Maritime data standardization in the Archimede Project

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ABSTRACT The concept of data standardization is explored with respect to the development of a highly heterogeneous meteo-marine archive, named Archimede. Meteo-oceanographic data collected from different instrumental platforms, spanning several decades, and obtained by many different subjects are found in the archive. Data standardization is introduced as Standardization = Metadata + Documentation + data Quality Control. The terms of the conceptual scheme are explained in different contexts and their relative importance is stressed. The operational use of the scheme is then dealt with to show how it can be exploited by scientists and qualified operators in the marine field for best use of Archimede data.

1. Introduction

Given the extensive coverage of contributions present in literature, the effectiveness of authoritative manuals and sets of recommendations freely and easily available on Internet, hardly anyone would be tempted to try and provide even a reasonably short review on the subject. Indeed, this contribution should be by no means considered as an attempt to give a possible set of rules about the treatment of marine data, nor is it intended to give any original ideas on a subject that has grown so much; encompossing so many different kinds of expertise. Such an exercise will stand and remain quite far from our scope.

The aim of the present contribution is merely to describe and discuss the set of practical methods that will be implemented to fulfill the various "best practice" recommendations for managing a highly heterogeneous archive of meteo-marine data, and, not secondarily, to try to build up a sort of common language to bridge the gap between different communities of users: oceanographers, coastal engineers and climatologists. We hope that such a common understanding will enhance the chances of a better implementation and development of the Archimede archive and might direct its users towards the best use of the available data.

As it will soon become apparent, a decadal experience in dealing with the management and archiving of meteo-oceanographic data has been fundamental in directing the course of our reasoning about the problems involved with the use (and misuse) of marine and meteorological measurements. Most of the examples and the concepts have been taken from our direct experience and some other simply by general common sense.

The logical path we will try to follow, stems from the need of using a common language for the term standardization of a relatively long series of data of very different nature, taking into account the evolution in time of the measurement methods, the problems related to the real-time operational networks of the instruments, and last but not least the issues related to the

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maintenance of large databases.

2. Overview of the monitoring measurement systems

The systematic monitoring of the sea level in coastal stations (initially not connected to a network) started well before the last century in Trieste (1859), Venezia (1871), Rimini (1867) and Genova (1883). Many other stations were built at an increasing rate in Italy, leading to the institution of a national permanent service for tidal monitoring (Servizio Mareografico), which dates back to 1920. During the long period of continuous operation [details of which can be found in literature, e.g.: Lama and Corsini, (2000)], it is important to mention (at least) that the national tide gauge measuring system (Rete Mareografica Nazionale - RMN) was upgraded in 1996 to a quasi - real time monitoring network of 26 stations, all equipped with meteorological sensors (Lama and Corsini, 2000). We must observe that, despite the long operational life of the network, only a few stations in Italy make very long term series of reliable observations available (with the noteworthy exceptions of Trieste, Genova, and Venezia). The explanation can be found in several causes, the main one being lies in the serious problem of long-term archiving of the long paper sheets of recordings (rolls).

According to historical records (Franco and Contini, 1997; Franco *et al.*, 2004), the systematic sea-wave monitoring started in Italy in the early 1970's due to the efforts of the Italian power company ENEL in the Ligurian Sea and the fuel company AGIP in the northern Adriatic. The work done in that period opened the way to a sudden increase of campaigns in the following decade and finally to the birth of a permanent national network, the national wave measurement system (Rete Ondametrica Nazionale - RON), in 1989. The RON national network has been fully real-time operational since 2002.

Besides this, wave, sea-level, current and meteorological data related to different areas of the central Mediterranean and collected in different time periods since the beginning of the 1960's in the framework of finalized projects of operational oceanography completes the Archimede archive.

To introduce the problem of quality control (QC) it would be useful to start from the generally accepted idea that there was a dramatic evolution in the measurement techniques around the 1970's in the field of geophysical measurements (i.e. wind, specific humidity, pressure, temperature, but also sea level). It would perhaps seem even obvious to assert that besides the big development in sensor technology, what really did change the method of measurement was the diffusion of automatic instruments coupled with computers, which were able to provide digital data without any human intervention. Before that time, data was read from a sheet of paper, validated on the basis of personal experience and manually recorded (written down in a log). The term validation of data refers, in practice, to the following operations:

1. manually reading the pen tracks on the paper roll at selected time references;
2. evaluating the value of the track on the y-axes correspondent to a prescribed time on x;
3. excluding spikes, gaps, errors;
4. eventually filling the gaps.

