Analysis of Time Data in Japanese Astronomical Almanacs for 1885 – 1943

Ki-Won Lee[1]**, G. E. Choi**[2]**,** and **Y. S. Ahn**[2]

[1]Catholic University of Daegu, 13-13 Hayang-ro, Hayang-eup, Gyeongsan 712-702, S. Korea
[2]Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 305-348, S. Korea
E-mail: leekw@cu.ac.kr

Abstract: In this study, we analysed Japanese astronomical almanacs for the period from 1885 to 1943. During this period, two astronomical almanacs were published each year in Japan: the *Honreki* (a formal almanac) and its simplified version, the *Ryakuhonreki*, which are the focus elements of this study. Japan introduced the solar calendar in 1873, adopted the standard meridian of 135° E in 1883, and adopted the location of the Tokyo Astronomical Observatory as the reference point for observations in 1891. In this paper, we verified facts regarding the introduction years of both the solar calendar and the standard meridian of 135° E. In addition, we investigated the accuracy of time data such as new moon time, sunrise time, and twenty-four seasonal subdivision times by comparing data from the astronomical almanacs with results based on modern calculations. We think that this study will contribute to a better understanding of Japanese astronomical almanacs.

Keywords: Historical Astronomy, Astronomical Almanac (Honreki, Ryakuhonreki, Taiyōreki, Taiyōryakureki , Reki), Astronomical Calendar

1 INTRODUCTION

Many changes were made to the Korean astronomical almanac [曆書] during the period of 1864 – 1945 (Choi 2010). In particular, Korean astronomical almanacs after 1913 were calculated and published by Japanese scholars (Ahn et al. 2010), because Japan had occupied Korea (beginning in 1910). During this period, Japan also underwent many changes such as the introduction of the solar calendar in 1873 (1896 in Korea), adoption of the standard meridian of 135° E in 1888 (1912 in Korea), use of the Tokyo Astronomical Observatory [東京天文臺] (now the National Astronomical Observatory of Japan; hereafter NAOJ) as the reference point for observations after 1893 (Incheon Meteorological Observatory after 1912 in Korea; for details regarding the Observatory, refer to Lee et al.2011), and so forth.

During preliminary research on the Japanese astronomical almanac, we verified the introduction years of the solar calendar and the standard meridian of 135° E. In addition, we investigated the accuracy of the time data such as the new moon [朔] time, and sunrise and sunset times, using the astronomical almanacs from 1885 to 1943.

This rest of paper is organized as follows. In section 2, we briefly introduce Japanese astronomical almanacs and list the almanacs used in this study. We describe our data reduction in section 3, present our results in section 4, and offer a summary in section 5.

2 REVIEW OF JAPANESE ASTRONOMICAL ALMANACS

According to the 337th official report [官報] of the *Dajōkan* (太政官), announced 9 November 1872, Japan would adopt the solar calendar starting in the year 1873 (refer to Appendix A). Based on the timing of this announcement, it was likely too late to prepare the almanac for the year 1873. However, we found an astronomical almanac based on the solar calendar, entitled *Taiyōreki* (太陽曆), in the library of the NAOJ together with that based on a luni-solar calendar, entitled *Hanreki* (頒曆) (see Figure 1). As mentioned in the *Dajōkan* report, the former almanac was published in early 1873. A similar situation was seen for the astronomical almanac of 1667 published by the *Joseon* (朝鮮) dynasty in Korea. The *Joseon* court urgently published a single-page almanac because the court had recently learned that the *Ching* (淸) dynasty of China would re-introduce the *Datong* (大統) calendar for the almanac of 1667 (Lee et al 2010).

In addition, the term “solar calendar” in the report seems to refer to the Julian calendar based on a clause explaining the method of inserting one leap day at four-year intervals. However, we found that there were

28 days in February in the almanac for the year 1900. Therefore, we know that the solar calendar refers to the Gregorian calendar, not the Julian calendar. Meanwhile, two types of astronomical almanacs were published in the *Joseon* dynasty in around 1900, *Myeongsiryeok* (明時曆), based on a luni-solar calendar, and *Ryeok* (曆), based on a solar calendar. There are 29 days in February in the former almanac, although this error was corrected in the almanac published in the following year (Lee et al. 2011).

Figure 1. Astronomical almanacs for 1873, published in Japan: *Hanreki* (left) and *Taiyōreki* (right).

