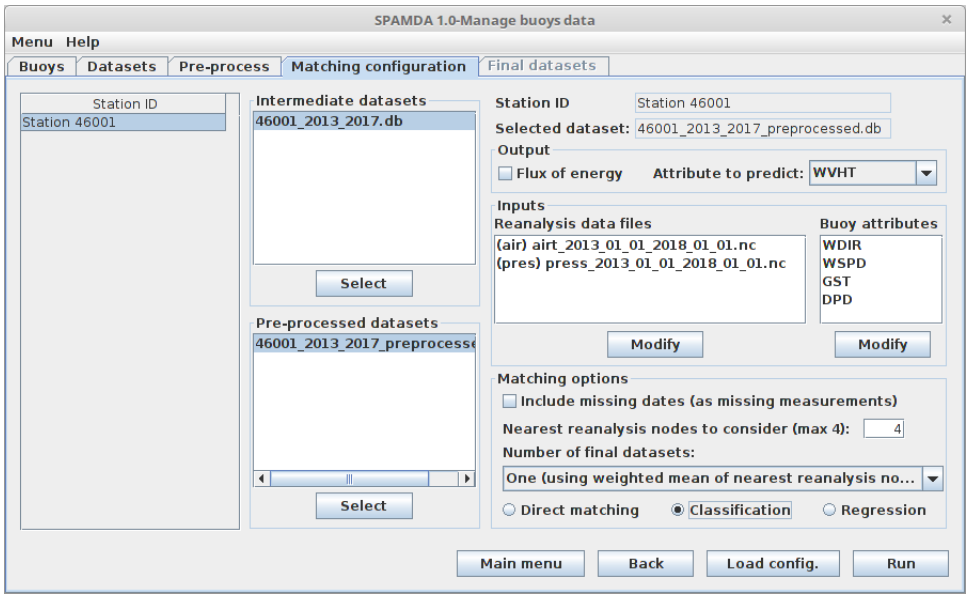

Figure 3.10: Tab *Matching configuration*.

The matching procedure is performed using an intermediate or pre-processed dataset, which includes the measurements collected by a buoy from NDBC, and also the corresponding reanalysis data files from NNRP. Note that SPAMDA is able to manage the NetCDF binary format for handling the information stored in such reanalysis files.

Such process merges the information of both sources that match on time, but due to the measurements of the buoys are hourly collected from 00:50 to 23:50 UTC, and the reanalysis data is available every 6 hours at 00Z, 06Z, 12Z and 18Z, the matching can only be carried out each 6 hours (discarding the unused measurements from the buoy data). Besides, and since there is still a difference of 10 minutes, the matching with the reanalysis data will be performed with the nearest measurement (previous or next) within a maximum of 60 minutes of difference. Finally, the matched instances of both sources will result in the final datasets.

SPAMDA allows the researchers to perform a customisable matching process, through which the researchers can easily obtain as different final datasets of the same meteorological data as needed, allowing them to consider different factors of the problem under study. These final datasets can be used for classification or regression prediction tasks, or direct matching. Prediction tasks are used to estimate the value of the output attribute in a concrete future using the information provided by the input attributes. Depending on the task to use, the final datasets must be prepared and configured in a specific way:

- *Classification*: The final datasets will be ready to use as input in classification methods, which require a nominal output attribute and whose specific preparation is explained in Section 3.1.5.

- *Regression*: The final datasets will be ready to use as input in regression methods, which require a real output attribute and whose preparation is also explained in Section 3.1.5.

- *Direct matching*: In this case the inputs attributes have a direct correspondence with the output attribute, and it is not necessary to perform any additional preparation. For example, the final datasets may be used in lost data recovering tasks, or in the way the researchers consider suitable according to the problem under study.

Following, the parameters that can be configured in the matching process are described:

- *Flux of energy* [19]: When the F_e is selected, it will be used as output. This attribute is not collected by the buoys, but it can be calculated from two wave parameters: H_s and T_e, which are collected as WVHT and APD attributes respectively. In this way, SPAMDA will obtain the F_e of each instance using the following equation:

$$F_e = 0.49 \cdot H_s^2 \cdot T_e \tag{3.1}$$

  where F_e is measured in kilowatts per meter, H_s is measured in meters and T_e is measured in seconds. Note also that F_e is defined in Eq. 3.1 as an average energy flux (H_s is a kind of average wave height), though for simplicity it will be referred just as flux of energy.

- *Attribute to predict*: Instead of using the F_e, the researchers can select any of the attributes collected by the buoys as output (e.g. significant wave height (WVHT), wind direction (WDIR), sea level pressure (PRES), etc.). Therefore, they can focus on different studies by selecting an attribute or other.

- *Reanalysis data files*: In order to have a more accurate description of the problem under study, more than one reanalysis variable can be considered as input. Remember that these files have to be previously downloaded by the researcher from the website of the NNRP [8], which should set the range of dates (temporal properties) and the desired sub-grid (spatial properties, see Fig. 1.1) for each variable of reanalysis. In that sense, the reanalysis data files must have the same spatial and temporal properties but relating to different variables each other.

  To select the needed reanalysis data files click on the corresponding *Add/Modify* button and the view represented in Fig. 3.11 will be displayed. SPAMDA facilitates this task by showing in cyan colour the reanalysis data files that are compatibles each other when selecting or clicking on a file. Click on the *Confirm selection* button when finished and SPAMDA will check that the selected files meet such condition.

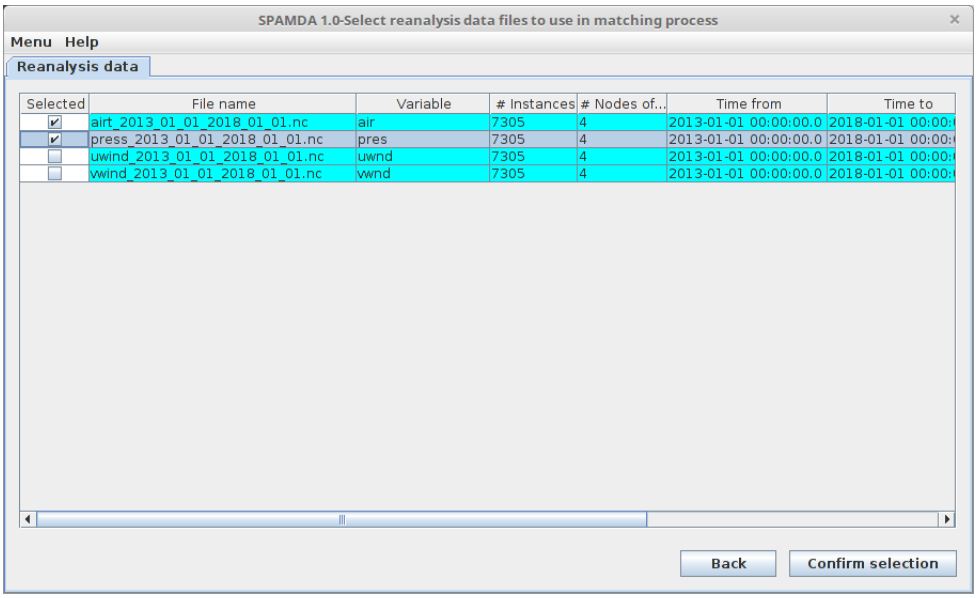

Figure 3.11: Selecting reanalysis data files.

- *Buoys attributes*: In addition to the reanalysis variables, the final datasets will also include the selected attributes as inputs (of the intermediate or pre-processed dataset used), providing a possible better characterisation of the problem under study, although it will depend on how correlated the attributes are.

  In the same way, in order to select the attributes of the buoy click on the corresponding *Add/Modify* button and the view represented in Fig. 3.12 will be displayed showing the available attributes of the buoy.

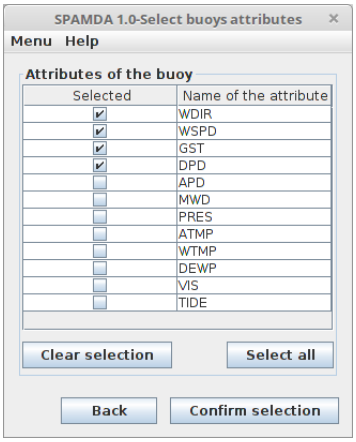

Figure 3.12: Selecting buoys attributes.