Generally speaking, once the data had been extracted to a record, it turned out to be also considerably smoother with respect to the original pen track, always depending on the personal experience of the operator.

Today, in the computer era, measurements are digitally recorded, transmitted away from the station and stored somewhere well before anyone can even have a look at the data. Moreover, in the last decades important changes have taken place also in the field of archiving: technology has rapidly moved from paper recording to magnetic tapes, solid state memories, CDs, DVDs and on-line digital archives made of redundant disk arrays. What was a process that was completely controlled by man is now almost exclusively done by computers.

There was no such abrupt change for more modern marine measurement techniques (i.e. remote wave buoys), since measurements were made possible only due to the availability of the new technologies.

Many different instruments and platforms have been tested in the many, more or less short campaigns, taken on in all the principal basins since the creation of the permanent national wave measuring network. Directional and non-directional buoys, spar buoys, disk buoys, pressure sensors, ultrasonic sensor and current meters mounted on platform offshore, all that and many more have been used according to the specific needs of offshore operations, coastal engineering, marine climatology. Most of the available information is in digital format, and a good quality description of the measurements is generally present.

3. Distribution of Archimede meteo-marine data

The Archimede meteo-marine data and metadata are available based on the rules of the Archimede data policy. In particular, the Archimede archive promotes national and international data sharing. All metadata are public. Each participant of the Archimede archive fixes his/her own rules for data distribution.

The meteo-marine data included in Archimede were released, during the first year of activity, by APAT (the RON and the RMN national networks data up to 2005), University of Salerno (C.U.G.RI.), Snamprogetti S.p.A. and OGS. Further contributions are expected for the second year.

In detail, Archimede wave measurements are distributed almost uniformly along the Italian coast, the Sicilian Channel and the Strait of Messina; span from 1971 to 2004, with 3,281,237 records from 42 stations. The sea level measurements also cover, almost uniformly, the Italian coastal area, with the highest platform density along the Adriatic coast and in the Strait of Messina; span from 1980 to 2004, with 10,469,912 records from 45 stations. Meteo recordings show the highest temporal covering including data from the Italian Meteorological Service in the stations of Bari, Pescara, Leuca, Rimini (29 years), Venezia (19 years), Dubrovnik, Pula, Split e Zadar (2 years). Even if the measurement points cover the Italian coast almost uniformly, the data give the highest density in the Adriatic coast and in the Strait of Messina; span from 1951 to 2004, with 2,091,755 records from 67 stations. Sea current recordings mainly cover the northern Adriatic, the Otranto channel, the Sicily strait, the Messina strait, the link between Sicily and Libya and some points along the Italian coast; span from 1973 to 1995, with 5,294,743 records from 166 stations.

Fig. 1 shows the overall spatial distribution of wave data stations (upper left panel), the measuring points of sea level data (upper right panel), the meteo parameters measuring points (including also meteo-marine buoy positions) (lower left panel), the sea current data stations (lower right panel). Data released by OGS are represented with a triangle, data released by APAT with a circle, data released by Snamprogetti S.p.A. with a star and data released by University of Salerno with a square.

4. Marine data standardization

Most of the frequent misunderstandings among users and maintainers of measuring stations are related to the use of the word validation. Even though it is quite transparent that data should be controlled for quality before being used or shared, to most of the operators the idea that someone else would validate their data sounds unpleasant if not offensive. To avoid any possible argument on the subject, which is central to the Archimede project development, it must be outlined that in the modern measurement technique there is no equivalent for the series of manual operations cited as validation above. Which does not necessarily mean that automatic stations provide automatically good quality data. Today manufacturers provide tools for the first automatic check on raw data directly on the platform (for example on the PC which also trims the sea level sensor acquisition).

Another relevant aspect (however obvious it might appear) is that technological improvements make available instruments with high time samplings, wide spectral bands, with many sensor and options. This often results (especially for connected networks of multi-use stations) in an enormous cascade of data, which must be dealt with properly just to avoid being overwhelmed. It must be stressed that garbage can result from bad quality measurement as well as from faulty transmission and storage. Even when the data are stored they are not secure from being messed up by errors in the database maintenance operations. Evident consequences derive from all that, many of which are relevant in the present discussion.

