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REVIEW

The importance of scientific data and historical heritage of the geophysical and astronomical observatory of coimbra university for the study of geophysical sciences

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Abstract
The Geophysical and Astronomical Observatory of the University of Coimbra (OGAUC) was officially created in 2013 after merging of two historical institutions: the Astronomical Observatory and the Geophysical Institute. As a result of almost 200 years of observations and research in astronomy and geophysical sciences, the OGAUC possesses a unique and valuable collection of long-term observational and instrumental records. These data have an indispensable value in current geophysical and climatic studies, being among the most complete and significant in Portugal and the world. The OGAUC's data collections are complemented by a vast technical-scientific production such as reports, research memoranda, articles, books, and instruments. This archive is largely not inventoried and poorly studied (particularly concerning meteorological, geomagnetic, and seismological data). This paper highlights the importance of the OGAUC's extensive data collection and discusses the difficulties and barriers related to its inventorying, preservation, and dissemination to the scientific community, policymakers, stakeholders, and the general public.

KEYWORDS
astronomical historical data, climate historical data, geomagnetic historical data, geophysical and astronomical observatory of the university of coimbra, seismic historical data

Dataset

Monthly means of the absolutely measured geomagnetic elements (DIHZF) – https://doi.org/10.5281/zenodo.4308022– Publication date: October 23, 2020; https://doi.org/10.5281/zenodo.4308022

Homogenized monthly means of all geomagnetic elements – https://doi.org/10.5281/zenodo.4308036– Publication date: October 23, 2020; https://doi.org/10.5281/zenodo.4308036

Hourly means of XYZ geomagnetic elements – https://doi.org/10.1594/PANGAEA.863000

Local geomagnetic K indices – https://doi.org/10.1594/PANGAEA.863108

There are some seismic data from the Geophysical and Astronomical Observatory of the University of Coimbra that are with DOI in some repositories (see Table 1 of the manuscript). However, the vast majority of the data from this observatory does not yet have a DOI, as stated in the manuscript.

1 | INTRODUCTION

The Geophysical and Astronomical Observatory of the University of Coimbra (hereafter OGAUC) was officially created in 2013 after the merging of two old institutions: the Astronomical Observatory (hereafter OAUC), built-in 1799, and the Meteorological and Magnetic Observatory, founded in 1864 (Lopes, 1893) renamed Geophysical Institute of the University of Coimbra (IGUC) in 1925 (Santos, 1995). Although formally a recent institution, the OGAUC is the heir of a unique observational and scientific history in Space and Earth sciences, placing itself as one of the oldest Portuguese scientific research and teaching institutions in those areas. The OGAUC has a significant collection of data and documentation, which places it in a privileged position both on the national and international scene, not only in geosciences but also in the history of science. Although virtually all records of astronomical activity made throughout the 19th century have been lost, images and data from solar observations made since 1926 are preserved (see later in this article). As for the geophysical collections and records of observations, the situation is different due to the preservation of an essential volume of information and data for the whole period of activity.

However, it is not only due to the scientific importance of the observational data that these archives are relevant. They are also especially important to the history of science, as they are essential for understanding the history, culture, and evolution of knowledge over time. Though, many of these archival collections are not readily available or even known to the scientific community.

This article aims to characterize the archives and collections of OGAUC and to present the difficulties and barriers to their preservation and dissemination. This discussion seems even more necessary and urgent as the transfer of IGUC, and its archives, to the buildings complex of the OGAUC located in the Santa Clara complex (see Figure 1) is being prepared.

2 | A BRIEF HISTORY of OGAUC AND ITS FORMER OBSERVATORIES

The Astronomical Observatory (OAUC) was conceived as part of the reform of the university studies undertaken by the all-powerful Marquis of Pombal, Minister of King José, in 1772 (e.g., Araújo, 2000). The 'Pombaline Reform' of the University aimed to introduce the teaching of exact and natural sciences in Portugal in a modern way. The OAUC was initially planned to be built on the site of the city's Castle. However, it would end up being built in the domains of the University, on the southern edge of the 'Paço das Escolas', in the 1790s. It remained in this location until the mid-twentieth century (Figueiredo, 2015) when it was demolished due to the University's requalification works carried out by the 'Estado Novo' in the 1940s–1960s. A new one was built in Santa Clara, a small hill on the left margin of the Mondego River, about 10 km from where the old observatory had operated for almost 150 years (see Figure 1). The astronomical role and practice required for the OAUC tied it to a particular dichotomy. Although linked to the University as a teaching facility, it was conceived as a national observatory to calculate astronomical ephemerides and help with cartographical and navigational issues. Its scientific program brought it into line with the foreign national observatories. Celestial mechanics and teaching role were its main scientific program until almost the end of the 19th century. However, due to the new scientific and technological discoveries about the nature of light and spectroscopy, in the mid-19th century, began the interest in the new solar observations. This interest was accompanied by the possibility of photographing the chromosphere and the solar corona, which were visible on those rare occasions of solar eclipses. In 1871, the OAUC acquired a spectroscope and a photoheliograph, and some years later, an instrument to observe solar protuberances. Despite that initial interest, the OAUC would not leap into this new field, remaining committed to its astronomical ephemerides' calculation program and the teaching of practical astronomy and celestial mechanics. Only in the 1920s would an astrophysics program related to the study of the Sun be implemented at OAUC (Bonifácio, 2017). In 1926, Francisco Costa Lobo (1864–1945), then director of OAUC, installed a systematic daily solar observations program of sunspots, faculae, filaments, and prominences, on Ca II and Hα lines. Costa Lobo also begins the systematic publication of his observations in a periodical entitled 'Anais do Observatório Astronómico da Universidade de Coimbra', published by Coimbra University Press. Curiously, the spectroheliograph used for these observations was installed in a building purposely built on the Geophysical Institute (IGUC) campus. In the 1950s, the spectroheliograph was transferred to the new OAUC facilities in Santa Clara. After subsequent technical upgrades, it is still in full solar observing activity today (using a CCD camera).

Back in the middle of the 19th century, the study of the sun–earth interactions, particularly through the interdisciplinary nature of solar physics, terrestrial magnetism, and meteorology, received great enthusiasm and financial support from nations. Portugal did not remain oblivious to this current scientific development. From early on, the University of Coimbra sought to create a meteorological and magnetic observatory similar to the best in Europe. Although some meteorological observations were already being made in the Physics Cabinet (Alcoforado et al.,

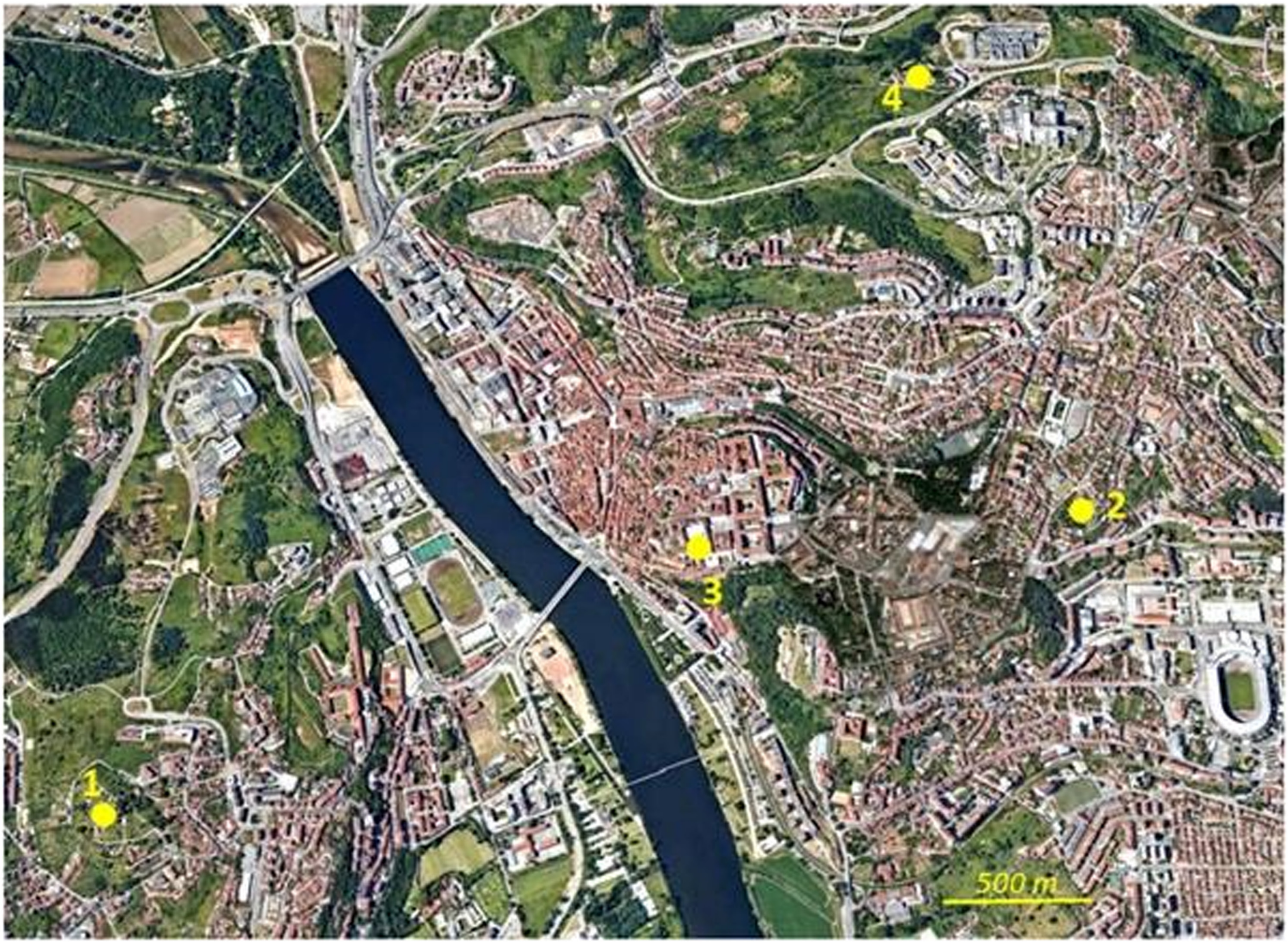

FIGURE 1 Locations in the city of Coimbra of the actual Geophysical and Astronomical Observatory (1), the former Meteorological and Magnetic Observatory (2), former Astronomical Observatory (3), and Alto da Baleia magnetic station (4)