  Once done the selection click on the *Confirm selection* button.

- *Include missing dates*: As mentioned in Section 3.1.2, the information collected by a buoy may be incomplete due to measurements not recorded by it. As a consequence, the matching of instances between both sources of information may mismatch (miss-

ing dates). In that situation, the researchers can consider two options: 1) discard the instances affected or 2) include them. In the latter case, the final datasets will contain the affected instances, but the measurements of the buoy will be stored as missing values in WEKA format, denoted as «*?*».

- *Nearest reanalysis nodes to consider*: As already shown in Fig. 1.1, the reanalysis data files may contain information of several reanalysis nodes. In this way, this parameter allows the researchers to choose from:

  - Consider all the reanalysis nodes: in this case, all the information of each selected reanalysis data file will be used.
  - Consider only some of the reanalysis nodes: in this case, only the information of the N closets reanalysis nodes (configurable) to the buoy will be used. To do that, SPAMDA uses the *Haversine* formula [20] to calculate the distance from each reanalysis node to the localisation of the buoy and obtain the closest ones. Haversine formula is also known as great circle distance, this formula perform calculation from main point to destination point with trigonometric function by using latitude and longitude. Haversine formula is calculated as follows:

    $$d(p_0, p_j) = \arccos(\sin(lat_0) \cdot \sin(lat_j) \cdot \cos(lon_0 - lon_j) + \cos(lat_0) \cdot \cos(lat_j)), \tag{3.2}$$

    where p_0 is the buoy geographical localisation, p_j stands for the location of each reanalysis node, and lat and lon are the latitude and longitude of the points, respectively.

- *Number of final datasets*: Depending on the number of the nearest reanalysis nodes to consider, the number of the final datasets to create and therefore the content of them can be configured according to the following options:

  - *One (using weighted mean of N nearest reanalysis nodes)*: Only one final dataset will be created, which will contain the attributes (the selected one as output and the selected ones as inputs) of the intermediate or pre-processed dataset used, along with a weighted mean of each variable of reanalysis used (one per selected reanalysis data file). This weighted mean is obtained by SPAMDA and uses the distance (using the formula defined in Eq. 3.2) from each reanalysis node to the localisation of the buoy. Once the distances have been calculated they are inverted and normalised as follows:

    $$w_i = \frac{\sum_{j=1}^{N} d(p_0, p_j)}{d(p_0, p_i)}, \quad i = 1, \ldots, N. \tag{3.3}$$

    After calculating these weights, they are applied to obtain a weighted mean

of each variable of reanalysis. Therefore, the closest reanalysis nodes to the localisation of the buoy will provide more information.

Considering as example the two nearest reanalysis nodes represented in Fig. 1.1 and the reanalysis variables air temperature and pressure, the weighted mean of each reanalysis variable will be calculated using the reanalysis nodes 57.5 N × 147.5 W and 55.0 N × 147.5 W.

– *'N' (one per each reanalysis node)*: As many final datasets as number of nearest N reanalysis nodes configured by the researcher will be created. Therefore, each final dataset will contain the value of each reanalysis variable used of the nearest corresponding reanalysis node, along with the selected attributes of the intermediate or pre-processed dataset used.

  In this case, and considering as example the four closest reanalysis nodes (see Fig. 1.1) and the reanalysis variables air temperature and pressure, then only four final datasets will be created, containing each one the information of both reanalysis variables of the corresponding reanalysis node: 57.5 N × 147.5 W, 55.0 N × 147.5 W, 57.5 N × 150.0 W and 55.0 N × 150.0 W, along with the selected attributes of the intermediate or pre-processed dataset used.

To proceed with the matching process follow the next steps:

- ***Step 1***: Select the desired buoy from the shown on the left side.
- ***Step 2***: Select the intermediate or pre-processed dataset to use.
- ***Step 3***: Configure the above-mentioned matching parameters and click on the *Run* button to start the matching process.

Then, SPAMDA will show the status of such process and the missing dates that were found, when it finished click on the *OK* button and the application will be redirected to the *Final datasets* tab (see Section 3.1.5) to perform the preparation of the matched data.

In Fig. 3.13 is represented the status of a matching process using the configuration showed in Fig. 3.10.

Instead of typing all the required parameters, it is possible to load a previously matching configuration saved. To do that click on the *Load config.* button, then the view represented in Fig. 3.14 will be displayed for selecting the configuration to be loaded (Section 3.1.5 describes how to save the configuration used in the matching process and for the preparation of the matched data).

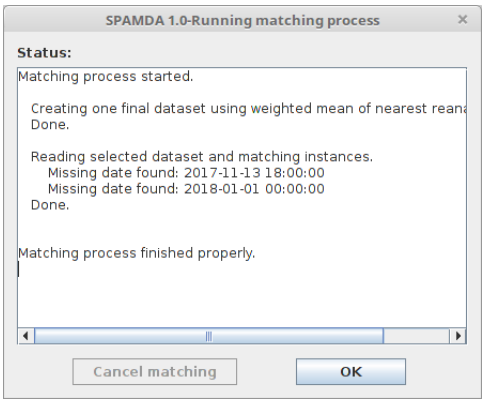

Figure 3.13: Status of the matching process.

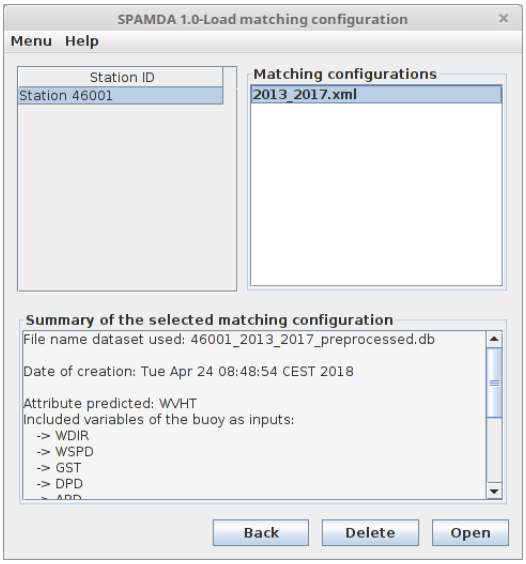

Figure 3.14: Load matching configuration.

3.1.5 Final datasets

The *Final datasets* tab, which is represented in Fig. 3.15, permits the researchers to prepare the matched data for the desired prediction task (*Regression* or *Classification*), obtaining as a result the final datasets. Remember that *Direct matching*, as it was described in Section 3.1.4, performs a direct correspondence between the attributes used as inputs and the output one, and it is not necessary to carry out any preparation.

SPAMDA allows the researchers to make such preparation by means of the following options:

- *Prediction horizon* (Classification and Regression): This option indicates the time gap for moving backward the output attribute. In this way, the input attributes (variables of the buoy and reanalysis data) will be used to predict the output attribute in a concrete future (e.g. 6h, 12h, 18h, 1 day, etc.).

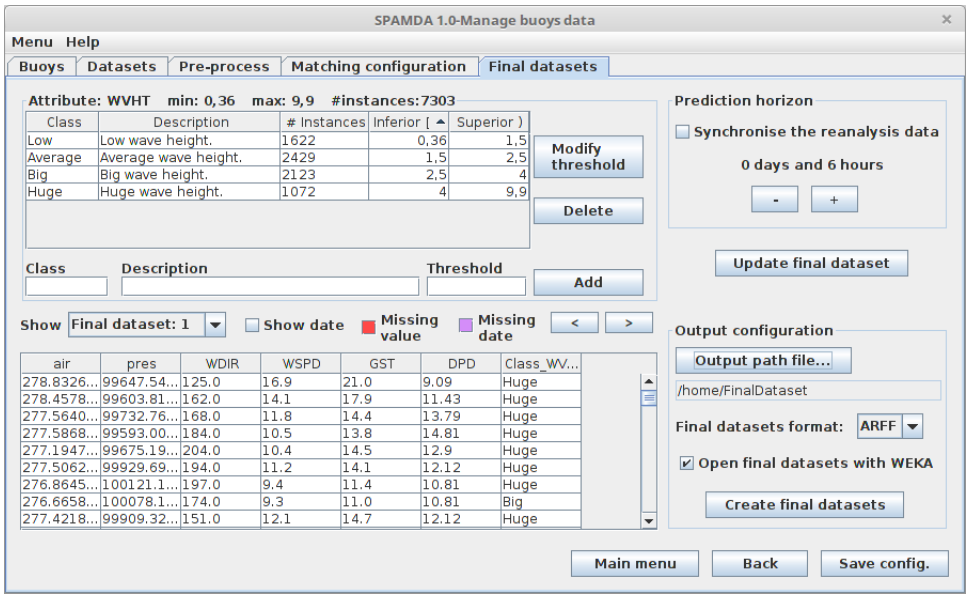

Figure 3.15: Tab *Final datasets*.