Regarding with the Gregorian almanacs from Japan, two types were published: *Taiyōreki* and *Taiyōryakureki* (太陽略曆), both published until 1880. *Reki* (曆; hereafter called the formal almanac) and *Ryakuhonreki* (略本曆; a simplified version of the formal almanac, hence, hereafter called the simplified almanac) were published after 1880. In Table 1, we list the astronomical almanacs used in this study together with the ownership of the formal almanac (marked in columns 4 and 8). As can be seen in the table, we mainly used the simplified almanac, which was collected by the author.

Table 1. Japanese astronomical almanacs used in this study.

Year	F. A[1]	S. A[2]	Note	Year	F. A[1]	S. A[2]	Note
1885		O		1915	O	O	Author
1886		O	BMSML[3]	1916	O	O	Author
1887		O		1917	O	O	Author
1888		O		1918		O	BMSML
1889		O		1919		O	BMSML
1890		O		1920		O	
1891		O		1921		O	NAOJ
1892		O		1922		O	BMSML
1893		O		1923		O	BMSML
1894		O		1924		O	BMSML
1895		O		1925		O	NLK[4]
1896		O		1926		O	NLK
1897		O		1927		O	
1898		O	BMSML	1928		O	
1899		O		1929		O	
1900		O		1930	O	O	NLK
1901		O		1931		O	
1902		O		1932		O	
1903		O		1933		O	
1904		O		1934		O	
1905		O		1935		O	NLK
1906		O		1936		O	
1907		O		1937	O	O	NLK
1908		O		1938		O	
1909		O	NAOJ	1939	O	O	NLK
1910		O		1940		O	NAOJ
1911		O		1941		O	
1912		O		1942		O	
1913		O		1943	O	O	NLK
1914	O	O	Author	Total	8	59	

[1]Formal Almanac, [2]Simplified Almanac. [3]The Busan Metropolitan Simin Municipal Library,
[4]National Library of Korea

3 DATA REDUCTION

3.1. Astronomical almanac data

We compiled the 11 types of time data from the Japanese astronomical almanacs from 1885 to 1943; seven related to the moon (i.e., new moon, first quarter moon, last quarter moon, full moon, moonrise, moonset, and lunar eclipse times) and four related to the Sun (sunrise, sunset, solar eclipse, and 24 seasonal subdivision [節氣] times). In those almanacs, sunrise/set and moonrise/set data are given in units of 1min; twenty-four seasonal subdivision times are in units of 0.1min up until 1886 and in units of 1min thereafter. Strangely, the simplified almanac provides only twelve seasonal subdivisions in its “date” data from 1923 onwards. In contrast, the formal almanac provides dates and hours for only four seasonal subdivisions (i.e., summer and winter solstices, and vernal and autumnal equinoxes). In the case of the eclipses, the data are given in units of 1min. In particular, the solar eclipse of the year 1933 was not visible in Japan; hence, the almanac contains observable time data at Seoul, Korea.

3.2 Modern calculations

In modern time data calculations, we use the algorithms of Meeus (1998), the astronomical ephemeris of Standish et al. (1997), and the ΔT (i.e., difference between terrestrial and dynamical times) values from the Nautical Almanac Office (2009). To calculate the solar eclipse time in a given circumstance, we used Besselian elements (see Lee 2008 for details). Regarding the lunar eclipse, we used time data compiled by the NASA (which can be found at http://eclipse.gsfc.nasa.gov/lunar.html).

Regarding the identification of dates used in the Japanese astronomical almanac, we do not need to convert a luni-solar calendar date into a Gregorian calendar date because Japan adopted the Gregorian calendar in 1873, as mentioned above. Instead, we must know the reference point for observations and the standard meridian of a time to compare the times in the astronomical almanacs with those derived from modern calculations. Regarding the reference point, we refer to the Japanese Astronomical Almanac [曆象年表] of 2010 (NAOJ 2009); *Tenshudai* (天守臺; main tower, 09h 19m 01s in latitude and 35° 41’ 06” in longitude) up to 1890 and the Tokyo Astronomical Observatory (09h 18m 58s in latitude and 35° 39’ 15” in longitude) thereafter. In contrast, Japan adopted the standard meridian of 135° E in 1888 (see Appendix B). Therefore, we assume that Japan started using the standard meridian as the reference point for observations some time before 1888.

We also have to know the definition of time data to compare the times listed in the astronomical almanacs with results from modern calculations. For example, nowadays, the sunrise or sunset times are defined as the moments when the upper part of the sun reaches the horizon, i.e., the zenith angular distance of the sun is 90° 50’ considering the sun’s angular radius of 16’ and a mean atmospheric refraction of 34’. Details pertaining to the definitions of the time data, including the changes of the reference point for observations in Japan, will be further discussed elsewhere.