2012; Leonardo et al., 2011a), the truth is that there was no actual observatory worthy of the name. A scientific establishment was planned to implement the desired systematic observational program that would place itself at the forefront of research in the so-called 'physique du globe' sciences. As a result of the University's efforts to create such an institution, the young professor of the Faculty of Natural Philosophy, Jacinto de Sousa (1818–1880) (Duque, 2018) was sent in 1860 to some European observatories to find out about their activities and scientific programs. One of the foreign observatories that he visited and spent some time on was the Kew Observatory in London. He met distinguished geophysicists, namely B. Stewart (1828–1887) and E. Sabine (1788–1883), who would give him all the support he needed. The relationship established with the Kew staff was crucial to all future planning of the scientific activity of the new Coimbra observatory.

The Meteorological and Magnetic Observatory was built on a small hill outside the city limits, about 1 km from the University. Today an important urban avenue (Av. Dias da Silva) in the city of Coimbra (see Figure 1).

The construction works began in 1862, according to an architectural design 'combining the greatest economy with everything that can be scientifically desired' (Sousa, 1862), made by the engineer R. Bekley (1821–1885) from the Kew Observatory. In 1864, the rectangular-shaped building on two floors and a basement, with a half octagon rising in the front, was completed (only the dome was still unfinished and had a temporary roof). By the second semester of that year, it goes into service. The influence of the Kew Observatory was also vital for the IGUC's primary instrumental equipment, which was acquired under the scientific supervision of B. Stewart. The first 30 years of IGUC were mainly devoted to meteorological and geomagnetic studies. However, trying to keep up with international developments in other geophysical studies, such as the modern earthquake research (new seismology) of the 1880s, the IGUC started experimental seismic recording with an Angot seismograph in 1891 (Kilian, 1894). In 1903 with the installation of a Milne seismograph, the IGUC started a continuous operation program of seismological registration, the first of Portugal's mainland

TABLE 1 Some data from IGUC on national and international databases

	Data	Period	Available online	Link to webpage	DOI
Bulletins IGUC	Meteorological and magnetic	1864–1890	Yes	#1	No
	Meteorological and magnetic	1891–1908	Yes	#2	No
	Meteorological, magnetic and seismic	1909–1920	Yes	#3	No
	Meteorological, magnetic and seismic	1921–1981	Yes	#4	No
	Meteorological (monthly)	2002–2005	Yes	#5	No
	Meteorological (monthly)	2015–2017	Yes	#5	No
Solar data	Spectroheliograms (H alpha, CaII K1, CaII K3)	1926–2007	Yes	#6	No
	Spectroheliograms (H alpha, CaII K1, CaII K3, H alpha continuum, dopplergram)	2007-present	Yes	#7	No
	Spectroheliograms (H alpha, CaII K1, CaII K3, H alpha continuum, dopplergram)	The last 6 days	Yes	#8	No
	Spectroheliograms (H alpha)	few	Yes	#9	No
	Spectroheliograms (H alpha, CaII K1, CaII K3)	2020–2021	Yes	#10	No
	Sunspot	1929–1941	Yes	#11	No
Meteorology	Temperature values	1865–2005	Yes	#12	Yes
	Climate variables (30 years average)	1961–1990	Yes	#13	No
	Climate variables (30 years average)	1971–200	Yes	#14	No
Magnetism	Annual means of all geomagnetic elements	1866–2020	Yes	#15	No
	Monthly means of the absolutely measured geomagnetic elements (DIHZF)	1866–2015	Yes	#16	Yes
	Homogenized monthly means of all geomagnetic elements	1866–2015	Yes	#17	Yes
	Hourly means of DHZ geomagnetic elements	1964–1965	Yes	#18	No
	Hourly means of DHZ geomagnetic elements	1979–1987	Yes	#18	No
	Hourly means of DHZ geomagnetic elements	1992–2004	Yes	#18	No
	Hourly means of XYZ geomagnetic elements	2007–2014	Yes	#19	Yes
	Local geomagnetic K indices	2007–2014	Yes	#20	Yes
	Minute means of XYZF geomagnetic elements	2007–2020	Yes	#21	No
	Monthly Bulletins (with K indices & Rapid variations)	2014–2020	Yes	#22	No
Seismicity	Seismograms	1915–1930	Only fews	#23	No
	Seismograms	1915–1994	Only fews	#24	No
	Seismograms	1909–1994	Only fews	#25	No
	Seismograms	1909–2004	Only fews	#26	No
	Seismic analysis	1904–2021	Only fews	#27	Yes
	Seismic analysis	2011-present	Yes	#28	No
	Seismic analysis	2007-present	Yes	#29	No
	Waveforms and seismic analysis	2016-present	Yes	#30	No

Note: #1 – http://webopac.sib.uc.pt/search~S17*por?/.b1597930/.b1597930/1,1,1,B/l856~b1597930&FF=&1,0,,1,0#re

#2 – http://webopac.sib.uc.pt/search~S17*por?/.b1594116/.b1594116/1,1,1,B/l856~b1594116&FF=&1,0,,1,0#re

#3 – http://webopac.sib.uc.pt/search~S17*por?/.b1597931/.b1597931/1,1,1,B/l856~b1597931&FF=&1,0,,1,0#re

#4 – http://webopac.sib.uc.pt/search~S17*por?/.b1597932/.b1597932/1,1,1,B/l856~b1597932&FF=&1,0,,1,0#re

#5 – http://www.astro.mat.uc.pt/novo/observatorio/site/clima.html

#6 – http://www.astro.mat.uc.pt/novo/observatorio/site/arquivo.html

TABLE 1 (Continued)

#7 – https://bass2000.obspm.fr/home.php
#8 – https://www.ipma.pt/pt/espaco/sol/
#9 – http://ghn.njit.edu/index.php
#10 – http://www.mat.uc.pt/~obsv/SPINLab/SPINLab_database.php#solar
#11 – http://haso.unex.es/haso/wp-content/uploads/2018/12/COI-catalogue.txt
#12 – https://doi.pangaea.de/10.1594/PANGAEA.785377
#13 – http://www1.ci.uc.pt/iguc/dados_cllima/norm6190.htm
#14 – http://www1.ci.uc.pt/iguc/dados_cllima/norm7100.htm
#15 – https://geomag.bgs.ac.uk/data_service/data/annual_means.shtml
#16 – https://doi.org/10.5281/zenodo.4308022
#17 – https://doi.org/10.5281/zenodo.4308036
#18 – http://wdc.bgs.ac.uk/dataportal/
#19 – https://doi.org/10.1594/PANGAEA.863000to https://doi.org/10.1594/PANGAEA.863007
#20 – https://doi.org/10.1594/PANGAEA.863108to https://doi.org/10.1594/PANGAEA.863115
#21 – http://wdc.bgs.ac.uk/dataportal/
#22 – https://spinlab.ogauc.pt/SPINLab_home.php
#23 – http://storing.ingv.it/es_web/Data/Es_map.html
#24 – http://storing.rm.ingv.it/es_web/
#25 – http://sismos.rm.ingv.it/index.php/sismogrammi
#26 – http://www.astro.mat.uc.pt/novo/observatorio/site/index2.html
#27 – http://www.isc.ac.uk/iscbulletin/search/
#28 – https://www.orfeus-eu.org/data/
#29 – https://www.ipma.pt/en/publicacoes/boletins.jsp?cmbDep=sis&idDep=sis&idTema=&curAno=-1
#30 – https://www.iris.edu/app/station_monitor/#Today/SS-COI/webicorder/

stations. In 1904, the seismic data of the seismic station of the IGUC (Viegas, 1910) appearing as COI[1]on the seismic analysis, became part of the international bulletins (Rosenthal, 1907).