The minimum interval for increasing and decreasing the prediction horizon is 6h (due to reanalysis data temporal resolution) [21], the same interval used when the matching process is carried out. Therefore, for each increment of the prediction horizon an instance is lost from the end of the final datasets. As the minimum prediction horizon is 6h at least one instance will be lost. The relation between the inputs and the attribute to predict will be defined as follows:

$$o_{t+\Delta t} = \phi(\mathbf{b}_t, \mathbf{r}_t) \tag{3.4}$$

Where t represents the time instant to study and Δt the prediction horizon; o is the attribute to predict, $\mathbf{b}$ is the vector containing the selected NDBC variables and $\mathbf{r}$ is the vector containing the selected reanalysis variables. Optionally, the reanalysis variables can be synchronised with the attribute to predict. Given that such variables are estimated by a mathematical model, it is allowed to use these future values, which could improve the performance of the results. In this case, the relation between the inputs and the attribute to predict would be:

$$o_{t+\Delta t} = \phi(\mathbf{b}_t, \mathbf{r}_{t+\Delta t}) \tag{3.5}$$

- *Thresholds of the output attribute* (Classification): Since the values of the variables collected by the buoys are real numbers, it is necessary to discretise (convert from real to nominal values) the selected attribute as output. SPAMDA allows the researchers to perform this process by defining the necessary classes with their thresholds, which will be used against the values of the output attribute to carry out such discretisation.

Follow these steps to proceed with the preparation of the final datasets:

- ***Step 1***: Define the classes and their thresholds (*Classification*).
  - To do that, use the buttons *Add*, *Modify threshold* or *Delete* to add a new threshold, modify or delete the selected one respectively.
- ***Step 2***: Define the prediction horizon (*Classification and Regression*).
  - To do that, use the buttons $-$ or $+$ to decrease or increase the prediction horizon, and select or deselect the option *Synchronise the reanalysis data* depending on needs.
- ***Step 3***: Click on the *Update final dataset* button to take the new configuration of the preparation.

Such preparation can be performed as many times as required and considering the typed options in each moment.

As shown in Fig. 3.15, the content of the final datasets obtained as a result of the custom preparation of the matched data, can be visualised enabling the researchers to check the final datasets before saving them on disk. Although the date will not be included in the final datasets, by selecting the *Show date* option it can be shown in order to know the dates of each instance of the intermediate or pre-processed dataset used, that matched with the reanalysis data. Moreover, by clicking on the $>$ and $<$ buttons it is possible to check the dates that were mismatched.

Finally, and before creating the final datasets, it is necessary to define the output configuration:

- *Output file*: Name of the final datasets and folder to save them on disk.
- *Final datasets format*:
  - *ARFF*: *Attribute-Relation File Format* [4] which is used by the tool WEKA. SPAMDA allows the researchers to open the final datasets created with this format by running the environment Explorer of WEKA (in the same context of work), enabling they to choose the most appropriate ML method to tackle the problem under study. To do that select the option *Open final datasets with WEKA*.
  - *CSV*: *Comma-Separated Values*. With this format the researchers may use the final datasets in the way they deem suitable.

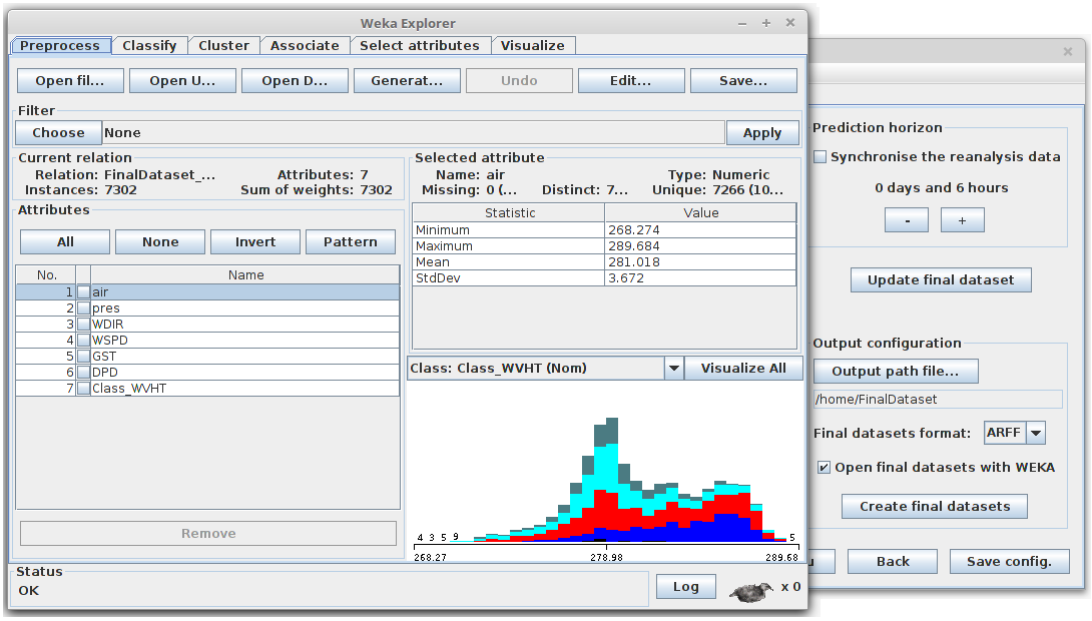

Figure 3.16: Opening with WEKA the final dataset created.

Once finished the preparation, by clicking on the *Create final datasets* button the final datasets will be saved on disk in the selected folder, an them will be opened by the tool WEKA, as represented in Fig. 3.16, if the researchers selected such option.

SPAMDA allows the researchers to save the configuration used in the matching process and for the preparation of the matched data, enabling the researchers to resume their studies at any other time. To do that click on the *Save config.* button, then the view represented in Fig. 3.17 will be displayed. After typing the description and the file name click on the *Save* button to save the configuration, which will be associated with the buoy used.

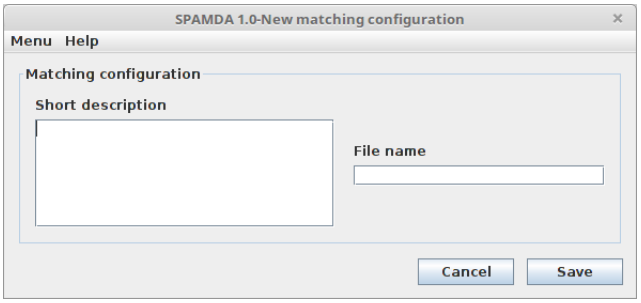

Figure 3.17: New matching configuration.

3.2 Manage reanalysis data

This module, which is represented in Fig. 3.18, allows the management of the reanalysis data provided by NNRP. In this way, the researchers can keep up to date the reanalysis files needed for their studies. Remember that such data is available in NNRP web page [8].