The basis of our discussion will be mostly the IOC and IOC/WMO Manuals and Guides [UNESCO (1985, 1994, 2002) for sea level observations; UNESCO (1987) for wave data; UNESCO (1999) for physical data; UNESCO (1975) for meteorological data] together with the report ESEAS-RI [Quality Control of sea level observations (Garcia *et al*., 2002)], the review prepared by Raicich (2007) and the methods proposed for wave measurement analyses in the Italian wave atlas (Franco *et al*., 2004).

The standardization issue has been faced when dealing with the Archimede meteo-marine data, being these related to different sectors, covering different time periods and coming from different sources.

According to the above cited recommendations, the process of standardization of data with respect to the Archimede activity is to be understood as:

Standardization = Metadata + Documentation + data QC

Within Archimede, data series are coded with respect to the QC procedures certified by the organizations which provide the data.

4.1. Metadata

We refer to metadata as the information generally needed to have a good chance of making a good use of data. Metadata should be concise, synthetic and exhaustive, which is somewhat

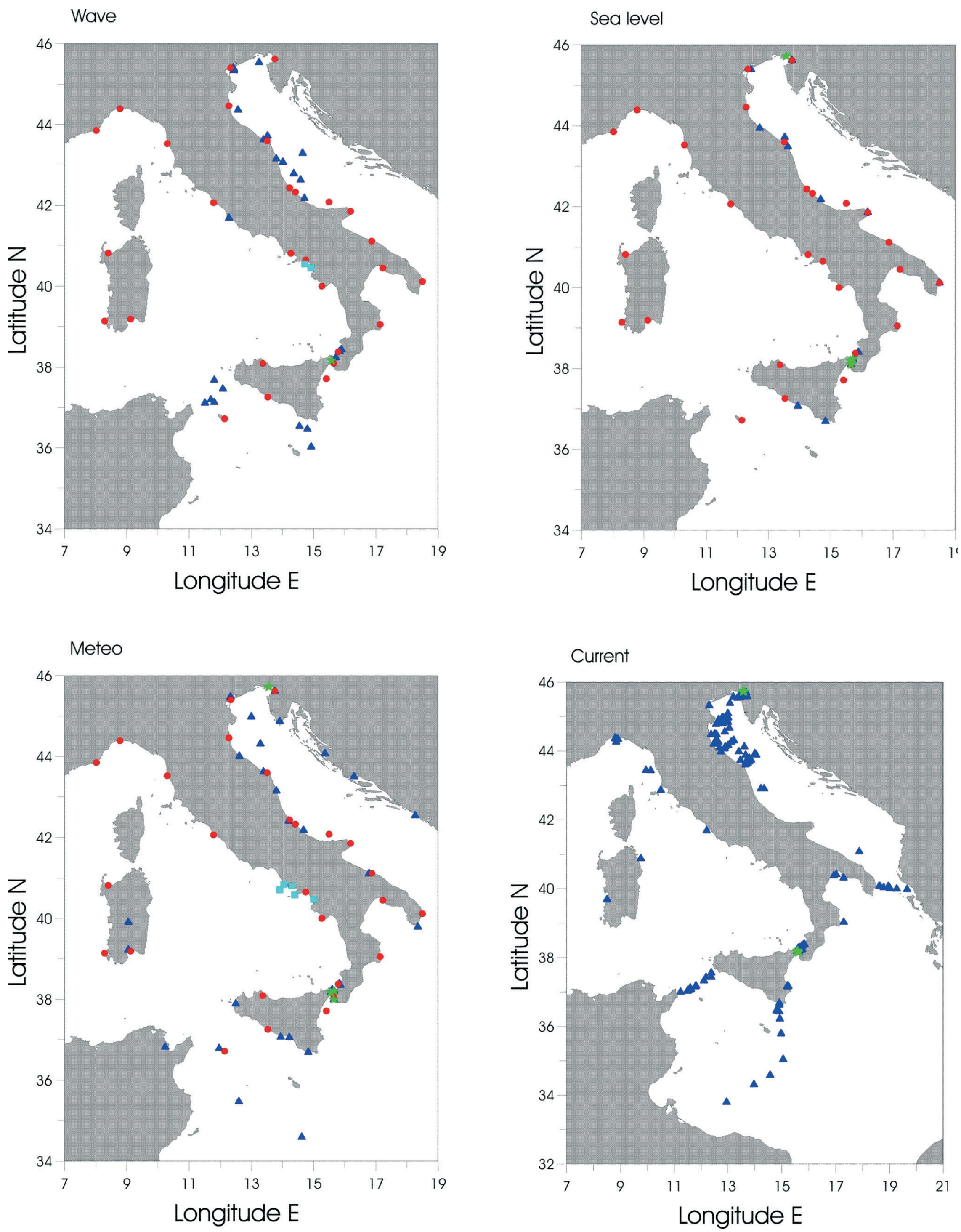

Fig. 1 - Spatial distribution of wave buoys (upper left), sea level stations (upper right), meteo and meteo-marine data (lower left), marine current data measuring points (lower right) released by OGS (blue triangle), by APAT (red circle), by Snamprogetti (green star) and by CUGRI (azure square).