In 1925, the Meteorological and Magnetic Observatory (OMMUC), reflecting the scientific evolution of the different primitive areas of the 'physique du globe' of the 19th century into the more comprehensive geophysical sciences of the 20th century, changed its name to Geophysical Institute (hereafter IGUC). Over time, some adaptations were made to the existing buildings. New ones were built to meet the successive demands of scientific practice and recent research areas. In the 1930s, due to the city's urban growth in the surrounding area of the observatory and its consequent electrification, magnetic observations were no longer possible in the IGUC installations. A new station for these observations was built within the city limits (Alto da Baleia, around 2 km from IGUC, Figure 1).

At the beginning of the 21st century, the IGUC began to make the transition from analogue to the automatic recording of meteorological, geomagnetic, and seismic stations. While it is understandable that digital data acquisition is usually accompanied by a reduction in the number of staff and observers (due to the automatization of processes), this transition was accompanied by clear disinvestment in personnel, beyond the minimum necessary to maintain the best operationality of the stations. More as part of an economic than scientific strategy, this progressive disinvestment of the Faculty of Sciences led the university authorities to propose the merging of the IGUC with the OAUC and its future relocation to the Santa Clara premises. Such a merger was carried out in 2013, giving rise to the 'new' OGAUC. With the transfer (currently underway) of all IGUC archives (documents, observational data, books, instruments, etc.), the main building and most of the other buildings will be transferred to the Faculty of Economics and Rectory. The historical decontextualization and eventual loss of a rich and invaluable scientific heritage are thus underway. The OGAUC, particularly the IGUC, had an essential contribution to Portugal's scientific knowledge and development. The acquisition of solar images and the recording of telluric activity began at IGUC, which has also been operating as the only Portuguese magnetic observatory since the beginning of the 20th century. Throughout its 200 years of scientific activity, OGAUC, through its founding institutions, has produced a unique and precious collection of long-time series of solar, meteorological, geomagnetic, and seismic data. These should be preserved, studied, and contextualized in this significant international geoscience scientific movement. Each series has a specific value, but the availability of all the series in one place is an added value worth considering.

[1]Station codes (as COI) were introduced in the 1960's. In previous years there were no codes.

3 | THE OGAUC'S ARCHIVES: LOOKING AT THE PAST TO FACE THE FUTURE

Geoscience data and collections are the sources of basic and applied geophysical research and essential resources in training and educating future scientists and the general public. They provide information to investigate geophysical phenomena and address response strategies for many natural hazards and critical societal problems (e.g., earthquakes, climate change, and space weather). In short, they are vital for understanding our planet's geophysical past and predicting what may occur in the future.

The OGAUC archival material faces significant challenges regarding its preservation, inventorying, cataloguing, study, and availability to the scientific community and public in general. These problems are common and transversal to most Portuguese archives, whether they belong to various institutions (public and private), provenances, and natures. The general and common idea to researchers that work and use the many and varied national archives is that much remains to be done, which compromises the use and access. The leading causes for this situation are identified as under-budgeting and management problems (Carvalho, 2019).

The historical archives of OGAUC have also suffered from these problems. The enormous collection of data and the varied technical-scientific documentation produced over several decades have not always had the attention and management (funding) necessary for its preservation and dissemination. Presently, due to the amount of data and the storage conditions, they require special attention regarding their maintenance and archival treatment to become available to the scientific community. We hope, therefore, that the OAGUC and the University of Coimbra will overcome the chronic problems of under-budgeting, recognizing in these archives the memory of the teaching and scientific work carried out over time, which is the raison d'être of the institution. Another problem that significantly affects these archives is their visibility and access, which is somewhat restricted beyond the gates of the University and its own research centers. The OGAUC archives are poorly inventoried and are minimally treated (Table 1), which does not allow their use and study to outside researchers (and often even to the University's researchers), much less to the general public. This archive has tens and tens of thousands of observational data and a multitude of documents and instruments in a precarious state of storage. Although the decision to transfer the IGUC archives to the OGAUC complex in Santa Clara before they are fully inventoried may involve some dangers (namely, throwing away many documents), however, this process may rescue the archive to a new life. This transfer implies keeping in mind issues such as selecting material to preserve, future storage, inventorying, and cataloguing of all documentation, and paying particular attention to scientific observational data.

All this process will be complex, and one of the primary problems is related to the room space and resources, which are finite, so deciding what to keep and discard will undoubtedly be necessary. Moreover, as far as the material to be kept is concerned, it must not be pushed into a basement or attic and deposited there. To ensure that unique documents of great importance to the scientific history of the institution are not lost, it is necessary to pay attention to these issues when relocating the collection and archives of the former IGUC. The significance and variety of the IGUC historical-scientific archive will require a careful analysis of all its documentation and material. The preservation of archives is a means, not an end. The archive's approach to treatment must be based on its future purpose: to research geosciences and the history of science (and eventually others). As mentioned by Nascimento et al. (2019), the implementation of measures aimed at preserving the information contained in historical records requires the involvement of a large team, given the importance of these data at a scientific and historical level. So, any intervention that will be made on the IGUC archive should be supported by geoscientists, historians of science, and people from the science of archives and museology. Historians of science provide a unified view of the science conducted at IGUC (its production, logic, and dissemination) and its value in the context of the institutionalization of the geosciences, both nationally and internationally. Knowing those scientific practices and methodologies, their evolution and dynamics will allow a critical reading of the archival material to be preserved or eventually discarded. The role of geoscientists is crucial to verify the importance of observational data and related metadata (notebooks, instruments, time setting, calibration and modifications into recording instruments, identification of signals, etc.).

On the other hand, archive materials' selection and classification (cataloguing) should be made according to three guidelines: institutions, people, and scientific production. That will allow a more careful selection of material to preserve and/or discard by archivists in each area. All this work is fundamental to enable the retrieval, availability, access, and future use of all the documentation, particularly for the community of geoscientists.

The dissemination, sharing, and study of existing data in scientific, historical, and cultural institutions are increasingly important. That can only be done effectively

FIGURE 2 IGUC's archive rooms

using digitization and digital platforms to create a historical database. Wilkinson et al. (2016) understood that there are numerous stakeholders involved in this issue. It was necessary to provide standard guidelines for all those involved and interested in digitally searchable academic objects. In 2016, the 'FAIR Guiding Principles for scientific data management and stewardship' were published in Scientific Data. The idea was to help all people who publish and/or preserve data, to have simple guidelines '*to improve the reuse of their data holdings*' (Wilkinson et al., 2016). As referred by those authors, good data management will strongly contribute to knowledge discovery and innovation. If the data are available and well managed, it is more easily and efficiently integrated and reusable by the scientific community. The FAIR principles define that the data must be: Findable, Accessible, Interoperable, and Reusable (Kinkade & Shepherd, 2021; Wilkinson et al., 2016), and should be applied to all scholarly digital research objects (SDRO) (data, algorithms, tools, workflows, etc.). However, it is crucial to ensure that all process components are available to assure its transparency, reproducibility, and reusability (Wilkinson et al., 2016). Data and its protection are nowadays a sensible and problematic issue. To help the archive services in Europe, the European Archives Group (EAG) published in 2018 a Guidance on data protection, particularly for personal data. The document gives guidelines for implementing the archive sector's general data protection regulation (European Archives Group, 2018). These issues should be considered when OGAUC intends to make all its archives available to the scientific and public communities in the future. The University of Coimbra is implementing a new web platform service to make available all the data and digital archives of the institution (https://ucpages.uc.pt/ucframework/apps/ucpages/). That is a great set to overcome barriers to disseminating the IGUC archive contents. Nevertheless, the difficulties of making the data in digital format are still present and require an urgent solution.

3.1 | The IGUC archive and collection

In virtue of more than 150 years of observations and scientific activity, the archive of former IGUC presents a unique and precious collection of a long series of geophysical data (the climatic records, 1864; geomagnetic records since 1866, and seismograms since 1903).[2] The long historical data series are almost uninterrupted till today. There are approximately 50,000 magnetograms and almost the same number of seismograms and a massive collection of paper records of graphs of various meteorological variables

[2]That fact was the motto for HISTIGUC Project, a scientific research project financed by FCT (PTDC\FER-HFC\30666\2017) which aims to study the scientific, historical and patrimonial heritage of the OMMUC/IGUC (https://sites.google.com/view/histiguc-project/).

(temperature, humidity, pressure, wind, rain, etc.; Figure 2). However, this vast collection is mostly in print/analogue format (e.g., Custódio et al., 2010, 2012; Gomes & Lopes, 2017; Leonardo, Custódio, et al., 2013; Leonardo et al., 2011b; Morozova & Valente, 2012; Ribeiro et al., 2011). In addition, there is a vast technical-scientific collection of reports, memoranda, books, scientific journals, notebooks (Figure 2), and instruments. The preservation of that material is imperative; otherwise, valuable and exclusive records will be lost forever.

The library covers a range of scientific areas (e.g., climatology, geomagnetism, aeronomy, seismology, environment, etc.) with an excellent and remarkably well-preserved collection of books and a massive collection of periodical publications (scientific journals and data bulletins/yearbooks). A testimony to the global network that these kinds of observatories have established among themselves over time.