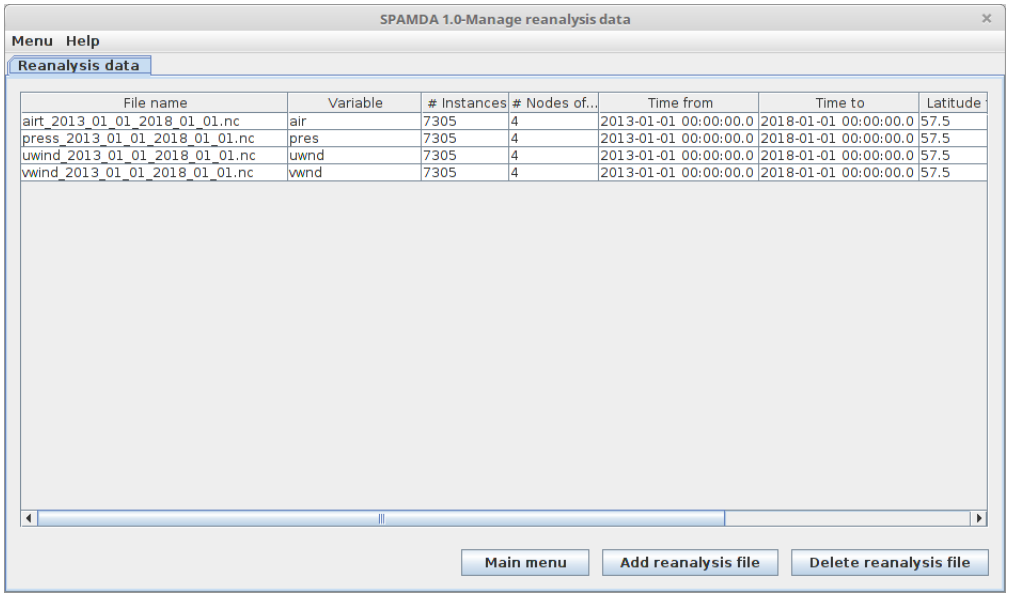

Figure 3.18: Module Manage reanalysis data.

To enter a new reanalysis file just click on the *Add reanalysis file* button and select the desired file, in order to delete a reanalysis file just click on the *Delete reanalysis file* button.

As it is shown in Fig. 3.18 useful information about the content of each reanalysis file can be consulted such as name of the file and the reanalysis variable, number of instances and reanalysis nodes, initial and final: time, latitude and longitude; which summarises the temporal and spatial properties of the data. Thus the researcher can quickly and easily identify each reanalysis file entered in SPAMDA.

3.3 Tools

This module includes two utilities, one for converting intermediate or pre-processed datasets to ARFF or CSV format and the other one for opening ARFF files with WEKA. Both features are accessible through the *Tools* option of the menu bar showed in Fig. 3.1.

3.3.1 Datasets converter

This utility permits the researchers to convert the desired intermediate or pre-processed datasets to ARFF and CSV format. In this way, the researchers can use these converted datasets as they consider opportune.

To convert an intermediate or pre-processed dataset click on the *Dataset converter* option and the view represented in Fig. 3.19 will be displayed. On the left side are shown the buoys entered in SPAMDA, by clicking on one of them its intermediate datasets will be shown on the top side. Similarly, by clicking on one intermediate dataset its pre-processed datasets will be shown on the bottom side. Once selected the desired dataset (intermediate or pre-processed) just click on the *Convert to ARFF* or *Convert to CSV* button, and a dialog box will appear asking for the name of the target file that will be created as a result of the conversion.

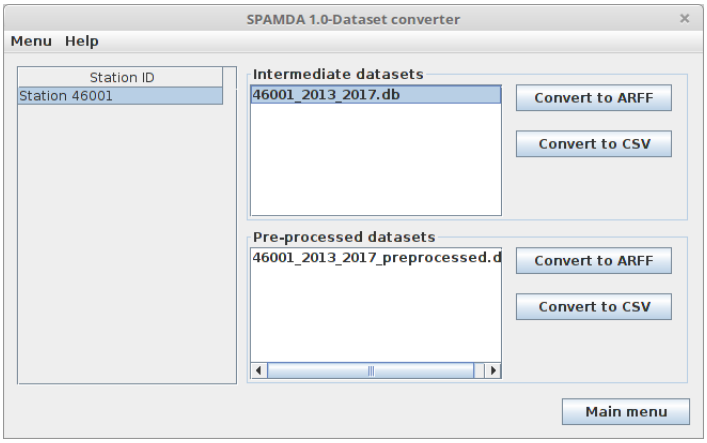

Figure 3.19: Utility Dataset converter.

3.3.2 Open ARFF file with WEKA

This other utility allows the researchers to open ARFF files by running the environment Explorer of WEKA in the same context of work, enabling they to resume experiments with previously created final datasets.

To open an ARFF file click on the *Open ARFF file with WEKA* option and the view represented in Fig. 3.20 will be displayed.

To search for and select an ARFF file click on the *Browse...* button, when finished click on the *Open file* button for opening it and the view represented in Fig. 3.21 will be displayed.

Remember that it is also possible to open the final datasets when creating them by selecting the option *Open final datasets with WEKA* (see Fig. 3.15).

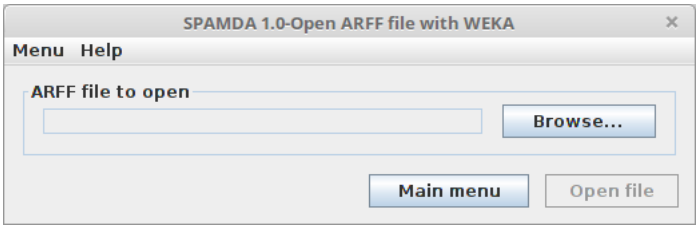

Figure 3.20: Utility Open ARFF file with WEKA.

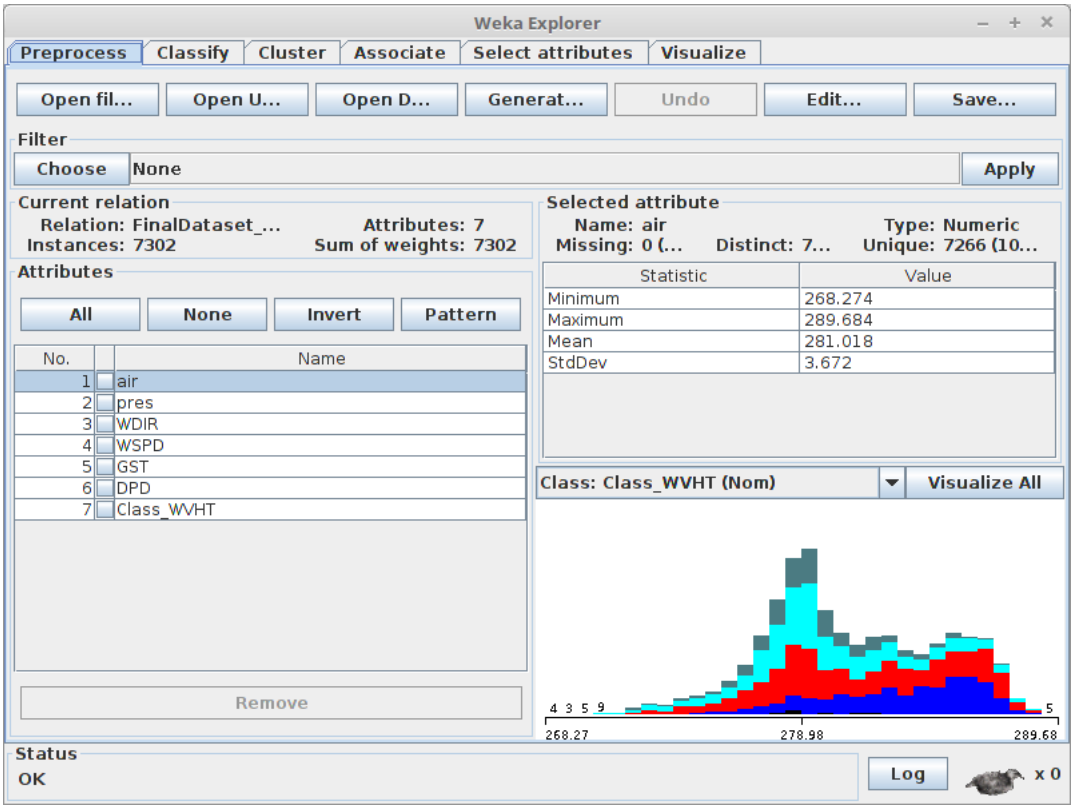

Figure 3.21: Opening an ARFF file with WEKA.