4 RESULTS

In Figure 1, we present the results for the new moon and full moon times, which are independent of the reference point for observations. In this figure, the horizontal and vertical lines represent a year and the difference (in minutes) between the times presented in the astronomical almanacs (T_A) and those obtained from modern calculations (T_C), $T_A - T_C$. In modern calculations, we use the standard meridian of 135° E for all years, for verifying whether the standard meridian of 135° E was actually used in the almanac for the year 1888. As a result, we found that the time differences show a large change in 1888, which verifies the *Dajōkan* report on the use of the standard meridian of 135° E.

In Table 2, we summarize the results for all time data. Column 1 presents the different types of time data, and columns 2, 3, and 4 present $T_A - T_C$ data in units of seconds (according to the period). We divide the period into three classes based on the reference positions of the observation and the standard meridians: periods I, II, and III. For the reference positions of the observation, we used the locations of the main tower in periods I and II, and the Tokyo Astronomical Observatory in period III. However, the first quarter, last quarter, twenty-four seasonal subdivision, and lunar eclipse data do not depend upon the reference position of the observation, as the cases of the new and full moon time data do. On the other hand, we assumed the main tower was used in period I, and 135° E was used in periods II and III as the standard meridian of time. As a result, we found that the accuracy is better than ~1min on average.

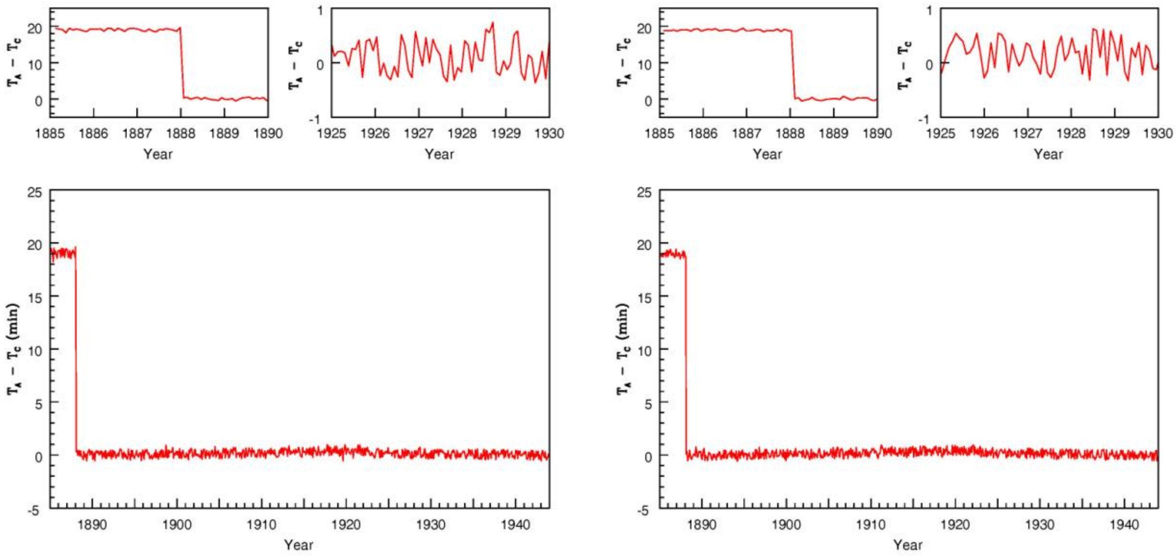


Figure 2. Time differences between astronomical almanacs and modern calculations in new moon (left) and full moon (right) data.

Table 2. Summary of results for time differences between astronomical almanacs and modern calculations.

Items	T_A - T_C (sec)		
	Period I[1)]	Period II[1)]	Period III[1)]
New moon	3.57±20.95	8.92±18.88	
First quater moon	1.93±16.63	11.60±20.17	
Full moon	–5.41±13.93	8.17±19.92	
Last quater moon	–5.28±18.20	7.80±19.57	
24 Sea. Subdiv.	–21.02±15.36	–7.43±26.38	
Sunrise	–14.10±18.56	–15.07±17.37	–5.50±17.94
Sunset	11.64±19.68	10.73±18.69	4.58±16.86
Moonrise	–14.12±17.03	–11.40±1778	–5.89±17.49
Moonset	15.64±18.60	14.99±1835	4.75±19.12
Solar eclipse	–7.0[2)]	no data	1.67±07.65
Lunar eclipse	2.30±19.61	–14.12±16.04	
Total	≤ 1min on average		

[1)]Refer to the text for the assumed reference position of the observations and the standard meridian.
[2)]Only one data point is used for this calculation.