Following its function as a research observatory, IGUC soon began publishing its observations in annual yearbooks and bulletins, in line with its foreign counterparts. Many of these yearly bulletins/yearbooks have been digitized under a research project on the history of science funded by the Fundação para a Ciência e Tecnologia (History of Science at the University of Coimbra (1547–1933), PTDC/HIS-HCT/102904/2008). Although they do not yet have a DOI, they are now freely accessible via the web.[3]The repository of the University of Coimbra, named 'Estudo Geral' (https://estudogeral.uc.pt/?locale=en), is currently going through the process to be able to assign DOIs, which means that in a very short period of time, all the digital documents present in this repository will have DOIs, which implies all the IGUC's bulletins. These data yearbooks also provide valuable information on the evolution and operation of the observatory, namely on the instruments used over time and the observation methods and routines. In the next section, we will discuss this issue in more detail.

Concerning the collection of historical scientific instruments, an important set of about one hundred meteorological and geophysical instruments is relatively well preserved. Some are still in situ where they were first installed (e.g., the Adie barometer acquired in 1864, or the Wiechert horizontal seismometer acquired in 1911). They are among the best preserved in the world (e.g., the Milne seismometer).

3.1.1 | The IGUC bulletins/yearbooks

Since its creation, the IGUC began publishing its observational data in annual bulletins, first published in 1870. This section will explore the four different organization phases of the Bulletins and the data present in them (Figure 3).

The first phase began with the publication of the volume regarding data from 1864 and ended with the volume for 1870. This series was constituted only by meteorological data. The first volume opens with a brief characterization of the IGUC and a description of its first meteorological instruments. The meteorological data published is the mean, maximum, minimum, and the variation per day of atmospheric pressure; the daily maximum and minimum temperature (at shadow), the atmospheric vapor tension, relative humidity, maximum and minimum temperature due to solar irradiation, the maximum and minimum temperature in the grass, the approximate wind direction and strength, the height of water raining, and the amount of water evaporating into the atmosphere. The general weather and meteorological conditions, the serenity of the sky, cloud configuration, and the ozone measure are also published.

From 1874 onwards, the annual bulletins also started publishing magnetic data, thus initiating what we can call the second phase of the IGUC's bulletins (in the volume of 1874 is published magnetic data from June 1866 to December 1873). The published magnetic data included the absolute monthly determinations of the horizontal force, declination, and inclination of the Earth's magnetic field. In 1876, the annual data bulletins began to include the names of the institutions and persons (organized by country) to whom the IGUC's publications were sent; in the following year (1877), the list of institutions that sent their yearbooks to the IGUC was also included. Over the years, there has been a reorganization in how the data are presented, reflecting successive instrumental updates. In the 1891 volume, the IGUC started to publish the sunshine duration, measured with a Jordan system installed on the southern facade of the observatory (these data have recently been homogenized and studied in Montero-Martín et al., 2021).

The 1900 Annual Bulletin appears the first reference to seismic observations. Historical administrative documents allow us to conclude that seismic records with the Angot seismograph would have started around 1893; however, such data and analyses were neither published nor found. Seismic observations would begin on a regular basis in 1903 with the Milne horizontal pendulum, but the publication of their analysis did not begin until 1910 (Figure 4), initiating the third phase of the annual Bulletins reflected in the change of their title

[3]http://webopac.sib.uc.pt/search~S17*por?/.b1597930/.b1597930/1,1,1,B/l856~b1597930&FF=&1,0,,1,0#re.

This task was carried out within the framework of a research project on the history of science at the University of Coimbra (PTDC\FER-HFC\30666\2017), in which one of the tasks was precisely to digitize significant works of literary and scientific production of the University.

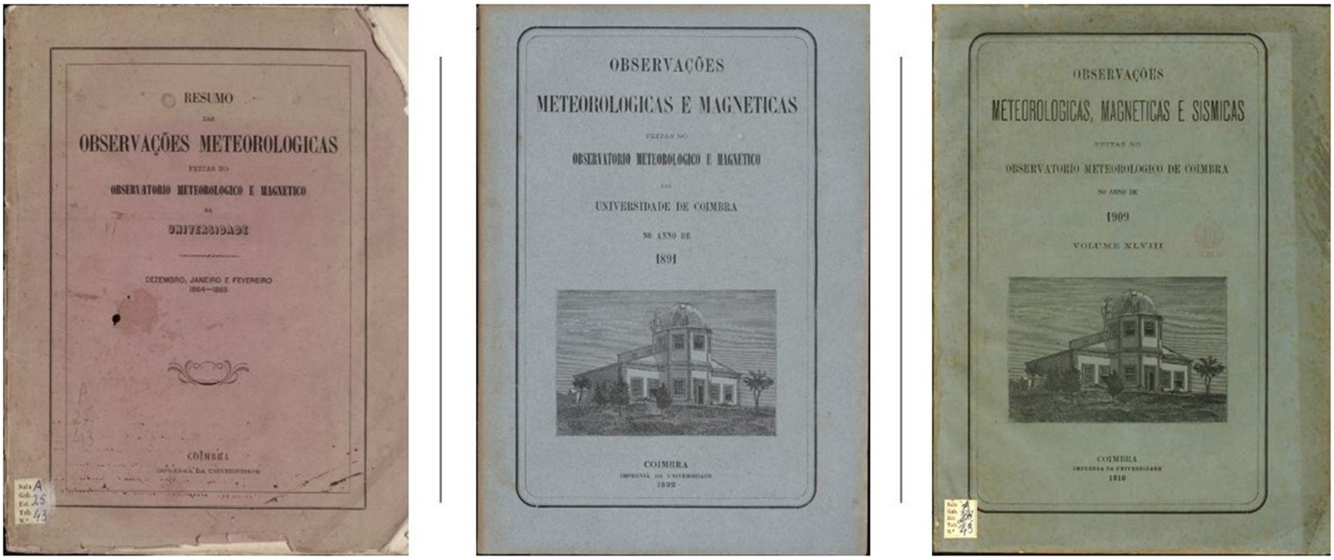

FIGURE 3 IGUC Bulletins covers

'Observações Meteorológicas, Magnéticas e Sísmicas feitas no anno de 1909' (Meteorological, Magnetic, and Seismic Observations made at the Coimbra Meteorological Observatory in 1909). In this bulletin is made a brief description of the functioning of the Milne seismograph and where it was installed (a small house was built to install it). The Milne seismograph allowed improved recording of distant earthquakes, enabling the COI station to integrate the international seismic observation network since 1904. After the earthquake of April 23, 1909, which affected continental Portugal, especially the region of Benavente (north of Lisbon), the annual bulletins started to publish seismic data systematically.

Since then, they have contributed significantly to sharing information with national and foreign institutions, once the COI station was the only one in mainland Portugal (Teves-Costa & Batlló, 2011). Relating seismic data, bulletins followed the guidelines of the Seismic Bulletins of the BAAS (British Association for the Advancement of Science). They listed the event date (day and month), the arrival times (hour and minute) of the different recorded seismic waves, the time of maximum amplitude, and the end of the earthquake. The maximum semi-amplitude in millimeters and the maximum wave slope (in arcseconds) were also published. The seismic events were, according to the epicentral distance from the COI station, classified as: 'Tremor domesticus', with an epicentre at less than 500 km; 'Tremor vicinus', with epicentre between 500 and 3,000 km; 'Tremor remotus', with epicenter between 3,000 and 10,000 km; and 'Tremor ultimus', with epicenter at more than 10,000 km.

The fourth and last phase of the IGUC's bulletins occurred in 1921. From then on, the bulletins were made up of three separate parts, one for each of the IGUC monitoring areas (meteorological, magnetic, and seismic). Over the years, the observatory upgraded its detection and recording equipment and developed new research areas. The data structure of the bulletins has accompanied and accommodated the standards of the international geophysical associations.

3.2 | Challenges for digital preservation and metadata

In the case of the OGAUC collection, some critical issues deserve special attention. After their inventorying and cataloguing, issues related to digitization options (e.g., image resolution) and metadata[3] are fundamental to ensure that the data are findable and usable. Due to the immense volume of data and other records and the difficulties of funding and personnel, it will not be possible to move towards a global digitization program in a short period of time. It will be necessary to follow a set of criteria that help select the priority data or records taking into consideration, namely the conditions of preservation, deterioration and accommodation, and/or eventually, its importance as a record of a significant global or local geophysical event. To make the data accessible for everyone, researchers or the public in general, it is essential to guarantee its Open Access. However, it must be in mind that when data are in archives, it is necessary to consider questions such as the appraisal policy, the arrangement and description of the archival, and providing access and protecting the data and the archive itself. In the case of the OGAUC, many of the annual bulletins published are