4 Case study

This chapter will describe how the application works in a practical approach. To do so, an example showing how to create a fully processed (final) dataset starting from the raw data will be performed. The objective of this final dataset is to be used in ML algorithms to classify waves in the Gulf of Alaska depending on their height.

4.1 Case study

The meteorological data that will be used to perform this case study is described bellow:

1. The measurements obtained from 2013 to 2017 by the buoy (46001) placed in the Gulf of Alaska, which are provided by NDBC as annual text files. This data is publicly available at the NDBC website.

2. Complementary information collected from reanalysis data containing air temperature, pressure and two components of wind speed (South-North and West-East) measurements. This information will be collected from the four closest reanalysis nodes surrounding the geographical location of the buoy. This data is publicly available at the NNRP website and can be downloaded in NetCDF format.

After gathering the information described above [1], the researcher can open SPAMDA.

In Figure 4.1 the main view can be found, in order to input the reanalysis data which will be used in further steps for creating the final dataset, the researcher will select the option *Manage reanalysis data* from the view.

[1] Further instructions for downloading this data can be found in Appendix A.

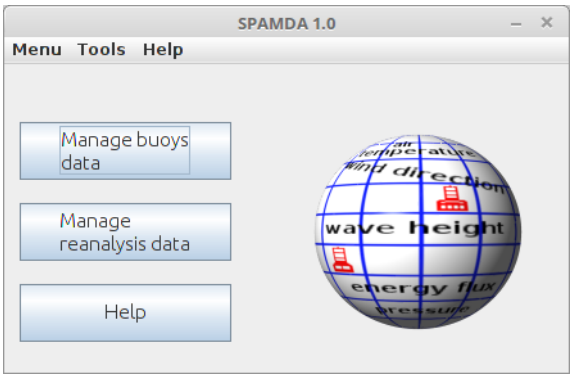

Figure 4.1: SPAMDA main view.

Then, the view represented in Figure 4.2 will appear. To enter the four reanalysis files (one per reanalysis variable) the researcher must click on the *Add reanalysis file* and a dialog box will appear for selecting them.

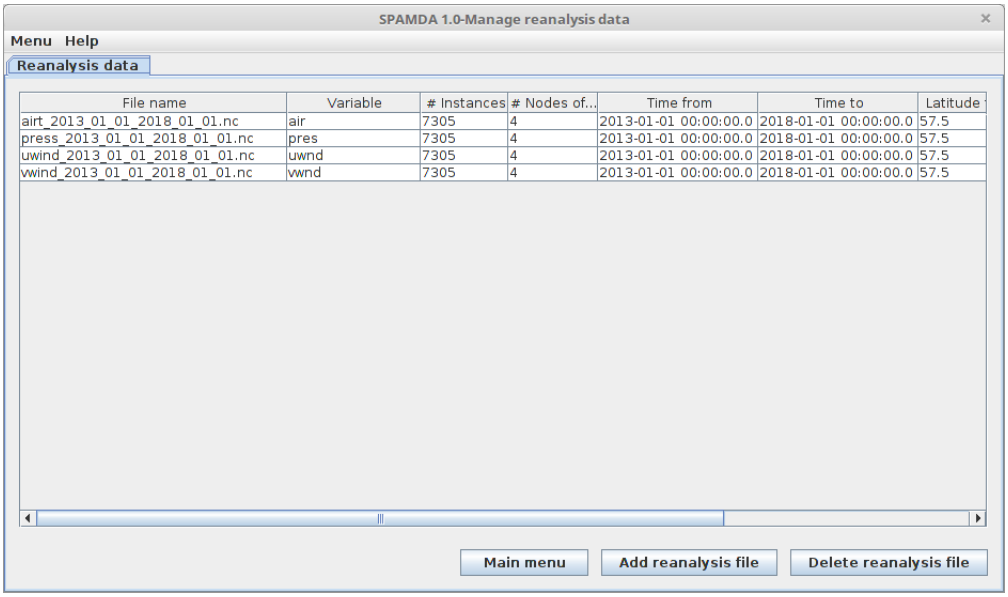

Figure 4.2: Module Manage reanalysis data.

After the reanalysis files has been introduced in SPAMDA, this window can be closed and go back to the main view to continue entering the information related to the buoy under study. The researcher will now select *Manage buoys data* to open the view shown in Figure 4.3. In order to enter such data, click on the *New* button, then the window shown in Figure 4.4 will pop-up.

Here the information about the buoy will be entered: the *Station ID*, its description, geographical localisation and the corresponding annual text files. In this case, the files containing the data from year 2013 to 2017 are inserted. To do so, click on the *Add file* button and a dialog box will appear for selecting them. Once the data has been introduced, it is necessary to click on the *Save* button to insert the buoy in SPAMDA database, after

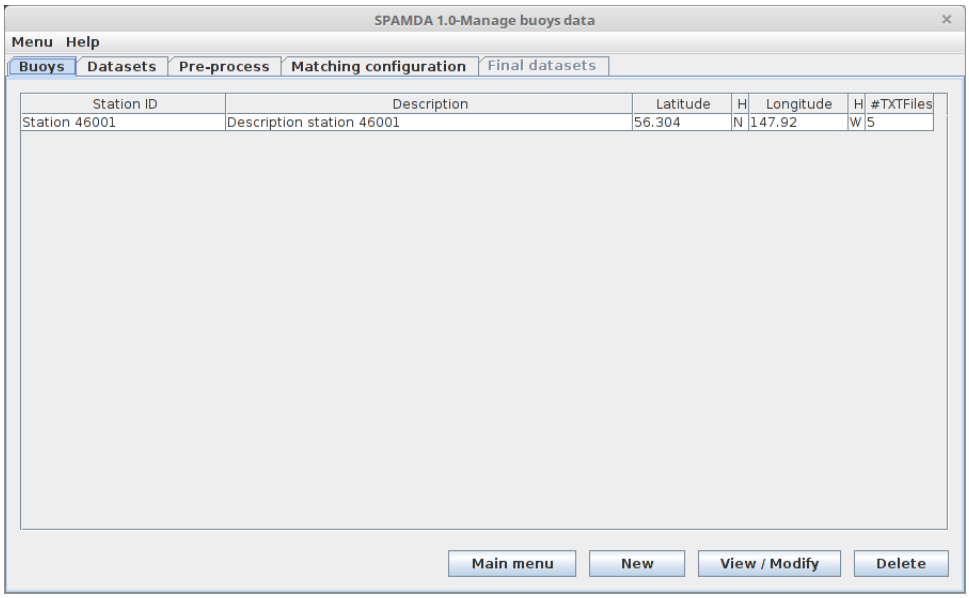

Figure 4.3: Tab *Buoys*.

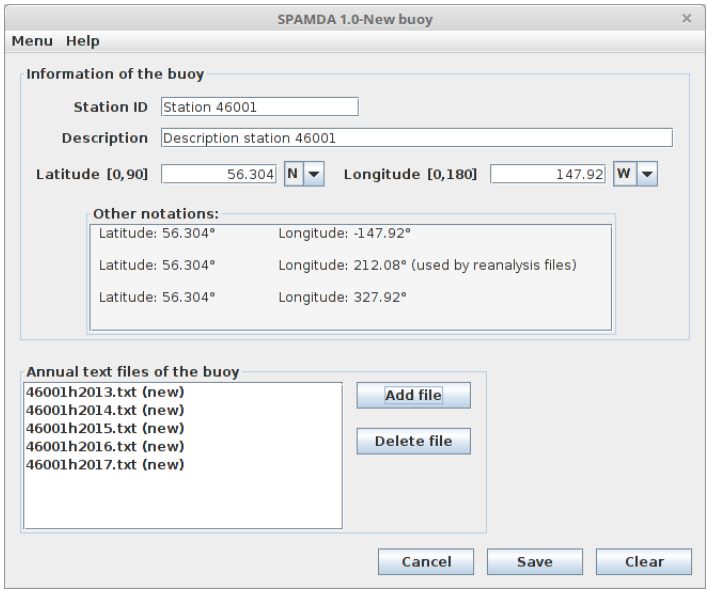

Figure 4.4: Entering a new buoy.

that, the window can be closed.