inconsistent in practice. A good starting point (for geo-spatially referenced data) is the codified

Table 1 - Metadata of the Alghero buoy.

Iso country code	ITA (380)
Archimede identifier	W8902 RON-ALGHERO
Organization responsible for data collection	APAT
Originator' identifier for series	ALGHERO 199
Geographic location	40° 32' 54" N 08° 06' 24" E
Instrument type	Boa Datawell MK-I
Description of the installation	Receiving station in a private house
Date, time of start of the data series (ds)	01.01.1999 03:00
Date, time of end of the data series (ds)	23.12.1999 00:00
Time interval	3/0.5 hours (0.5 if height over threshold)
QC (L1, L2, Not QC)	L2
Data policy	Free
Available parameters	Hm0 (m), Dir (deg N), TP (s), Tm(s), TMP (°C)

set ratified as ISO-19115. According to this standard, the RON Alghero buoy wave data is complemented in the archive by the metadata reported in Table 1.

Table 2 - Metadata of the Lido station.

Iso country code	ITA (380)
Archimede identifier	L8606 RMN-VENEZIA
Organization responsible for data collection	APAT
Originator' identifier for series	VENEZIA 200
Geographic location	45° 25' 22" N 12° 25' 25" E
Instrument type	Ultrasonic tide gauge
Description of the installation	Stilling well is located near breakwater south
Date, time of start of the data series (ds)	01.01.2000 00:00
Date, time of end of the data series (ds)	31.12.2000 23:50
Time interval	10 min
QC (L1, L2, Not QC)	L1
Data policy	Free
Available parameters	Sea level (m)

In the same way, the Lido sea level station is complemented in the archive by the metadata reported in Table 2.

4.2. Documentation

In order to perform any type of analysis on the data, supplementary documentation becomes essential when measurements are qualified with automatic checks, with tools provided by the manufacturer.

To use these data correctly, the best (possible) documentation should be given. This includes the description of :

a) the instrument and where it is installed (both the sensor and the receiving station if it exists), the schedule of the maintenance, the operational history, including the settings (and changes) for the sampling rates and transmission;

b) the site, whose knowledge assumes a special importance for meteorological and sea level data, especially if, during the operative lifespan of the station, significant changes in the environment can systematically affect the measurements;

c) quality control and all procedures used to correct problems in the series of data (gap filling, timing/datum correction, despiking, smoothing or interpolating operations);

d) malfunctioning of the devices, unfortunate manual operations, power supply or battery faults, problems in transmission or storage. Reports on accidents and events are most useful.

Finally, of course, the specifics and results of the automatic check are essential.

4.3. Data QC

The QC procedure applied to measured data includes a first automatic check on the row data, the so-called Level 1 quality check (L1), and a subsequent human evaluation, or Level 2 quality check (L2). As mentioned before, the first one can be applied directly on the platform with the tools provided by the manufacturer. The second one is generally needed to assess the reliability of collected data with respect to the particular requested analysis (for example tidal analysis). For an L2 check, detailed information about the environmental operational conditions are generally needed.

4.4. QC procedure - Level 1 check

Usually the automatic acquisition system runs a series of automatic quality checks on the measured data setting a QC flag (number 1-10). But, as mentioned before, an automatic standard L1 check at the station does not guarantee that everything is still ok once data has been transmitted and stored in the archive. As an example, for wave buoys, most of the missing data are normally due to radio transmission problems, compatibility between the software on board and on the station, faults in the procedures of collecting and storing data from many stations.

A slight generalization of the normally recommended L1 controls, to be performed every time data has been moved or modified, should include:

- control on the text formatting (alphanumeric characters, numbers, signs, special characters);
- control that date and time are consistent with the sampling rate specification and metafile;
- control the presence of missing data or long gaps, out of range data, spikes, constant values in a time interval, suspicious values (not consistent with other measurement or information or repeated in different tables or at different times).

