A new catalogue of historical Korean auroral records during 1012-1811

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Abstract

Aurora displays provides an essential diagnostic to spatial and temporal variations of terrestrial space environment and is also an important proxy of solar activity. Contemporary auroral observations have just continued for more than half a century. In the long history prior to modern era, visual auroral observations can dates back to 1450 AD in mid-latitudes and polar regions in Europe. In mid- and low-latitude regions in East Asia, official historical books in China, Korea, and Japan also recorded numerous visual auroral phenomena began from 1000 AD until modern times. In this study, we compiled a new auroral catalogue from ancient Korean historical books, including 2013 auroral records with day-level resolution from 1012 to 1811 AD, especially for the records searched from the . The occurrence of the aurora in the new catalogue is generally consistent with previous datasets. This extended dataset provides valuable support for various studies related to solar-terrestrial space weather and ancient climates.

A new catalogue of historical Korean auroral records during 1012-1811

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Abstract

Aurora displays provides an essential diagnostic to spatial and temporal variations of terrestrial space environment and is also an important proxy of solar activity. Contemporary auroral observations have just continued for more than half a century. In the long history prior to modern era, visual auroral observations can dates back to 1450 AD in mid-latitudes and polar regions in Europe. In mid- and low-latitude regions in East Asia, official historical books in China, Korea, and Japan also recorded numerous visual auroral phenomena began from 1000 AD until modern times. In this study, we compiled a new auroral catalogue from ancient Korean historical books, including

2013 auroral records with day-level resolution from 1012 to 1811 AD, especially for the records searched from the *Seungjeongweon Ilgi*. The occurrence of the aurora in the new catalogue is generally consistent with previous datasets. This extended dataset provides valuable support for various studies related to solar-terrestrial space weather and ancient climates.

Key Points:

1. Compilation of a new catalogue of historical Korean auroral records during 1012-1811.
2. The dataset contains 2013 red auroral records with date, local time and direction information.
3. The dataset provides valuable support for various studies related to solar-terrestrial space weather and ancient climates.

1. Introduction

Since Fritz (1873) first identified an ancient aurora list from historical books, many astronomers and space physicists have constructed regional or global lists of ancient auroral records for different purposes with respective emphasizes, such as Link (1964) for years before 1700, Silverman & Blanchard (1983) for England observations, Lee et al. (2004) from Korea histories, and Hayakawa et al. (2017a) for Chinese ancient results. Based on these auroral lists, a variety of studies have been done over decades, especially on estimating the ancient solar and geomagnetic activities given their dominated effect on the aurora occurrence. For example, the auroral records from the Orient played an important role in confirmation of the Maunder Minimum of solar activity (Eddy, 1976), Siscoe (1980) investigated global aurora occurrence based on five available aurora catalogues and identified most known grand solar minimums covering more than 2000 years. He also resolved 80- and 10-year cycle during the Middle Ages, which implies that the solar cycle was then operative. Silverman (1992) analyzed 45000 visual aurora observations during the past 500 years, examined its secular variation through comparison with other solar and magnetic indices, and confirmed the disappearance of 11-year cycle around the Maunder minimum. González-Esparza & Vuevas-Carnoda (2018) used the naked eye aurora observations from Mexico to determine the amplitude of the 1859 great geomagnetic storm and storm evolution, which actually makes significant sense on the extreme storm occurrence estimation for the technique system design given relatively shorter modern observations are available. Furthermore, ancient auroras are also used to investigate the geomagnetic field evolution (Siscoe & Verosub, 2012) and even assist archaeomagnetic dating (Liritzis, 1988)[0].