The next step would be to create an intermediate dataset, the researcher will double-click on the buoy under study or click on the *Datasets* tab to switch to the next view (see Figure 4.5).

To proceed with the creation of the intermediate dataset, click on the *New* button and the view shown in Figure 4.6 will appear.

Here the researcher can select the annual text files that he wants to include in the intermediate dataset by clicking on the −> button (click on the <− button to deselect a

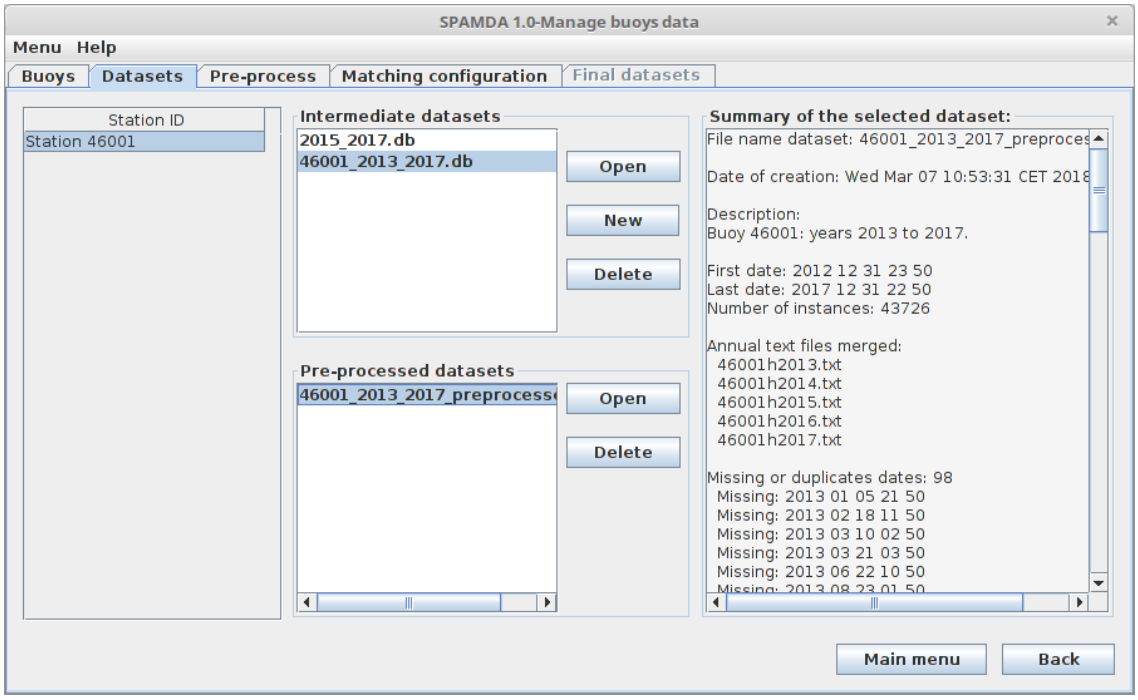

Figure 4.5: Tab *Datasets*.

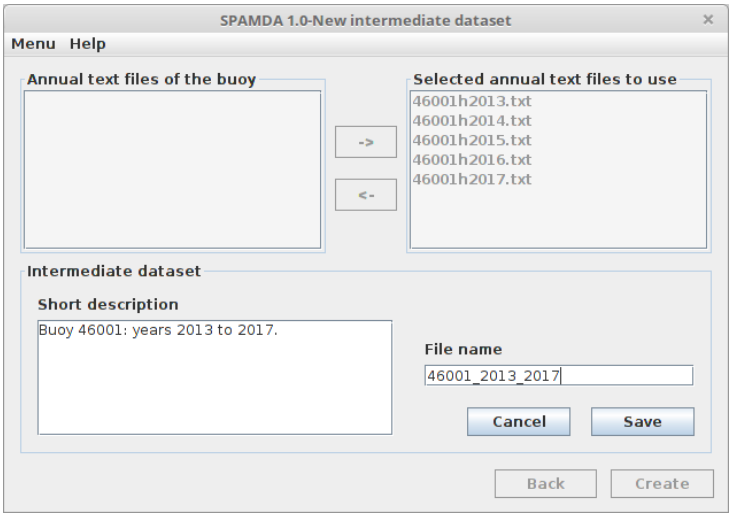

Figure 4.6: New intermediate dataset view.

previously selected one). In this case, all the files introduced before which correspond to the buoy under study were selected. When the files selection is finished, *Create* button will be clicked in order to be able to introduce the description and the file name of the current intermediate dataset, and then clicking on the *Save* button, the creation process will start, and the application will show the status of such process.

After that, in order to prepare the intermediate dataset to be able to be used by ML algorithms correctly, the dataset to be prepared is selected, and then the button *Open* is clicked to jump to the tab *Pre-process* (represented in Figure 4.7).

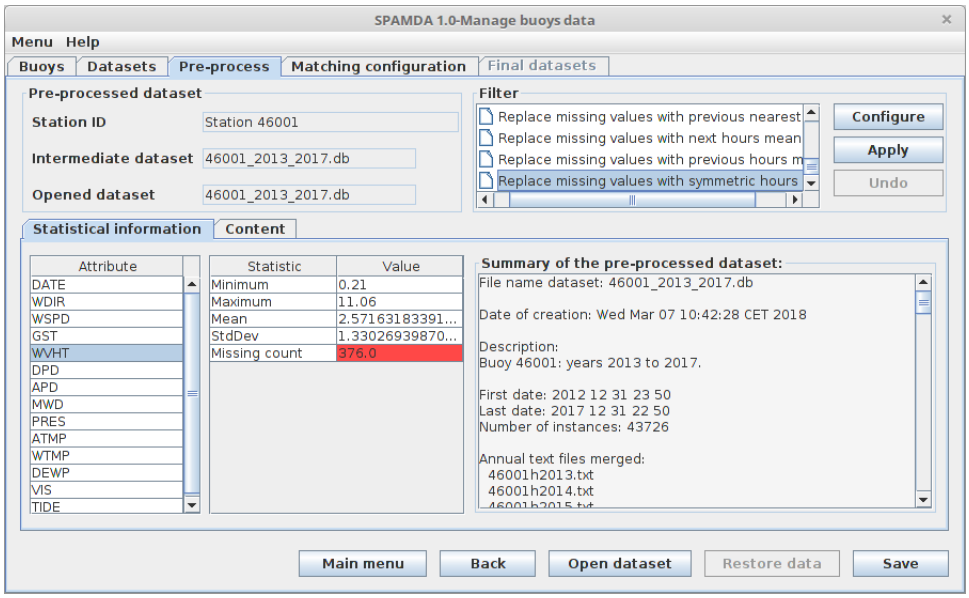

Figure 4.7: Tab *Pre-process*.

As mentioned at the beginning of this chapter, this case study will process the data to be ready to classify waves considering their height, so any missing data from wave height (376 values) and the remaining attributes are recovered, using the filter *Replace missing values with symmetric* 3 *hours mean*. Furthermore, the attributes MWD, DEWP, VIS and TIDE are removed from the dataset by applying the filter *RemoveByName*, since the first two had more than 92% of missing data and the last two 100%. After finishing the pre-processing of the dataset, the researcher can click on the *Save* button, to introduce the description and file name for the current pre-processed dataset.

At this point, the researcher has registered the buoy in SPAMDA, then entered its raw data and selected the required data for the problem (intermediate dataset), finally, the data was pre-processed in order to be ready for its future use in ML algorithms. In order to achieve a more accurate description of the problem under study, a matching process can be carried out to merge the processed data from NDBC with the reanalysis data (also entered previously) from NNRP. The next step is to click on the *Matching configuration* tab, to open the view shown in Figure 4.8.