4.5. QC procedure - Level 2 check

The ensemble of L2 checks is done on the entire (or a long part of the) series, and is intrinsically related to the particular type of observation to be checked and to the particular data analysis to be done. In some sense, data are evaluated on the basis of the goodness of the results of the analysis. Consistent and robust results suggest that the data which are used are good enough.

5. Implementation of data standardization in the Archimede archive

In the framework of Archimede activities, a big effort has been made to provide the most accurate metadata and documentation. In fact, all metadata accompanying the data are archived together with the measured values and can be extracted in Medar/MedAtlas text format (Maillard *et al*., 2001). This includes a platform header with all measuring site information, a profile header with all time series information and the series of measured values.

In the case of the example previously reported of the Lido sea level station (Table 2), the metadata archived in the Archimede database are extracted with the text format shown in Table 3.

All Archimede metadata are freely and immediately available on-line at http://archimede.caspur.it and http://nodc.ogs.trieste.it/archimede/, being the visibility of the marine monitoring activity in Italy the principal aim of the project. Interactive selection procedures for data retrieval will allow anyone to search for classes of instruments in selected periods of time or in a selected area. The idea is that once the generic user knows what data are available and which organization is responsible for it, it becomes easier to request and obtain all the information. According to the data policy, data series are directly available on-line only for the organizations who participate in the project, i.e. which provide marine data to Archimede.

The documentation collected in the course of the project has been made available on Internet,

Table 3 - The Archimede metadata for the Lido sea level station in Medar/MedAtlas ASCII format. The first seven lines refers to platform header while in the following lines the profile header information are reported.

```
*IO481986L8606 RMN-VENEZIA                      XXXX UNKNOWN
28/08/1986 31/12/2004 ADRIATIC SEA
48 APAT, Agenzia per la Protezione dell'Ambiente e per i servizi Tecnici, Roma
Stefano Corsini                          Project=RMN
Regional Archiving= IO                   Availability=L
Data Type=D09 n=1     QC=N
COMMENT
*IO481986L8606VENE0 Data Type=D09
*DATE=28081986 TIME=1700 LAT=N45 25.80 LON=E012 20.22 DEPTH=999999 QC=1111
*NB PARAMETERS= 4 RECORD LINES= 384129
*YEAR CALENDAR YEAR                              (yyyy)              def.=9999
*DATE DATE WITHIN YEAR                           (mmdd)              def.=9999
*TIME TIME WITHIN DAY                            (hhmmss)            def.=999999
*SLEV OBSERVED SEA LEVEL                         (metre)             def.=999.99
*GLOBAL PROFILE QUALITY FLAG=0 GLOBAL PARAMETERS QC FLAGS=0000
*DC HISTORY=
*
*DM HISTORY=
*
*COMMENT
*ADDITIONAL INFORMATION - TIME SERIES
*EDATE=31122004 ETIME=0000 ELAT=N45 25.80   ELON=E012   20.22   EDEPTH= 99999      QC=1111
*SENSOR DEPTH= 0 (meter)                DISTANCE TO BOTTOM=99999 (meter)           QC=11
*DURATION= 6701 (day)                                                              QC=1
*SAMPLING RATE= -00099 (second)          MAGNETIC DECLINATION= (degree)
*MEASUREMENT DEPTH= 0 (meter)
*SURFACE SAMPLES=
*
```