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N.º	Data	V₁	V₂	B	M	F	A	I	Notas
	1909 Jan.	h m	h m	h m	h m	h m	mm	″	
1	15	17 24,6	17 36.9	17 41,8	17 43,3	18 0,2	0,20	0,05	*Tremor ultimus.* (Fillipinas).
2	23	* ?	* ?	3 13,7	3 16,7	* ?	6,20	1,61	*Tremor remotus.* (Persia).
		* V_1, V_2 e F perdem-se nos movimentos microsismicos habituaes. — Microsismos seguidos nas noutes de 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30 e 31.							
	Fev.								
3	9	11 36,6	11 39,5	11 43,5	11 45,5	12 26,8	1,20	0,32	*Tremor remotus.*
4	9	14 53,4	14 58,4	14 59,5	15 0,4	15 16,1	0,30	0,08	*Tremor remotus.*
5	10	20 3,3	20 7,3	20 10,3	20 12,1	20 28,9	0,20	0,05	*Tremor remotus.*
6	14	15 45,1	—	15 49,1	15 49,1	16 6,8	0,40	0,11	*Tremor vicinus.*
7	16	17 8,8	—	17 10,8	17 10,8	17 24,6	0,20	0,05	*Tremor vicinus.* (Sentido no norte do reino).
8	26	17 8,4	17 15,3	17 24,1	17 26,5	18 21,6	2,00	0,54	*Tremor remotus.*
		Microsismos nas noutes de 1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23, 24, 25, 26, 27 e 28.							
	Março								
9	7	18 53,6	—	18 59,5	19 1,5	19 19,2	0,20	0,06	*Tremor ultimus.*
10	8	12 25,5	12 37,9	12 42,9	12 52,3	13 20,2	0,30	0,08	*Tremor ultimus.*
11	12	23 43,5	23 55,3	—	—	—	1,30	0,46	*Tremor ultimus.* (Costa oriental do Japão).
	13	—	—	0 17,1	0 21,8	1 9,0			
12	13	14 46,6	14 56,4	15 22,4	15 27,3	17 16,1	2,00	0,56	*Tremor remotus.* (Costa occidental do Japão).
13	17	23 21,6	23 35,7	—	—	—	1,10	0,31	*Tremor ultimus.*
	18	—	—	0 1,0	0 7,9	11 48,2			
14	22	20 29,7	—	20 52,2	21 2,1	21 37,5	0,20	0,05	*Tremor ultimus.*
15	22	23 27,6	—	23 36,5	23 38,5	23 57,2	0,20	0,05	*Tremor ultimus.*
		Microsismos nas noutes de 2, 8, 10, 11, 12, 14, 15, 16, 17, 24, 28, 29 e 30.							
	Abril								
16	23	Desde as 13ʰ–55ᵐ,4 deste dia o pendulo mostrou-se inquieto até ás 17ʰ–40ᵐ,1, hora a que executou uma oscillação, partindo de E. para W., com a amplitude de 2ᵐᵐ,40 (0″,62). Seguidamente registou-se uma serie de oscillações, 7 das quaes de amplitude superior a 17ᵐᵐ,00 (4″,42), produzindo o deslocamento da posição d'equilibrio A amplitude das oscillações diminuiu gradualmente até attingir 0ᵐᵐ,70 (0,″18) ás 18ʰ–10ᵐ,3, em que voltou a augmentar, partindo o pendulo de W. para E., e attingindo o valor de 1ᵐᵐ,40 (0″36). Tornou a diminuir e parou, ás 18ʰ–55ᵐ,4.							*Tremor domesticus.* Epicentro em Benavente Sentido em Coimbra com a força VI (Forel-Mercalli).
17	25	23 29,7	—	23 41,6	23 51,5	—	0,20	0,06	*Tremor ultimus.*
	26	—	—	—	—	0 9,2			
18	27	13 14,2	—	13 53,6	14 3,9	15 1,8	2,00	0,54	*Tremor ultimus.* (Nova Guiné).
19	29	23 2,9	23 12,6	23 28,4	23 30,4	—	1,00	0,27	*Tremor remotus.*
	30	—	—	—	—	0 11,2			
		Microsismos nas noutes de 4, 7, 8, 9, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29 e 30.							
	Maio								
20	11	14 17,9	—	—	14 19,2	14 53,7	0,30	0,09	*Tremor ultimus.* (China).
21	11	16 42,8	—	—	—	16 55,6	0,10	0,03	*Tremor vicinus.*
22	12	0 17,8	0 27,6	0 44,8	0 47,7	1 8,4	0,40	0,12	*Tremor remotus.* (Novas Hébridas).
23	17	8 15,1	8 24,0	8 31,8	8 39,7	10 39,9	2,20	0,62	*Tremor remotus.* (Mexico).
		Microsismos nas noutes de 1, 2, 5, 6, 7, 8, 9, 11, 14, 15, 17, 18, 19, 20, 24, 25, 26, 27, 28 e 31.							

FIGURE 4 First page on OGAUC bulletins with seismic data from COI station (in Observações Meteorológicas, Magnéticas e Sísmicas feitas no anno de 1909, vol. 48, 1910)

scans available for consultation on the UC website.[4] The data are accessible but not easily converted, for example, into a text or excel format. Some of these scans have OCR, but almost all of them do not. Furthermore, the fact that all the bulletins are written in Portuguese causes additional constraints to the usability and findability of the data in these volumes for non-Portuguese-speaking users. And as already mentioned, all these IGUC's bulletins do not yet have DOI and metadata associated.

Besides the data tables published in yearbooks and bulletins, the observatory has a massive volume of daily analogue records of geophysical variables (climate data, magnetograms, and seismograms), where only some data concerning specific events are published in some international databases (e.g., https://doi.pangaea.de/10.1594/PANGAEA.785377; https://doi.org/10.5281/zenodo.4308036; doi.org/10.5281/zenodo.4308022; doi.org/10.31905/D808B830; doi.org/10.31905/EL3FQQ40). This data collection must also be catalogued and organized in a digital database to preserve and render it available to the worldwide geoscientist community. That also raises important questions. A raw scanning without associated metadata is unsatisfactory for extracting the richness of the information that the data holds. A simple scan of a magnetogram only creates a digital image of it, which is, in fact, of little use. Creating and associating metadata is necessary to make that register complete and usable (see next section in this paper). Another issue concerns the fact that data series homogenization and analysis only can be made with a parallel study of the instruments used to collect them. Data cannot be wholly understood without reference to their instruments. The recording instruments analysis (and desirable preservation and restoration) will clarify the data acquisition procedures and help to characterize better the results obtained. Unfortunately, in some cases, significant logbooks have not yet been found and the likelihood of them being lost is enormous.

4 | CASE STUDIES BASED ON OGAUC'S DATA ARCHIVES

4.1 | The solar images collection

One of OGAUC's emblematic data series concerns observations of solar activity. Monitoring solar activity provides valuable information about our star's dynamics and energy flow, the main energy source for Earth's climate system. Moreover, it allows studying and predicting solar phenomena that may drastically affect the physical and human activity on our planet. So, significant research in climatology, solar physics and space weather has been made analysing and studying old series of solar data found in old catalogues of the network of observatories that have been established since the last quarter of the 19th century in multiple observatories around the globe (Vaquero, 2007).

From 1926 until 1944, the astronomical observatory made daily observations of sunspots, faculae, filaments, and prominences on lines Ca II and Hα using a spectroheliograph installed primarily in the IGUC premises (Figure 5). These observations were published in catalogues (Bonifácio, 2017). In the 1950s, that equipment was relocated to the Santa Clara campus. In 1990 regular observations in the Hα line have also started. Initially, the solar images were recorded in glass plates. However, since 2007 began to be recorded in digital format (using CCD cameras).

In this sense, the catalogues and solar activity data covering almost 100 years are of great importance. In recent years, several colleagues have carried out studies and comparative analyses of the Coimbra catalogue (Carrasco et al., 2018). Those authors compared the Coimbra catalogue with records made at the Royal Observatory of Greenwich (which has monitored solar activity and sunspots since 1874), concluding that the OGAUC historical sunspots catalogue contains reliable data that can therefore be used in studies of solar activity. The OGAUC solar image archive is huge (e.g., Lourenço et al., 2019; Table 1) and several studies have been carried out to develop automatic methods for recognizing and studying these images. Barata et al. (2018) and Carvalho et al. (2020) have achieved promising results with software tools to automatically detect and analyse chromospheric plages. This type of work highlights the importance and timeliness of the OGAUC solar data. It opens new perspectives for work in the fields of space weather, geosciences, data analysis, modelling, and image processing.

4.2 | Climate data collection

Today, it is more vital than ever that we have long and reliable historical records of the Earth's climate. Extremes of weather and climate can have devastating effects on human society and the environment. Understanding past changes in the characteristics of such events, including recent increases in the intensity of heavy precipitation and heat waves events, is critical for reliable projections of future changes (Min et al., 2011).

[4] 1864–1890: http://webopac.sib.uc.pt/search~S17*por?/.b1597930/.b1597930/1,1,1,B/l856~b1597930&FF=&1,0,,1,0#re; 1891–1908: http://webopac.sib.uc.pt/search~S17*por?/.b1594116/.b1594116/1,1,1,B/l856~b1594116&FF=&1,0,,1,0#re; 1909–1920: http://webopac.sib.uc.pt/search~S17*por?/.b1597931/.b1597931/1,1,1,B/l856~b1597931&FF=&1,0,,1,0#re; 1921–1981: http://webopac.sib.uc.pt/search~S17*por?/.b1597932/.b1597932/1,1,1,B/l856~b1597932&FF=&1,0,,1,0#re.