In this view, the researcher can customise (or load) the parameters of the matching process according to his needs, and select the prediction task (described in Section 3.1.4) that the final dataset will be used in. For this example the pre-processed dataset created and the following parameters were selected:

- ***Attribute to predict***: WVHT.
- ***Reanalysis data***: Air, pressure, u-wind and v-wind.
- ***Buoy attributes to be used as inputs***: WDIR, WSPD, GST, DPD, APD, PRES,

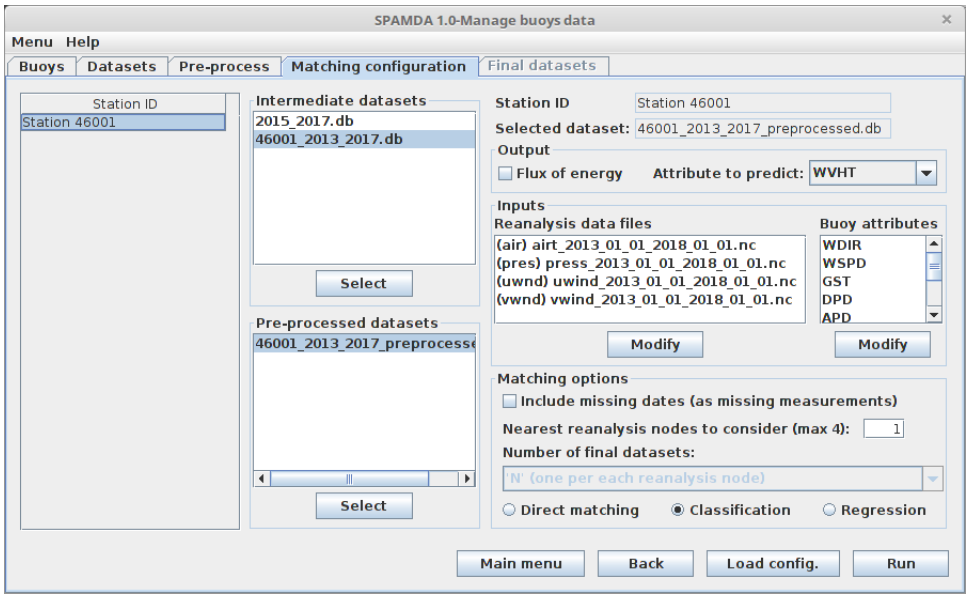

Figure 4.8: Tab *Matching configuration*.

ATMP and WTMP.

- ***Reanalysis nodes to consider***: 1.
- ***Number of final datasets***: In this example that option is disabled because only 1 reanalysis node is considered.
- ***Prediction task***: Classification.

After configuring the matching process, the researcher can click on the *Run* button to jump to the view shown in Figure 4.9 and proceed to define the final dataset structure according to the selected prediction task.

As in the previous window *Classification* was selected, now the researcher is able to add, modify or delete the thresholds (usually defined by an expert) used to discretise the output variable. After adding the necessary thresholds, the next step is to set the time horizon desired and also to activate (if desired) the synchronisation (in time) of reanalysis variables with the output one as explained in Section 3.1.5. Then the researcher would click on the *Update final dataset* button to see the content of the final dataset which is shown in the bottom left corner and finally, after checking that everything is correct, the last step would be to select the name (and path) of the dataset file, its output format and click on the *Create final datasets* button. For this case study the following configuration was applied:

- Thresholds: see in Table 4.1.
- Prediction horizon: 6 hours
- Synchronisation: Disabled

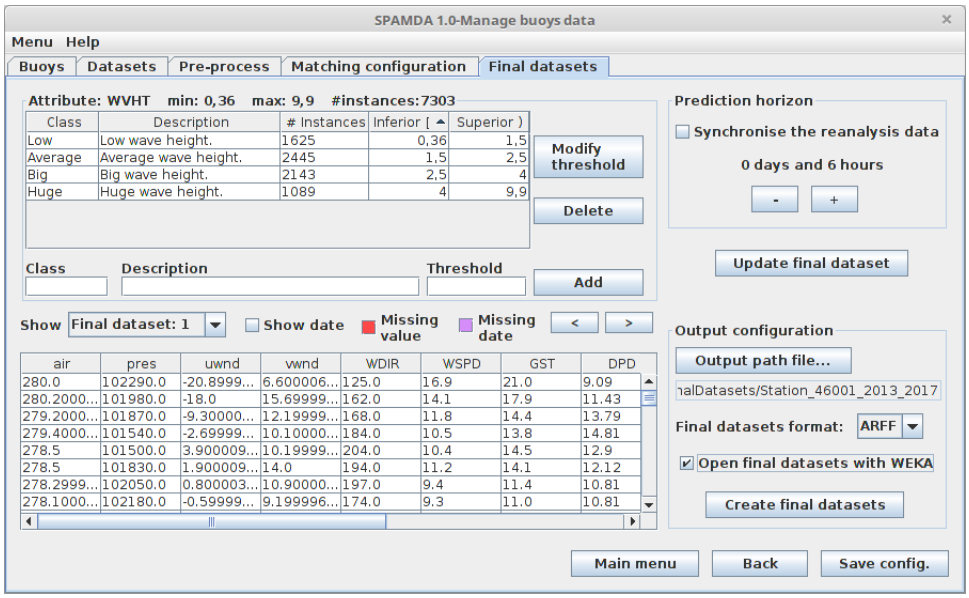

Figure 4.9: Tab *Final datasets*.

Table 4.1: Defined thresholds.

Class	Description	Inferior [	Superior)
Low	Low wave height	0.36	1.5
Average	Average wave height	1.5	2.5
Big	Big wave height	2.5	4.0
Huge	Huge wave height	4.0	9.9

At this point the final dataset would be created and stored in the computer of the researcher. Also there is an option to open the dataset with WEKA (after creating it) in order to perform a first classification approach or a preliminary study of the data structure, as shown in Fig. 4.10.

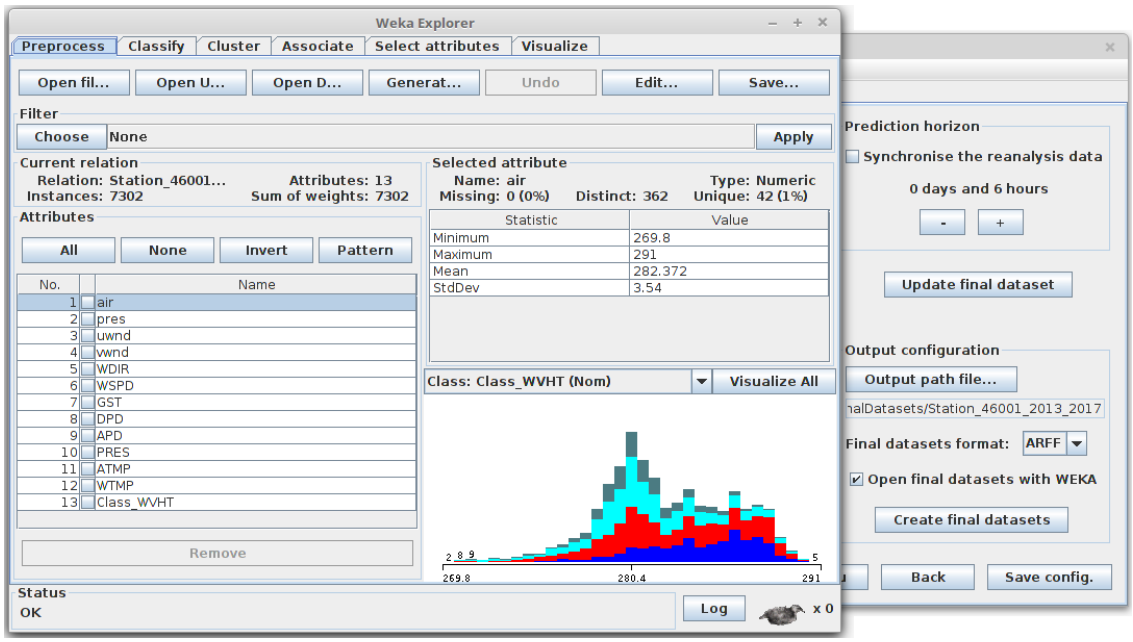

Figure 4.10: The final dataset opened with the environment Explorer of WEKA.

5 License of SPAMDA

A copy of the license of SPAMDA regarding the use and distribution of the source code and binary is included in the appendix entitled "License of SPAMDA" C.