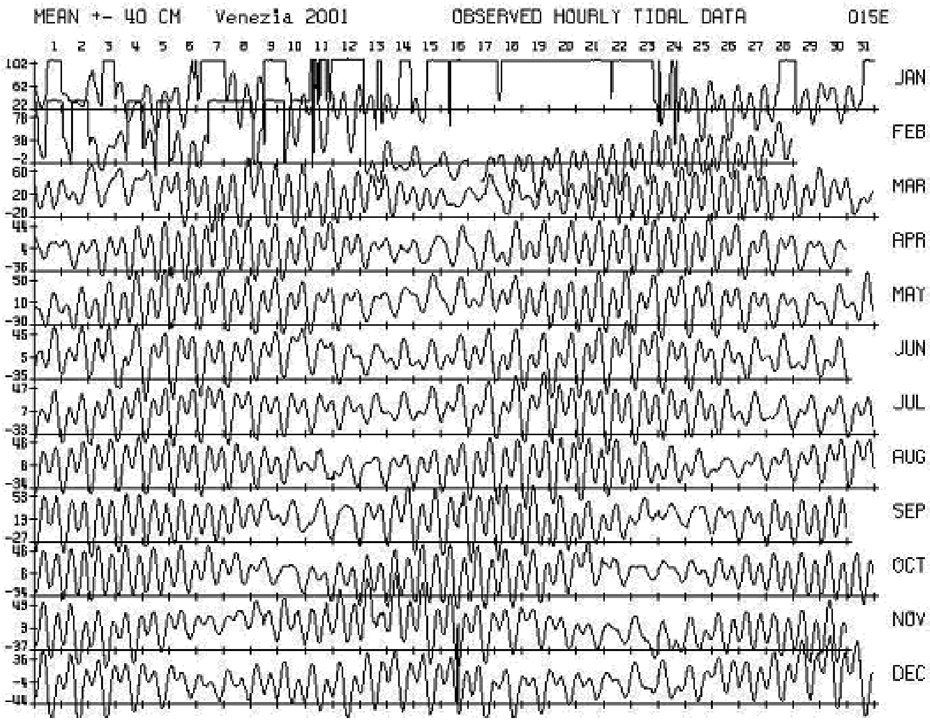

Fig. 2 - Hourly sea level data at Venice Lido station for the entire year 2001.

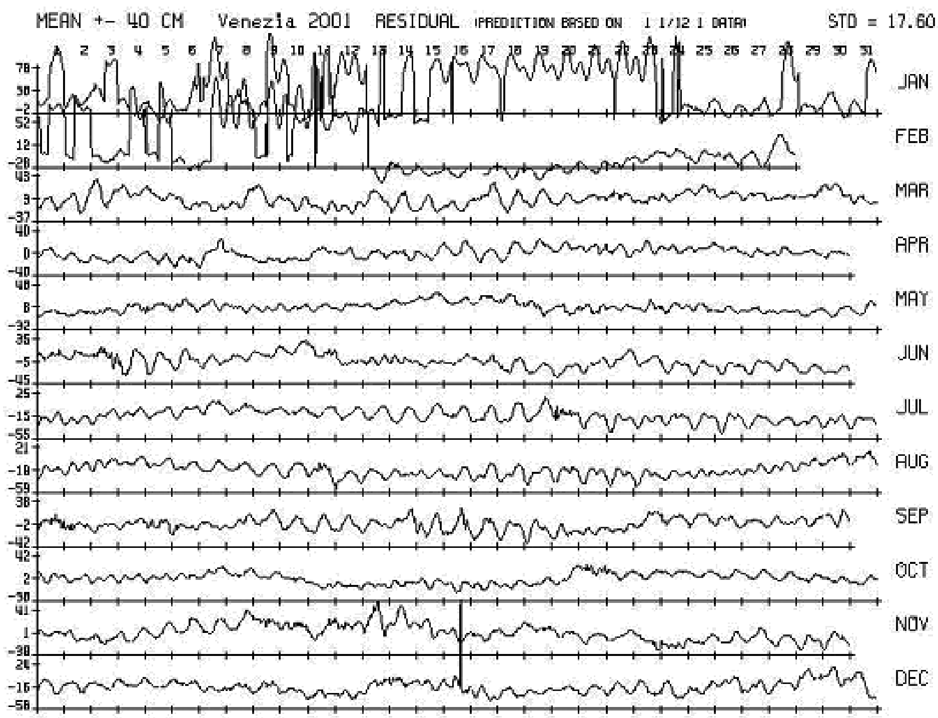

Fig. 3 - Residuals from hourly sea level data at Venice Lido station – year 2001.

Table 4 - Joint Frequency Functions table of Significant Wave Height versus Wave Direction (Hm0-dir) relative to the Alghero buoy for the period 01-07-1989 to 31-12-2003.