In these available ancient aurora lists, some of them actually have shown that Korean ancient books

recorded a large number of ancient auroras, especially around the Maunder minimum (Dai & Chen, 1980). However, due to the relatively low geomagnetic latitude of Korea Peninsula, the current aurora borealis theory cannot explain a large number of auroral records especially in the year of extremely low solar activity. Therefore, in previous studies, most researchers selectively ignored the auroral records of ancient Korea. Here, we systematically collated the auroral records from *Koryo-Sa* (AD 918–1391), *Choson Wangjo Sillok* (AD 1392–1910) and *Seungjeongweon Ilgi* (AD 1623-1910) through formatted digital search. Then we manually checked each entry from original books to get detailed information of azimuth, date, local time, lasting time, and etc. Finally, we got 2013 auroral records during 1012–1811 and formed this auroral catalogue. In comparison with previous results, this Korean auroral catalogue has several outstanding advantages. Firstly, it was formed based on daily record, which implies that it has time resolution up to one day. Secondly, it was observed from a fixed location with azimuth and local time provided. Thirdly, it has plenty of observations around the Maunder minimum. We expect and believe that the newly created Korean auroral catalogue could be used in a variety of researches in the future.

2. Data and Method

2.1 Auroral records in Korean chronicles

The Korean chronicles are daily official records of the activities of the kings, the state affairs, and the weather and astronomical phenomena. The existing historical records began in the 1000s and lasted for more than 800 years. Three Korean official historical books: *Koryo-Sa* (AD 918–1391, or *History of Koryo*), *Choson Wangjo Sillok* (AD 1392–1910, or *The Veritable Records of the Choson Dynasty*) and *Seungjeongweon Ilgi* (AD 1623-1910, or *The Daily Records of the Royal Secretariat of Joseon Dynasty*) were used in this study. These extensive chronicles were written in Chinese

characters.

The most frequently recorded nocturnal sky glows in the above three books are “vapours like fire light” (pronunciation in Chinese: *qì rú huǒ guāng*) (Stephenson & Willis, 2008). In Chinese, fire light (*huǒ guāng*) refers to red light. This implies that these records represent red glows. In previous works, the records “vapours like fire light” are processed as auroras. Dai and Chen (1980) first systematically sorted out the auroral records in historical books of China, Korea and Japan, but focused on the northern light (auroral borealis), meaning the “vapours like fire light” occurred at north of Korea. Then, Zhang (1985) preliminarily interpreted these records as stable auroral red arcs. Conjugate observations definitely reveal that such “vapours like fire light” in the northern nocturnal sky are auroral borealis (Willis et al., 1996; Hayakawa et al., 2017b). Yau et al. (1995) reorganized the auroral records sorted in previous works (Stephenson & Willis, 2008; Keimatsu, 1970-1976) and published the first comprehensive catalogue of auroral records in East Asian in English. Comparing auroral records in China and Japan with the geomagnetic activity in the 19th century, Willis et al. (2007) propose that the airglow phenomena in the middle and low latitudes is sporadic auroras, as those observed in the United States.

Figure 1 shows a drawing of the auroral borealis in historical book of Japan in AD 1770. During this event, although auroral records are not found in *Seungjeongweon Ilgi*, possibly due to the bad weather in Korea[0], it is believed that the records of “vapours like fire light” in Korean documents refer to the similar auroral structures in Figure 1. Apart from the records in the north, most of the records of “vapours like fire light”, “red vapours” (pronunciation in Chinese: *chì qì*) and “odd red vapours” (pronunciation in Chinese: *chì jìn*) appeared in the southern nocturnal sky. Recently, Wei and Wan (2020) compiled a new chronology of such auroral records in Chinese from the above-mentioned historical books, including 2013 records during AD 1012-1811.