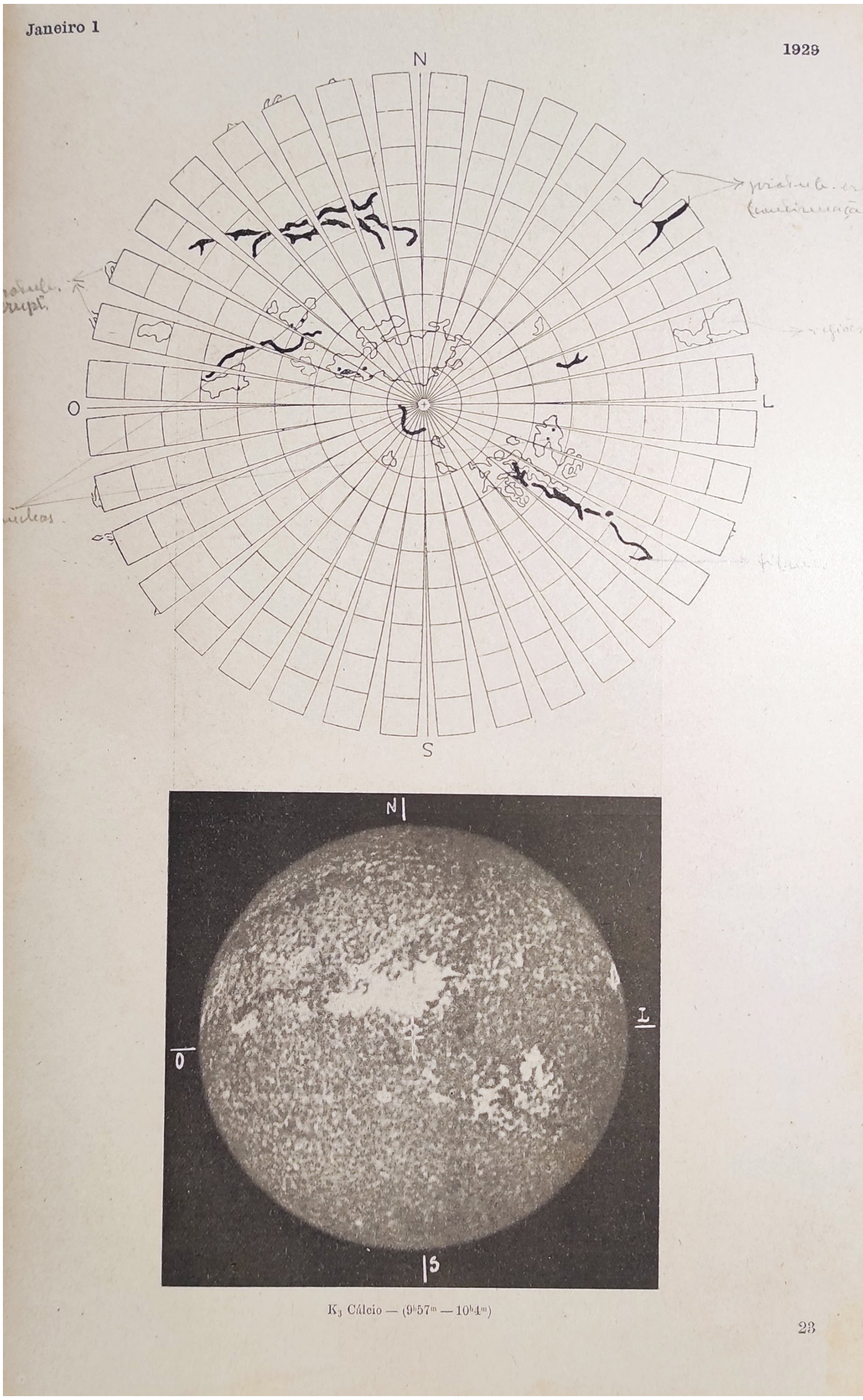

FIGURE 5 Solar image and it's interpretation, from 1st January 1929 (in Anais do Observatório Astronómico da Universidade de Coimbra, Tomo I, 1929)

The IGUC historical data series have been fundamental to Coimbra's climate change knowledge. The first study was published in 1922 by Anselmo Ferraz de Carvalho (at the time director of IGUC) based on 51 years of observations from 1866 to 1916 (Figure 6). From the 1990s onwards, local climate data were used in different studies applied to urban planning, natural hazards (landslides and floods), and human health (e.g., Domingues et al., 2021; Ganho, 1998; Mateus, 2014; Quinta Ferreira et al., 2005). Nonetheless, the climate data series used in these studies were compiled by their researchers from yearbooks and bulletins published on paper, and most of them are still unavailable in publicly accessible digital archives (Table 1). An exception can be found in Morozova and Valente (2012) that studied long-term temperature data series measured in three Portuguese meteorological stations. Series of monthly minimum and maximum temperatures measured in Lisbon (from 1856 to 2008), Coimbra (from 1865 to 2005), and Porto (from 1888 to 2001) were tested to detect and correct non-climatic

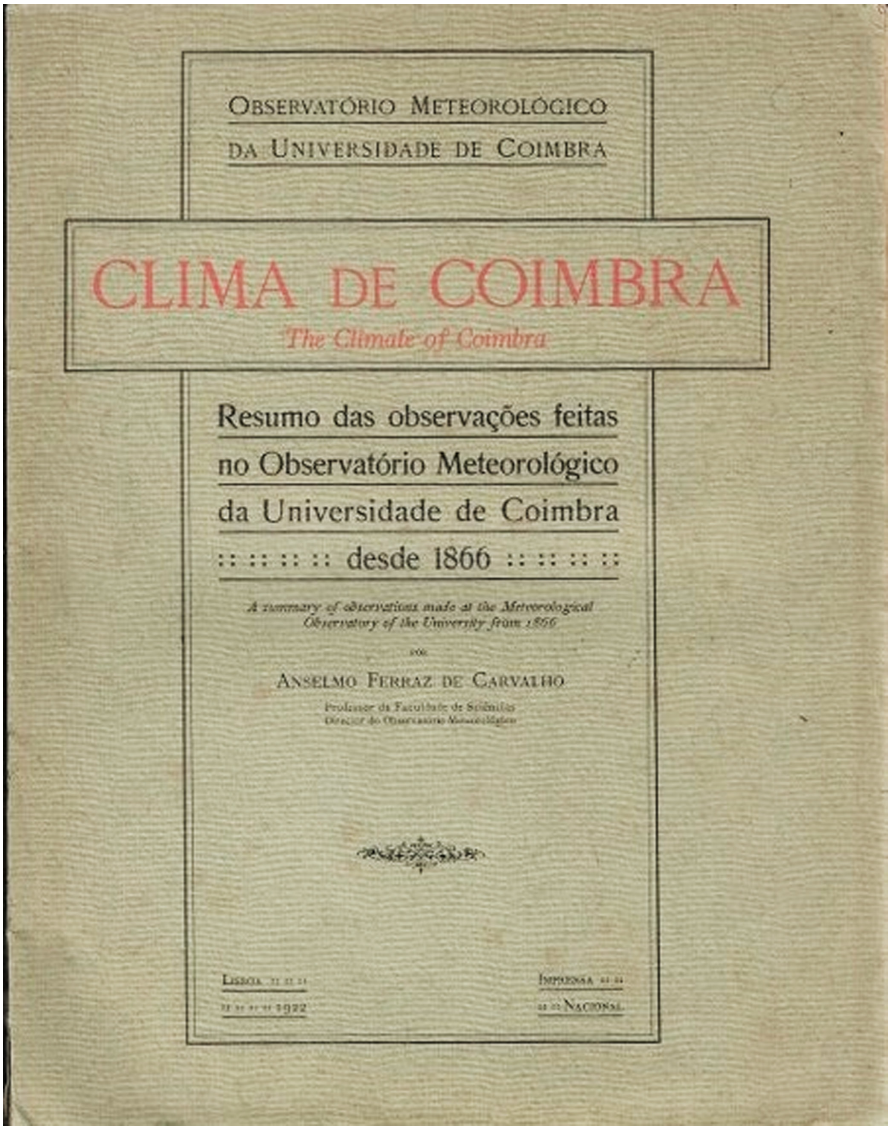

FIGURE 6 Front cover of the study 'Clima de Coimbra' (The climate of Coimbra); a summary of observations made at the Meteorological Observatory of the University from 1866 (Carvalho, 1922)

homogeneity breaks (using metadata, visual analysis, and widely used homogeneity tests). Corrected (and original) series are now available within the framework of the ERA-CLIM FP7 project for future studies of climate variability (https://doi.pangaea.de/10.1594/PANGAEA.785377; Table 1).

The OGAUC has made special efforts to rescue the historical weather data into digital format in the last months (Table 1). This first phase of data rescue concentrates on daily values of main climate variables: temperature, relative humidity, pressure, precipitation, and wind (intensity and direction). This work of digital data logging has been accomplished by hand and with limited human resources, which is high time-consuming. So far, the daily data series from 1866 to 1920 has been digitally recovered and is expected to be completed as soon as possible when it should be made publicly available on the OGAUC's digital platform.