N.D.A.	N.D.P.	N.D.M.	N.Calms
42376	39094	3282	3856

Hm0 (m)																								
	549	189	114	71	65	54	49	47	46	52	89	429	1443	1755	1309	1535	2305	2168	1875	2857	8483	6596	1770	1388	35238
>=9.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2
8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2
8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-	-	5
7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	9	-	-	17
7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	20	13	-	-	34
6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	32	40	-	-	74
6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	44	40	-	-	85
5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3	2	78	75	-	-	161
5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	4	7	7	131	99	1	-	254
4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	12	14	6	14	172	153	1	-	375
4.0	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3	13	11	17	32	269	238	4	3	593
3.5	-	-	-	-	-	-	-	-	-	-	-	-	1	2	1	8	30	42	30	60	437	347	11	2	971
3.0	1	-	-	-	-	-	-	-	-	-	-	-	-	1	8	35	90	68	59	71	595	451	18	3	1400
2.5	9	-	-	-	-	-	-	-	-	-	-	1	5	7	21	66	208	136	105	137	789	586	44	11	2125
2.0	13	5	-	-	-	-	-	-	-	-	4	9	24	52	61	117	287	238	139	267	1029	717	90	46	3098
1.5	52	9	7	3	3	3	1	1	2	3	6	52	144	150	149	209	359	361	247	374	1330	949	131	116	4661
1.0	161	67	27	20	16	6	3	13	5	4	15	122	446	422	285	404	519	448	408	659	1611	1152	289	315	7417
0.5	313	108	80	48	46	45	45	33	39	45	64	245	823	1119	780	690	784	844	854	1228	1932	1726	1181	892	13964
-	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345	

α deg (N)

whenever needed and/or possible.

The QC procedure applied to Archimede data includes, in the first activity phase, a series of L1 checks. Beside this, the L2 control on sea level data could, as an example, work in this way: typically sea level data are reduced (checked for typical errors and filtered to hourly series), standard tidal analysis is carried out, residuals are calculated and inspected, statistics (daily, monthly, annual averages) are calculated. All results are compared with those of nearby stations, with different times and finally with models and forecasts. All the steps are important in order to detect anomalies and inhomogeneous values.

In Fig. 2 the time series of hourly sea level data series taken from the Lido station are shown month by month for the entire year 2001. The inspection (L1) shows constant values and spikes in January and spikes in November.

When the standard tidal analysis is performed, and the estimated tidal signal is subtracted

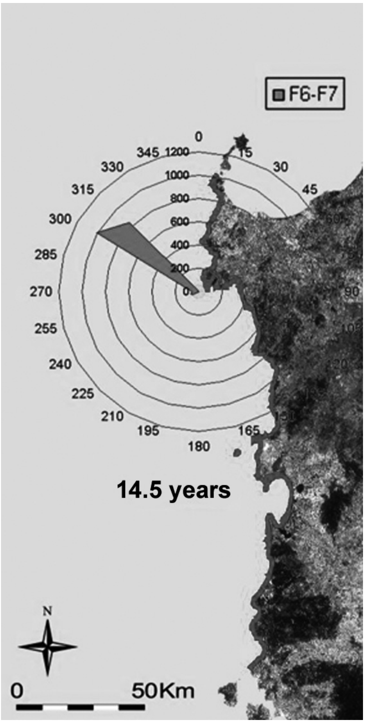

Fig. 4 - Radar plot of 3.5<Significant Wave Height<6 & Wave Direction relative to the Alghero wave buoy for the period 01-07-1989 to 31-12-2003.

from the series to give the residuals, the series of the residuals look like Fig. 3. Not only the presence of constant data and spikes in January and November is highlighted, but it is also clear that a problem of timing is likely to have occurred at the station.

The some applies to wind waves measurements, the L2 operations could, as an example, take into account the comparison with recordings of ordinary or special maintenance operations, calculation and inspection of Joint Frequency Functions tables for Spectral Significant Wave Height versus Wave Direction (Hm0-dir), Wave Spectrum Peak Period versus Wave Direction (Tp-dir), Spectral Significant Wave Period versus Wave Direction (Tm-dir). In Table 4, the Joint Frequency Function table of Spectral Significant Wave Height versus Wave Direction (Hm0-dir) relative to the Alghero wave buoy for the period 01-07-1989 to 31-12-2003 is shown. It is evident that not every direction has the same probability of being hit by waves, the higher the waves, the smaller the directional amplitude of the admissible waves. In the particular example, no waves greater than 2 m are expected in the range from 15 to 150 degrees N. The same conclusion can be drawn from Fig. 4, where the number of events with waves greater than 3.5 m and less than 6.0 m are represented. That, of course, is because waves have not enough fetch available to grow when the wind comes from the coast. This means that, if any significant event falls into that directional range, it would immediately be classified as wrong. The same could be applied, in principle, to wind data, even though, these being no fetch limiting directions, the observations can only be compared to climatological wind regimes. It can nevertheless be effective in detecting periods of malfunctioning of the wind vane.