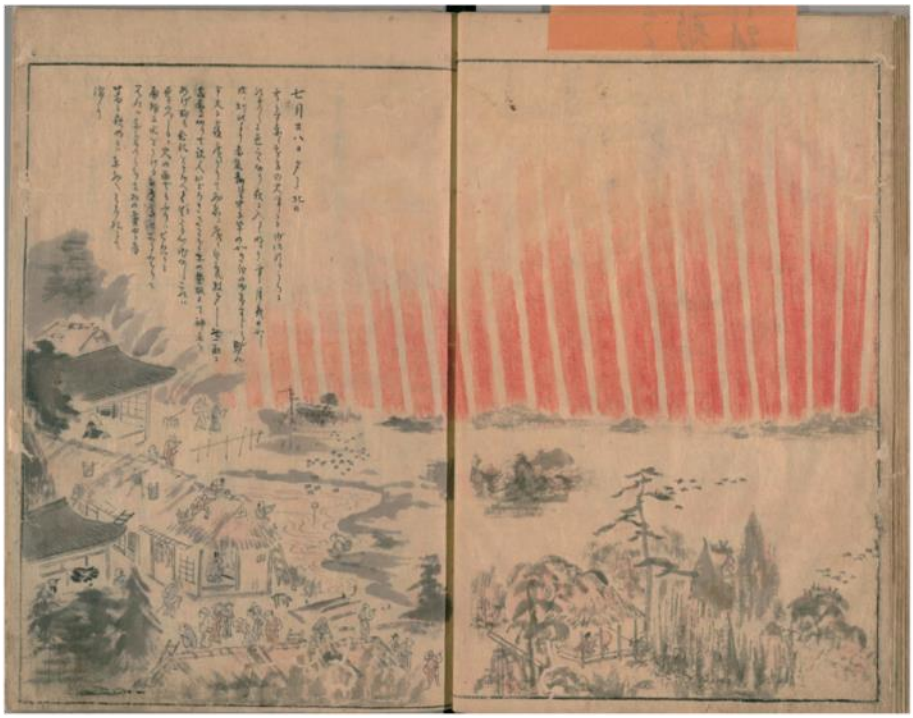

Figure 1. A drawing of auroral borealis in historical book of Japan in AD 1770 (adapted from Hayakawa et al. (2017)).

2.2 Compilation of the dataset

In history, the Korean Peninsula and the Chinese dynasties maintained close astronomical communications, and they both followed a unified standard of astronomical observations and judgement. The red aurorae were depicted by the Chinese character "*qì* (气)" with different adjectives, including "*chì qì* (赤气)" (red vapours), "*qì rú huǒ* (气如火)"/"*qì rú huǒ guāng* (气如火光)" (vapours like fire or vapours like fire light), "*rú huǒ qì* (如火气)" (fire-like vapours), and "*chì jìn* (赤祲)" (odd red vapours). These keywords are used to search the auroral records in the three Korean official historical books.

The National Institute of Korean History has digitalized the three books, and we can quickly search the interested contents using the above keywords from the books' websites. Each pages of the books are also scanned and labelled with a unique identification number (IDN, e.g., IDN=SJW-A24020230-00200 for the case shown in Figure 2).