5 SUMMARY

In this paper, we analysed Japanese astronomical almanacs from 1885 to 1943, relying primarily on the simplified almanacs. First, we found that the astronomical almanac used the solar calendar beginning in 1873, although the 337th official report of the *Dajōkan*, regulation on the use of the solar calendar, was announced too late to allow the preparation of the astronomical almanac of the calendar. In addition, we pointed out that the solar calendar actually refers to the Gregorian calendar based on information in the astronomical almanac of 1900. Second, we verified that the standard meridian of 135° E was used in the almanacs from the year 1888 onwards in Japan, based on the analysis of the new moon and full moon time data. Last, we estimated the accuracy of the time data presented in the Japanese astronomical almanacs of 1885 – 1943, which were collected from various sources including a private owner. As a result, we found that the time data are very accurate, that is, better than 1min. We think that this study contributes to a better understanding of historical Japanese astronomical almanacs.

6 ACKNOWLEDGEMENT

Ki-Won Lee would greatly like to thank Dr. Mitsuru Sôma of NAOJ for providing the opportunity to talk at the third symposium on Historical Records and Modern Science and providing travel and accommodation funds. The authors would like to thank the librarians at NAOJ, National Library of Korea, and the Busan Metropolitan Simin Municipal Library for help in reading the Japanese astronomical almanacs.

7 REFERENCES

Ahn, S. H., Lee, K.-W., & Mihn, B. H., 2010, *Modern Astronomy in Korea*, Korea Astronomy and Space Science Institute

Choi, G. E., 2010, A Study of Korean Astronomical Almanacs for 1864 – 1945, Msc Thesis, Chungbuk National University

Lee, K.-W., 2008, A Study of Solar Eclipse Records during the Three Kingdoms Period in Korea, *Journal of the Korean Earth Science Society*, 29, 408

Lee, K.-W., Ahn, Y. S., Mihn, B.-H., & Lim, Y. R., 2010, Study on the Period of the Use of Datong-li in Korea, *Journal of Astronomy and Space Sciences*, 27, 55

Lee, K.-W., Ahn, Y. S., Mihn, B. H., & Shin, J.-S., 2011, Database Construction and Textual Analysis of Korean Astronomical Almanacs, *Publications of the Korean Astronomical Society*, 24, 1

Lee, K.-W., Ahn, Y. S., Mihn, B.-H., & Kim, B.-G., 2011, *The* Incheon *Meteorological Observatory and Its Astronomical Activities*, in Proceedings of the Seventh International Conference on Oriental Astronomy, eds T. Nakamura, W. Orchiston, M. Soma, & R. Storm, 238