In Fig. 5, a comparison between wave data extracted from the Archimede meteo-marine database and the European Center for Medium-Range Weather Forecasts wind wave WAM model (WAMDI Group, 1988) evaluated at the grid point closest to the buoy is shown. A close inspection of wave observations (dots only) pinpoints what looks like a very suspicious double high sea event. When observations are compared with model hind casts (line) it becomes clear that the second event is not real but it is only a spurious repetition of the first one. That has been confirmed by the comparison with the original records.

6. Conclusion

The Archimede archive is the first large example of a comprehensive and organized collection of meteo-marine data in Italy. The more it is populated and the more the information is used by the scientists the greater the result obtained by the Archimede project and the collection itself. A

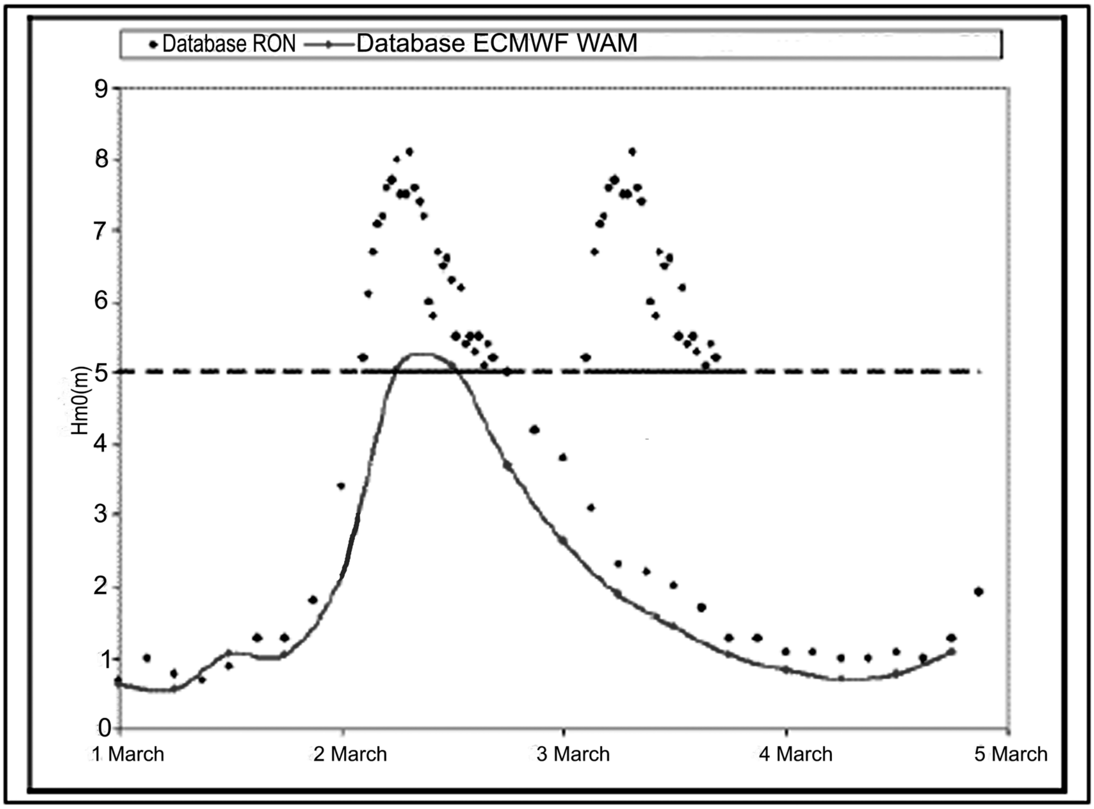

Fig. 5 - Comparison between buoy observations (dots) and ECMWF WAM data (line).

broad definition of data standardization has been a necessary step, having to handle measurements heterogeneous in typology, in time and space. The operational implementation of the conceptual scheme in the case of the Archimede meteo-marine data archive has been mainly devoted to fulfill the measured data with validated metadata and documentation. As a result, all users can select and have access to the Archimede metadata through a web based searching mask.

The better use of the available data will be supported promoting the implementation of L2 quality controls on Archimede data series. Upgrading of the data series is a long-term activity, that by starting with all the available data will, hopefully, improve with time.

International cooperation, exchange of both data and experiences will be fully supported by the Archimede project, promoting individual organizations to take part in all the significant activities at intergovernmental level.

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