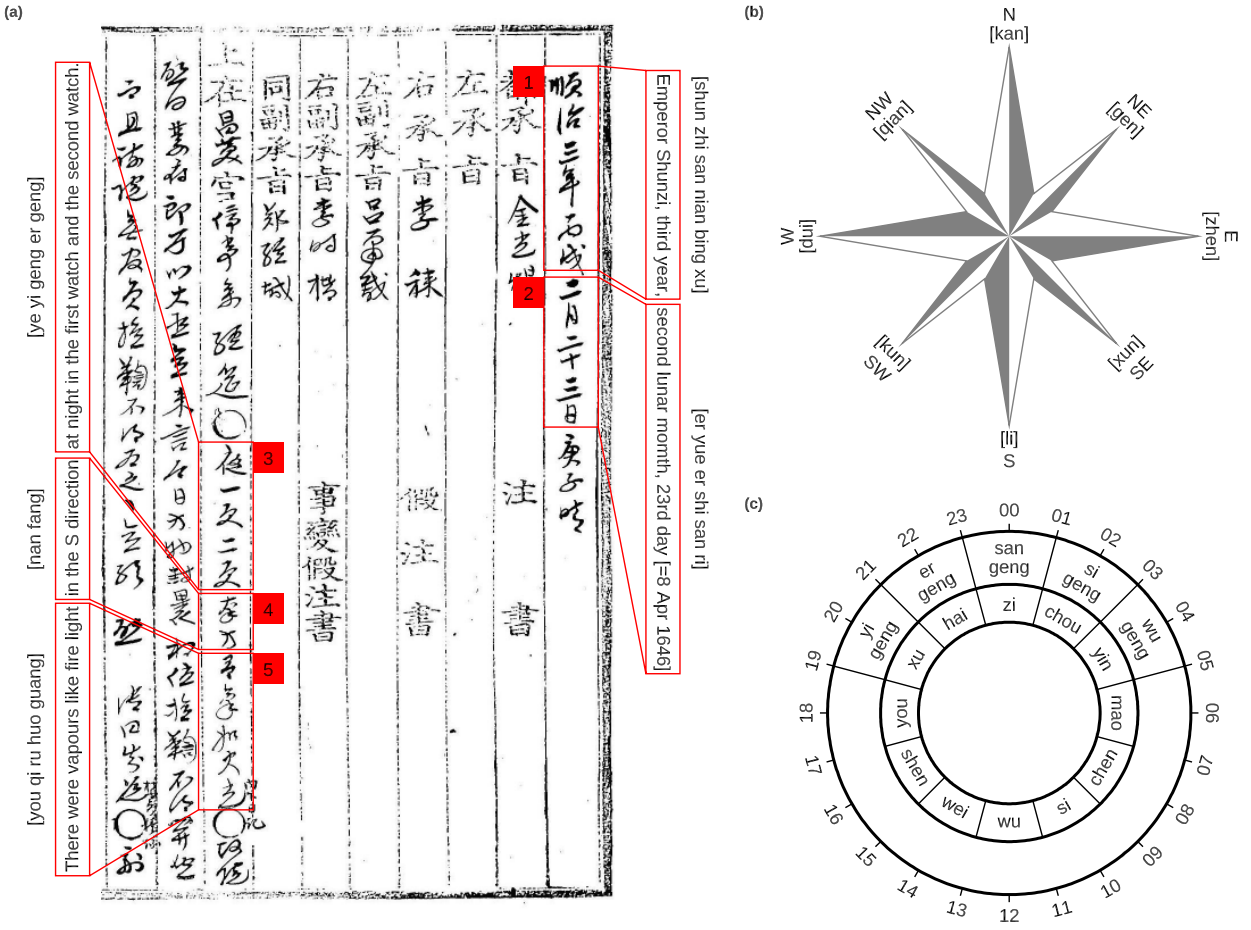

Figure 2. An example of Korean red equatorial auroral record. (a) Part of a page from the Sunjongwon Ilgi containing a red airglow observation. The scanned copy of this record can be accessed at the National Institute of Korean History (http://sjw.history.go.kr/id/SJW-A24020230-00200). (b) Definition of local directions. (c) Definition of local times.

First, search the three books with the above five keywords to establish a preliminary dataset, in which there may be false/dummy records or records with incomplete information (date or time). Therefore, it is necessary to set up a series of criteria to eliminate the bad records. The criteria are as follows:

- The record contains one of the keywords and should at least contain date information. Most of the records contain the full information of date, local time, and observed directions.

- The phenomena should be observed at night, i.e. 19:00 LT to 05:00 LT, to eliminate the influence of twilight, solar halo, and other light sources such as clouds, planets, stars, comets, and meteors.
- If fire disaster is mentioned in that day, the record is excluded.
- Since there is overlap in time for the three books, records from different books on the same day are merged as one and the IDN's for each book are kept in the dataset.

After application of these criteria, the final dataset contains 2013 ancient Korean auroral records. Figure 2 shows an example from the *Seungjeongweon Ilgi*. This observation was made in the third year of Emperor Shunzi (the 3rd emperor of the Qing Dynasty), in the 2nd lunar month, and on the 23rd day as shown in the 1st and 2nd red rectangles in Figure 2a. the lunar month and dates were converted to the Gregorian calendar with the Buddhist Studies Time Authority Databases (https://authority.dila.edu.tw/time/index.php), and the description "*shùn zì sān nián bǐng xū èr yuè èr shí sān rì*" is equivalent to April 8, 1646. A translation of the red auroral record is highlighted by the 3rd-5th red rectangles. Their Chinese pronunciation are shown in the square brackets, respectively.