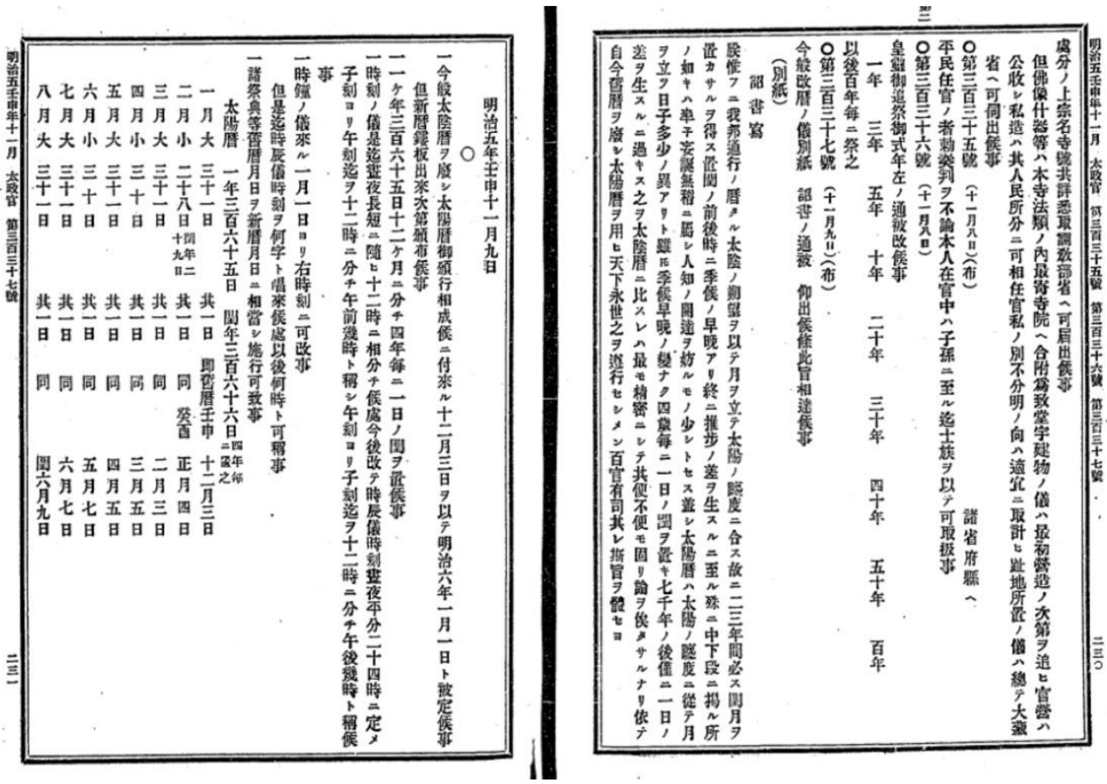
National Astronomical Observatory of Japan, 2009, *Japanese Astronomical Almanac [暦象年表] of the Year 2010*, National Astronomical Observatory of Japan

Nautical Almanac Office, 2009, Astronomical Almanac for the Year 2010 and Its Companion,

Meeus, J., 1998, *Astronomical Algorithms*, Willmann-Bell Inc.

Standish, E. M., Newhall, X. X., Williams, J. G., & Folkner, W. F., 1997, JPL Planetary and Lunar Ephemerides (CD-ROM), Willmann-Bell Inc.

APPENDIX A


明治五壬申年十一月　太政官　第三百三十五號　第三百三十六號　第三百三十七號

處分ノ上宗名寺號共詳悉取調教部省ヘ可届出候事
　但佛像什器等ハ本寺法類ノ内最寄寺院ヘ合附爲致堂宇建物ノ儀ハ最初營造ノ次第ヲ追ヒ官營ハ公收シ私造ハ其人民所分ニ可相任官私ノ別不分明ノ向ハ適宜ニ取計ヒ跡地所置ノ儀ハ總テ大藏省ヘ可伺出候事

○第三百三十五號　(十一月八日)(布)　諸省府縣ヘ
平民任官ノ者勅奏判ヲ不論本人在官中ハ子孫ニ至ル迄士族ヲ以テ可取扱事

○第三百三十六號　(十一月八日)
皇靈御追祭御式年左ノ通被改候事
一年　三年　五年　十年　二十年　三十年　四十年　五十年　百年
以後百年毎ニ祭之

○第三百三十七號　(十一月九日)(布)
今般改暦ノ儀別紙　詔書ノ通被　仰出候條此旨相達候事
(別紙)
詔書寫
朕惟フニ我邦通行ノ暦タル太陰ノ朔望ヲ以テ月ヲ立テ太陽ノ躔度ニ合ス故ニ二三年間必ス閏月ヲ置カサルヲ得ス置閏ノ前後時ニ季候ノ早晩アリ終ニ推歩ノ差ヲ生スルニ至ル殊ニ中下段ニ掲ル所ノ如キハ率子妄誕無稽ニ屬シ人知ノ開達ヲ妨ルモノ少シトセス蓋シ太陽暦ハ太陽ノ躔度ニ從テ月ヲ立ツ日子多少ノ異アリト雖モ季候早晩ノ變ナク四歳毎ニ一日ノ閏ヲ置キ七千年ノ後僅ニ一日ノ差ヲ生スルニ過キス之ヲ太陰暦ニ比スレハ最モ精密ニシテ其便不便モ固リ論ヲ俟タサルナリ依テ自今舊暦ヲ廢シ太陽暦ヲ用ヒ天下永世之ヲ遵行セシメン百官有司其レ斯旨ヲ體セヨ