In addition to the vast amount of meteorological hourly, daily, and monthly data published in the yearbooks from 1864 onwards, the OGAUC also holds a large volume of paper graphs of daily records of meteorological variables that need to be inventoried and catalogued for digitizing and archiving (Table 1). This rescue is essential to preserve historical instrumental observations that are at risk of being lost due to the vulnerability of the original paper data sources (World Meteorological Organization, 2016). These daily curves are particularly important in revisiting and reanalysis storms and other extreme historical events since they reconstruct the respective atmospheric conditions with a resolution close to the minute. In addition, when this single-station data are complemented with records from other regional stations it allows for the synoptic analysis and knowledge of the air masses evolution responsible for the historical severe weather conditions.

4.3 | Geomagnetic data collection

The Coimbra magnetic observatory has been measuring and registering the geomagnetic field elements for more than 150 years. It is part of a very small group of historical observatories with such a long series.

Although absolute experimental observations started as early as 1864, it was not until June 1866 that they began to be made on a regular basis for H and I, while D observations began regularly a year later, that is, July 1867. This year also saw the start of the continuous recording of magnetic variations using the Adie magnetographs (Kew model). Since then, the Coimbra observatory has tried, to overcome various vicissitudes to maintain the regularity and quality of the observations. These long instrumental geomagnetic records (Figure 7) constitute an essential collection of fundamental scientific data in the study of the time variations of the geomagnetic field resulting from two primary processes: the so-called secular variation (SV) of the main field of internal origin and the variation of the external field (Solar–Earth interactions).

During the long life of the Coimbra observatory, some inevitable changes such as its relocation and the replacement of instruments and routines affected the quality of the data collected, causing discontinuities and jumps in the geomagnetic time series, which led to its exclusion in some global analyses of the SV (Pais & Miranda, 1995). Nonetheless, to study the SV in Coimbra using the available monthly means, those authors tried to establish a better quality data set based on a critical evaluation of the existing records and documents of the history of the observatory. The authors identified the significant gaps in the monthly values for the interval 1860–1990 and, where possible, applied corrections and filled the gaps to obtain a more complete and homogenized times series.

A more comprehensive homogenization of the historical monthly series from the Coimbra Magnetic Observatory for an enlarged time interval 1866–2015 was recently performed (Morozova et al., 2014, 2021; Table 1). The homogenization procedure consisted of both the visual analysis and a statistical homogeneity test, namely the standard normal homogeneity test. The homogenized COI series, showing more consistency with the data from other geomagnetic observatories, can be accessed at https://doi.org/10.5281/zenodo.4308036(Morozova et al., 2020), while the original data are available via the following addresses: https://doi.org/10.5281/zenodo.4308022(Ribeiro et al., 2020; Table 1). These homogenization analyses have also highlighted the importance of using the most homogeneous series possible in producing good quality geomagnetic SV models. In this sense, it would be advantageous to plan a shared effort among the oldest magnetic observatories to collect old metadata and implement corrections for homogeneity breaks in old series.

As mentioned above, the OGAUC also owns a long series of old magnetograms starting in 1867. Until 2006, when the first automatic digital system was installed, the daily records were acquired on photographic paper using the Adie magnetographs (Kew model) until 1933 and the Askania-Werke magnetographs (Eschenhagen model) afterwards. The massive number of records of these two collections was recently subject to inventorying and cataloguing with a view to their digitalization, archiving, and preservation (Table 2).

The planned database for the analogue magnetograms will allow studies with timescale resolution from nearly minute (storms and pulsations) to the solar cycle (11 to 23), including hourly, daily, and seasonal variations. In particular, geomagnetic storms display high-frequency variations that reflect the rapid electromagnetic interactions when high-energy particles and electromagnetic radiation from the Sun reach the Earth's environment. Some studies using magnetograms from Coimbra have proved their quality and usefulness in characterizing extreme historical storms (Hayakawa et al., 2020; Ribeiro et al., 2016; Vaquero et al., 2008). These studies are of utmost importance to evaluate the likelihood of occurrence of similar events in the future and in this way to obtain an added understanding of the space weather inherent risks, which are harmful to the different technology and infrastructures as satellite constellations, communication systems, airplanes or electrical power networks.

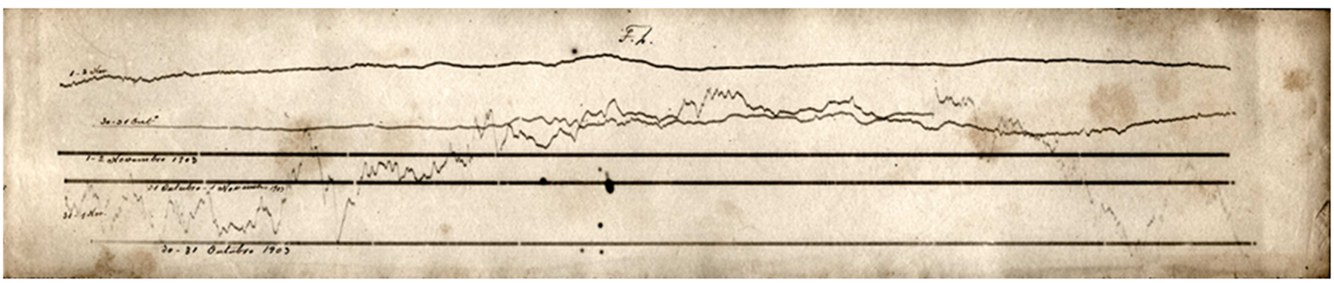

FIGURE 7 Magnetogram of the horizontal force (H) recorded by the Adie magnetographs in Coimbra between 30/10 and 2/11, 1903

4.4 | Seismic data collection

The seismic recording began regularly at the IGGUC only in May 1903, with the installation of a horizontal pendulum Milne (e.g., Custódio et al., 2011, 2012). Since then, the Coimbra station became part of the first international seismological network that inaugurated the era of instrumental seismology, and its observations were integrated into the seismic catalogue of the International Association of Seismology for the year 1904 (Table 1).

Due to the continuous recording of telluric activity at IGUC and the updating of instrumentation done over the years, the seismological collection is well illustrative of the historical evolution of this scientific area. In the OGAUC are present all the types of equipment used on the record of seismic activity since 1903: a Milne seismograph, a Wiechert E–W and N–S horizontal seismograph, a Wiechert vertical seismograph, a Grenet seismograph, three Geotech S13 seismographs, three Geotech SL210 seismographs, a Streckeisen STS-2 (Custódio et al., 2012; Table 3). Alongside, the OGAUC has many thousands of records made by these instruments in its collection. Although practically all these records are in analogue format, some data concerning specific seismic events are in digital format (Figure 8; Correia et al., 2019; Gomes & Lopes, 2019; Lopes et al., 2020). It should be noted that some seismograms have been scanned as part of the European EuroSeismos Project[5]and are available on the webpage of that project (http://storing.ingv.it/es_web/Data/Es_map.html; http://sismos.rm.ingv.it/; http://sismos.rm.ingv.it/index.php/sismogrammi; Table 1). However, the seismic phases analysis of some specific events recorded by COI are available in some international databases and international catalogues (Table 1), such as the real-time record (https://www.orfeus-eu.org/data/; https://www.iris.edu/app/station_monitor/#Today/SS-COI/webicorder/(Table 1)).

Along with the seismographic instruments and data, OGAUC has a very significant collection of working documents, such as logs and notebooks with the calculations of the seismic constants for each instrument and detailed information about the time and clock setting, which are fundamental metadata for a better understanding and exploration of the seismic data.

Some exploratory studies were carried out to verify the importance of revisiting the historical records and seismic series of data from the yearbooks and logbooks in the IGUC archive's collection. Because seismic data only started to be published from 1910 onwards, some case studies addressed the years before that date (e.g., Gomes & Lopes, 2017, 2019; Gomes, Lopes, et al., 2021; Gomes, Ribeiro, et al., 2021; Lopes et al., 2020; Ribeiro et al., 2019). One of those studies focused on identifying earthquakes with a magnitude equal to or higher than 6.0 on the seismograms recorded at IGUC between 1903 and 1908 (Ribeiro et al., 2019). In that study, it was possible to identify 119 earthquakes of the 161 presented in international catalogues for that period. That shows, being the IGUC at the time the most western seismic station in continental Europe, its importance in the international context, with records of more than 74% of the significant global earthquakes that occurred in that period. In more recent work (Gomes, Ribeiro, et al., 2021), we sought to know the number of seismic events in the first 1904 ISA annual catalogue with the COI seismic station data; of the 32 main earthquakes in the ISA catalogue, only about 40% had data from the COI station. Gomes, Ribeiro, et al. (2021) revisited the OGAUC Milne seismograms to confirm those data. It was possible to verify that instead of the 12 events mentioned on the ISA annual catalogue as recorded at Coimbra, 24 of the significant international seismic events that occurred in 1904 were also registered by the COI seismic station. This study shows the importance and needs to revisit and re-analyse the old seismograms of the OGAUC collection to contribute to updating and enriching national and international catalogues and the advancement of seismological knowledge.

The growing demand by researchers for data present in old seismograms should also be noted because, at the beginning of the 19th century, there were few seismic stations in the world, which make these documents an essential and unique source for knowledge of the telluric activity of our planet. In recent years, there has been an increased demand and interest from several national and international researchers for historical seismic data from IGUC to complete databases on global earthquakes that the COI station may have recorded and are not available in the ISC database.