For local directions shown in Figure 2b, there are primarily eight directions of *kǎn*, *gèn*, *zhèn*, *xùn*, *lí*, *kūn*, *duì*, and *qián* in ancient China, also called "eight trigrams", corresponding to north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), and northwest (NW), respectively. It is noted that the four directions NE, SE, SW and NW are also spelled in Chinese as "*dōng běi*", "*dōng nán*", "*xī nán*" and "*xī běi*', respectively, in ancient documents. Denotations such as "*dōng běi nán*" in the record should refer to three different directions of E, N, and S, meaning that the aurora occurred simultaneously in the three directions.

For local time, one day was divided into twelve regular divisions in ancient China, and their correspondences to local times are shown in Figure 2c. Particularly, the nighttime after sunset and before sunrise was divided into five *gēng*'s or five watches, i.e., *yī gēng* (first watch, 19–21 h), *èr gēng* (second watch, 21–23h), *sān gēng* (third watch, 23–1 h), *sì gēng* (fourth watch, 1–3 h), and *wǔ gēng* (fifth watch, 3–5 h).

3. Results and Discussion

The ancient auroral dataset presented in this paper was compiled from three Korean official historical books: *Koryo-Sa*, *Choson Wangjo Sillok* and *Seungjeongweon Ilgi*. The dataset is deposited as an Excel table (Ancient Korean Aurora.xlsx) and the corresponding scanned copies of the original books are deposited as PDF files named after the IDN of each auroral record (IDN.pdf). The table contains 8 columns. The 1st column showed the index of the record, the 2nd-4th columns stored the calendar year, month and date, which were converted to the Gregorian date, the 5th and 6th columns stored the lunar month and lunar date, the 7th column stored the description of the auroral record translated from the original books, and the 8th column stored the IDN, through which the scanned copy of the original texts can be accessed. One can also find the scanned copy of the auroral records from the three Korean official historical books using the following links.

Koryo-Sa: http://db.history.go.kr/id/IDN (e.g., IDN=kr_053_0010_0030_0100_1000)

Choson Wangjo Sillok: http://sillok.history.go.kr/id/IDN (e.g., IDN=waa_10201025_001)

Seungjeongweon Ilgi: http://sjw.history.go.kr/id/IDN (e.g., SJW-C14020201-02000)

Totally, there are 192 records found from *Koryo-Sa*, 536 records from *Choson Wangjo Sillok*, and 1359 records from *Seungjeongweon Ilgi*. After merging duplicate records from either book pair, the final number of the auroral records is 2013. All the original Chinese texts are downloaded from the

website of the National Institute of Korean History and deposited to the World Data Center for Geophysics, Beijing, together with the Excel table.

In 2004, Lee et al. (2004) published 788 auroral records (containing one duplicated record on 1537.6.13) from five historical documents of Korea in the 11th–18th century. Most of the records are collected from the three books used in this paper. However, many records are missing in Lee's list due to manual search of the documents and the original Chinese texts are not appended. Benefitted greatly from the digitalization of the three books by the National Institute of Korean History, systematic and complete search can be done to compile a more comprehensive dataset.

In compilation of the dataset, the auroral records are limited to the descriptions of "*chì qì*" (red vapours), "*qì rú huǒ*"/"*qì rú huǒ guāng*" (vapours like fire or vapours like fire light), "*rú huǒ qì*" (fire-like vapours) and "*chì jìn*" (odd red vapours), and four criteria are applied to exclude false/bad records. Figure 3 depicts the distributions of the 2013 ancient Korean auroral records. Figure 3a demonstrates that the majority of the auroral records occur between 1500 and 1800. There are scarce records before 1500 and the distribution is in consistent with Lee's list (Lee et al., 2004). After 1500, more records are found from *Seungjeongweon Ilgi*. Figure 3b shows the seasonal variation of the records. A peak of the occurrence of the aurora appears in the March, which is consistent with the result of Stephenson's work (Stephenson & Willis, 2008). Figure 3c presents the variation of the records with lunar date. It is found that there are fewer records around full moon and more records around new moon.