二三〇

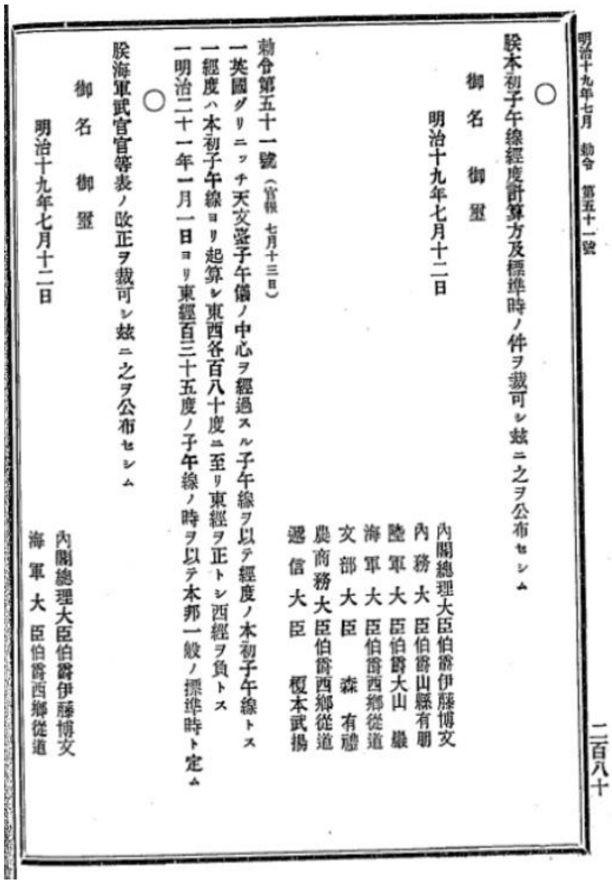
明治五年壬申十一月九日
○
一今般太陰暦ヲ廢シ太陽暦御頒行相成候ニ付來ル十二月三日ヲ以テ明治六年一月一日ト被定候事
　但新暦鏤板出來次第頒布候事
一一ケ年三百六十五日十二ケ月ニ分チ四年毎ニ一日ノ閏ヲ置候事
一時刻ノ儀是迄晝夜長短ニ隨ヒ十二時ニ相分チ候處今後改テ時辰儀時刻晝夜平分二十四時ニ定メ子刻ヨリ午刻迄ヲ十二時ニ分チ午前幾時ト稱シ午刻ヨリ子刻迄ヲ十二時ニ分チ午後幾時ト稱候事
一時鐘ノ儀來ル一月一日ヨリ右時刻ニ可改事
　但是迄時辰儀時刻ヲ何字ト唱來候處以後何時ト可稱事
一諸祭典等舊暦月日ヲ新暦月日ニ相當シ施行可致事
　太陽暦　一年三百六十五日　閏年三百六十六日（四年毎ニ置之）

一月大	三十一日	共一日	即舊暦壬申	十二月三日
二月小	二十八日（閏年二十九日）	共一日	同　癸酉	正月四日
三月大	三十一日	共一日	同	二月三日
四月小	三十日	共一日	同	三月五日
五月大	三十一日	共一日	同	四月五日
六月小	三十日	共一日	同	五月七日
七月大	三十一日	共一日	同	六月七日
八月大	三十一日	共一日	同	閏六月九日

明治五壬申年十一月　太政官　第三百三十七號
二三一

(source: http://kindai.da.ndl.go.jp/info:ndljp/pid/787952/172)

APPENDIX B



明治十九年七月 勅令 第五十一號

二百八十

○

朕本初子午線經度計算方及標準時ノ件ヲ裁可シ玆ニ之ヲ公布セシム

御名 御璽

明治十九年七月十二日

内閣總理大臣伯爵伊藤博文
内務大臣伯爵山縣有朋
陸軍大臣伯爵大山巖
海軍大臣伯爵西鄉從道
文部大臣 森有禮
農商務大臣伯爵西鄉從道
遞信大臣 榎本武揚

勅令第五十一號（官報 七月十三日）

一英國グリニッチ天文臺子午儀ノ中心ヲ經過スル子午線ヲ以テ經度ノ本初子午線トス

一經度ハ本初子午線ヨリ起算シ東西各百八十度ニ至リ東經ヲ正トシ西經ヲ負トス

一明治二十一年一月一日ヨリ東經百三十五度ノ子午線ノ時ヲ以テ本邦一般ノ標準時ト定ム

○

朕海軍武官官等表ノ改正ヲ裁可シ玆ニ之ヲ公布セシム

御名 御璽

明治十九年七月十二日

内閣總理大臣伯爵伊藤博文
海軍大臣伯爵西鄉從道

(source: http://kindai.da.ndl.go.jp/info:ndljp/pid/787968/362)