5 | FINAL REMARKS

With this work, we aimed to give an overview of the analogue data available at the OGAUC and highlight the difficulties and obstacles to their recovery and availability to the scientific communities and all interested parties.

The OGAUC has one of Portugal's most extended series of geophysical data (meteorological, magnetic, and seismic) and solar images. The beginning of meteorological and magnetic data dates to the early the second half of the 19th century, while seismic and solar data started at the beginning and at the second quarter of the 20th century, respectively. The archival material is thrilling and

[5]408 seismograms obtained from the Wiechert and Grenet seismographs, and 40 weekly record rolls from the Milne seismograph.

TABLE 2 Characterization of the OGAUC archive of historical magnetograms

Recording period	Recording instruments	Recorded components	Number of magnetograms	Support and dimensions
1867–1933[a]	Adie Magnetograhs (Kew model)	H, D, Z	~19,000	Paper (photografic); ~10 × 40 cm
1933–1944 1951–2006[b]	Askania-Werke magnetographs (Eschenhagen model)	H, D, Z	~25,000	Paper (photografic); ~21 × 55 cm

[a]Recorded on photosensitive paper with a normal running speed of ~15.5 mm/h by the Adie magnetographs. The recording paper sheets used to be replaced daily at about local noon. Each recording sheet has three curves of the same component and the corresponding baseline (a procedure used to spare paper).

[b]Recorded on photographic paper with a normal running speed of ~20 mm/h by the Askania magnetographs. During the initial period 1933–1944, only the horizontal components (H, D) were recorded, with recording sheets being replaced around noon, while in the second period 1951–2006, all the three components (H, D, Z) were generally recorded, with the recording sheets being replaced around 9 a.m. local time; in general, for this period, each recording sheets shows the curves of the three components on successive days).

TABLE 3 Characterization of the OGAUC archive of historical seismograms (adapted from Custódio et al., 2012)

Recording period	Recording instruments	Recorded components	Recorded system	Number of seismograms
1891–1899(?)	Angot	EW, NS, Z	Ink	Missing
1903–1926	Milne	EW	Photographic paper	841
1915–1969	Astatic Wiechert	EW, NS (long period)	Smoked paper	[a]
1926–1953	Vertical Wiechert	Z (long period)	Smoked paper	[a]
1954–1979	Wizine[b]	Z (long period)	Photographic paper	[a]
1961–1985	Grenet	Z (short period)	Photographic paper	[a]
1972–2012	Geotech S13	EW, NS, Z (short period)	Sensitive paper (heat)/Ink/Digital	[a]
1974–2012	Geotech SL210	EW, NS, Z (long period)	Sensitive paper (heat)/Ink/Digital	[a]
2007-present	STS-2	EW, NS, Z (broadband)	Digital	[a]

[a]In progress, the inventory of the number of seismograms.

[b]Concatenation of Vertical Wiechert with Galitzin (Custódio et al., 2012).

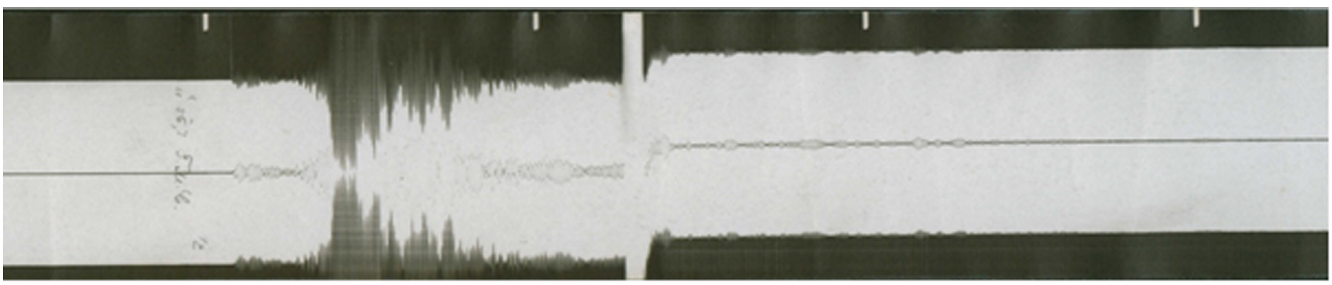

FIGURE 8 Example of a COI Milne seismogram: San Francisco 18th April, 1906 earthquake record

promises interesting scientific challenges and results. Some work that has been done on revisiting some of the historical data are an excellent example of this.

The current growing interest in revisiting historical geophysical data obtained by secular institutions with intense and continuous scientific activity is a challenge for their administrations as it has become urgent to make their data available. If this interest was not new to historians and sociologists of science in the recent past, it has been extended to the community of geoscientists, mainly driven by climate change studies. Thus, it is imperative that the OGAUC, and similar institutions, inventory, and make available the documentation and observational data produced and collected over more than 150 years of existence. The climate, geomagnetic, seismological, and solar series existing at OGAUC are invaluable for the current climate and geophysical studies, which shows the need to rescue both the long series of data and institutional history for a better understanding of current changes and mitigation of associated risks.

We are aware that the huge amount of data available only in analogue format will make the task of converting all this data to FAIR very challenging. OGAUC has already a workable digital database of solar images (Table 1), and we are very interested in creating a somewhat comparable database for historical data of geophysical observations. Inventorying and converting to digital format requires time and technical, financial, and human resources (e.g., Bezerra & Oliveira, 2013; Santos et al., 2021), conditions that are relatively far from being fully guaranteed. The institution seems to be struggling with other concerns and difficulties and has not shown much willingness to fund and provide the necessary resources. It seems to us, therefore, that the solution will be to request the necessary funding through applications to national and/or international projects oriented toward the rescue of historical data. Only a small amount of the collected legacy data at the OGAUC are available in digital format at different repositories (Table 1), and some of them are without assigned DOI. It is necessary and imperative to have a unique repository where researchers can find the whole set of OGAUC's data in an integrated manner. The University of Coimbra, aware of this problem, which is a cross-cutting issue for most of the departments and scientific labs of this institution, is implementing a new web service and repository to make available all the University's data and digital archives, including the possibility of assigning DOIs to all the scientific production of the University of Coimbra. That is an added value that may lead to new research results in different areas of knowledge and increase the dissemination and use of the OGAUC data.

A practical issue (but with financial implications) that must also be considered in this process of digitization and database design for the historical series concerns the storage space; without forgetting the memory space required to save the current series generated continuously at an increasing rate, as in the case of OGAUC. As we have seen, the urgency in rescuing and saving historical time series by digitizing them and integrating them into databases has twofold reason: (1) their preservation and (2) their dissemination by the various stakeholders (scientists, policymakers, and the general public). Only in this way will it be possible to explore and extract the maximum information from the data, namely through the use of computer tools, while also allowing the revisiting of old results that may lead to the reformulation of knowledge. Another issue is related to the digitalization itself, which means transforming the images (raster format) in vectorial data. Many working groups around the world are trying to find software able to do this transformation in an easy and minimum human intervention way. That is an important and fundamental step for making the data usable for the creation of new knowledge. However, that only can be done if all the institutions that have old data in analogue format can provide them.

Together with the metadata and instruments used, historical data provide essential information for understanding scientific practices over time. The metadata are vital for understanding and using the data associated, In turn, knowledge of the instruments, as well as the observation methods and routines, will contribute to the assessment of the quality and homogenization of the data series, which should preferably be used in the understanding of global and local changes of climate, geomagnetic field (and Sun–Earth interactions), and seismic activity.

Finally, an aspect that we have not highlighted in this article, but which deserves a final note, concerns the historical heritage of the IGUC building complex itself and its historical-scientific importance and educational interest. Its architectural structure is unique in Portugal; its modular pavilion distribution is a typical form of 19th-century scientific spaces, particularly the 'observatory sciences', and one of the few preserved in the world. The phases of its construction and the traces of its age and use have given it a unique shape and appearance that testify the science produced and the instruments it housed.

Science heritage sites are privileged places for transmitting unique narrative experiences to understand better the scientific/historical process and an opportunity to involve all kinds of public in the analysis and construction of history (Handler & Gable, 1997; Tal & Morag, 2007). That is also a challenge for the future. The IGUC transfer to the Faculty of Economics as is planned must be done trying, as far as possible, to preserve all that scientific heritage history. So that future generations will recognize that there existed a scientific institution that played an essential role in geosciences research in Portugal over the last 150 years.

AUTHOR CONTRIBUTION

Ana Morais Gomes: Conceptualization (equal); Data curation (lead); Investigation (equal); Writing – original draft (equal); Writing – review & editing (equal). **Anabela Ramos:** Conceptualization (equal); Data curation (supporting); Investigation (equal); Writing – original draft (supporting); Writing – review & editing (equal). **Fernando Figueiredo:** Conceptualization (equal); Data curation (supporting); Investigation (equal); Writing – original draft (equal); Writing – review & editing (equal). **Paulo Ribeiro:** Conceptualization (equal); Data curation (lead); Investigation (equal); Writing – original draft (supporting); Writing – review & editing (equal).

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