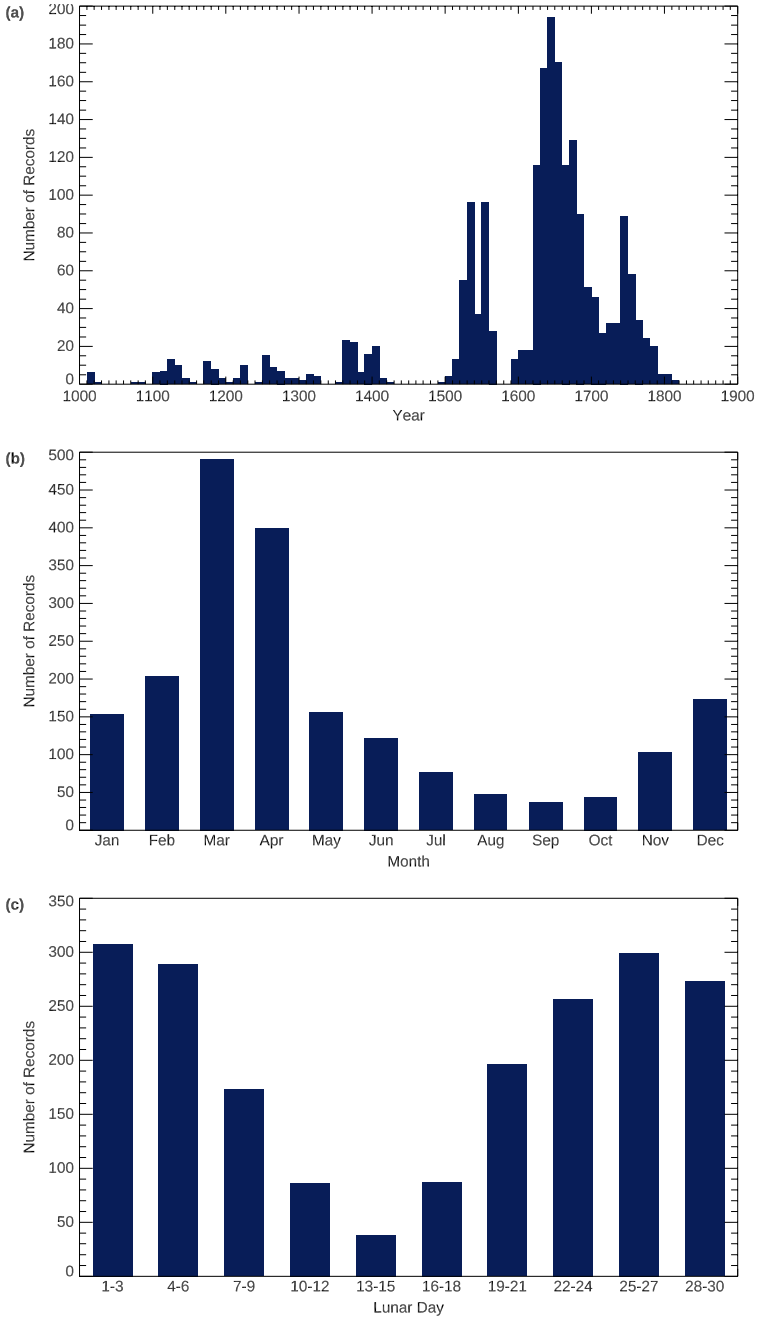

Figure 3. Statistics on the distributions of the ancient Korean auroral records. (a) Histogram of auroral records versus year binned in 10-year intervals. (b) Histogram of auroral records versus month. (c) Histogram of auroral records versus lunar date binned in 3-day intervals.

4. Summary

In this work, a new catalogue of historical Korean auroral records during 1012-1811. The dataset contains 2013 red auroral records with date, local time and direction information. The compiled

dataset is provided as XLSX file which can be opened in Excel or other text editors. The original Chinese texts are provided as PDF files which can be opened in PDF Reader. All these files have been deposited to the World Data Centre for Geophysics, Beijing (http://www.geophys.ac.cn/ArticleDataInfo.asp?MetaId=207, doi: 10.12197/2020GA008) and can be permanently accessed. The dataset can be freely used for research and education purposes only. The dataset provides valuable support for various studies related to solar-terrestrial space weather and ancient climates.

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