6 Acknowledgments

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We also thank to University of Waikato for the Weka (Waikato Environment for Knowledge Analysis) software tool, to University Corporation for Atmospheric Research/Unidata for the NetCDF (network Common Data Form) Java library and to QOS.ch for the SLF4J (Simple Logging Facade for Java) library.

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Appendices

A Getting meteorological data

A.1 Getting an annual text file from NDBC

The following steps shows the procedure to obtain an annual text file that contain the measurements collected by a buoy from NDBC, concretely the file of the year 2017 corresponding to the buoy identified as *Station 46001*, moored at Western Gulf of Alaska.

- ***Step 1***: Open the web browser and visit the NDBC web page [6].
- ***Step 2***: Navigate to the desired buoy and click on the year to download (see Fig. A.1).

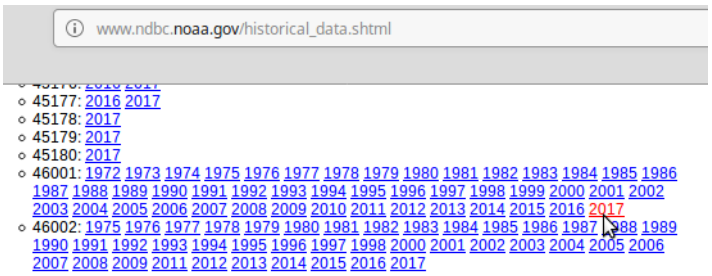

Figure A.1: Selecting the desired buoy and year.

- ***Step 3***: In the option ***Method Two*** click on the file (see Fig. A.2) and its content will be shown.
- ***Step 4***: In the menu bar of the web browser select ***File*** and ***Save As*** to save the file in the computer.

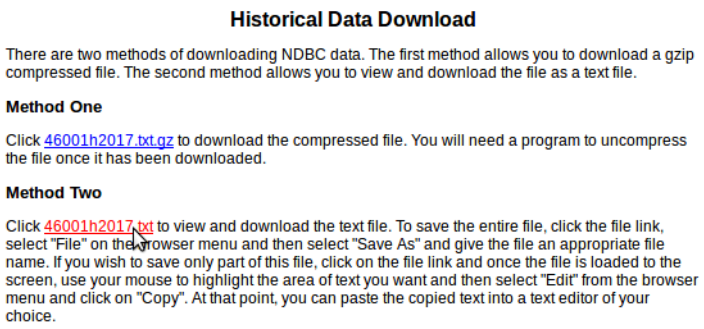

Figure A.2: Downloading the annual text file.

A.2 Getting a reanalysis data file from NNRP

The following steps shows the procedure to obtain a reanalysis data file from NNRP, concretely for the variable *Air temperature* and corresponding to the year 2017 and the reanalysis nodes 57.5 N × 147.5 W, 57.5 N × 150.0 W, 57.5 N × 152.5 W, 55.0 N × 147.5 W, 55.0 N × 150.0 W and 55.0 N × 152.5 W.

- ***Step 1***: Open the web browser and visit the NNRP web page [8].
- ***Step 2***: Navigate to the ***Surface*** section and click on it (see Fig. A.3).

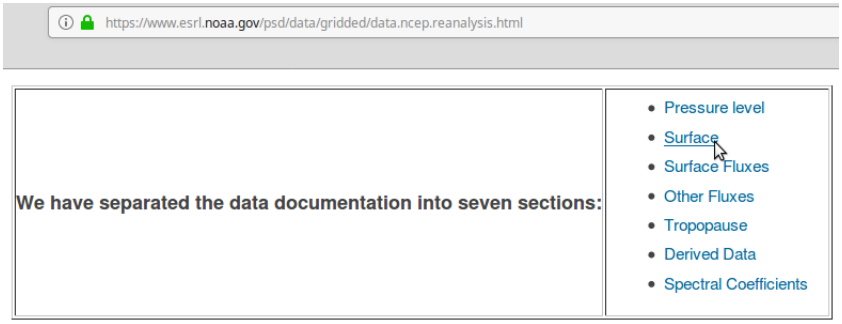

Figure A.3: Selecting ***Surface*** section.

- ***Step 3***: Navigate to the ***Update Schedule*** section, search for the statistic ***4-times Daily*** of the desired variable and click on the image for creating a plot or subset (see Fig. A.4).
- ***Step 4***: Navigate to the ***Surface*** level and click on ***Make plot or subset*** (see Fig. A.5).
- ***Step 5***: In the new web page that has been appeared do the following (see Fig. A.6):
  - In ***Axis Dimensions*** type the desired sub-grid (spatial properties).

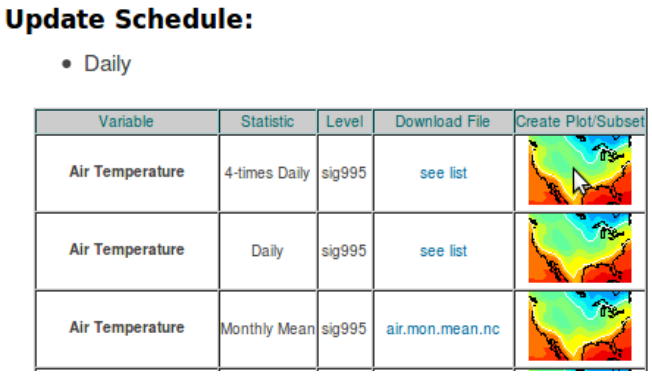

Figure A.4: Selecting reanalysis variable.

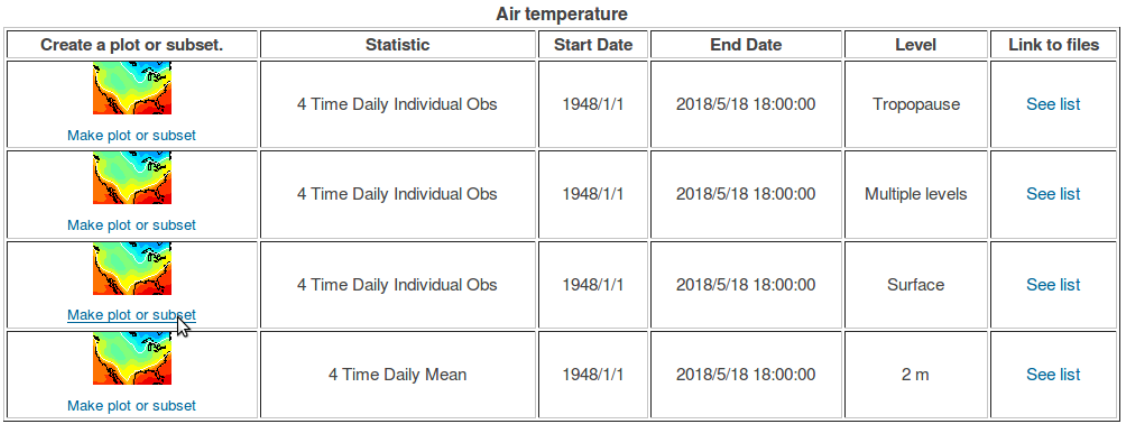

Figure A.5: Selecting ***Make plot or subset.***

  - In ***Other dimension value(s)*** type the desired ranges of dates (temporal properties).
  - In ***Output options*** select the option *Create a subset without making a plot.*
  - Click on ***Create Plot or Subset of Data*** button (at bottom of the web page) to generate the reanalysis data file with the desired properties.

- ***Step 6***: Finally click on ***FTP a copy of the file*** button to download the reanalysis data file on the computer.

Figure A.6: Typing desired properties of the file to get.

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Contact information:

Antonio Manuel Gomez Orellana.

email: am.gomez@uco.es

Address: University of Córdoba, Department of Computer Science and Numerical Analysis, Rabanales Campus, AYRNA Research Group, Einstein Building, 3rd floor. Road Madrid-Cádiz, Km 396-A. 14071 - Córdoba (Spain)

Juan Carlos Fernández Caballero.

email: jfcaballero@uco.es

Address: University of Córdoba, Department of Computer Science and Numerical Analysis, Rabanales Campus, AYRNA Research Group, Einstein Building, 3rd floor. Road Madrid-Cádiz, Km 396-A. 14071 - Córdoba (Spain)

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