Variation of Solar Activity and Historical Climate Change[1]

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Abstract

We examine climate change last two thousand years using Korean historical records. Korea has a long history in astronomy and there are amount of observational records in Korean chronicles. There are 43 sunspot records in Goryeo dynasty (918-1392) and 13 records in Joseon dynasty (1392-1910). According to analysis of Korean historical records, it is known that sunspot records in Goryeo dynasty show well in match with the well-known solar activity of 11.3 years. It means that Korean historical sunspot records show real solar phenomena. Korean sunspot records also show that solar activity decrease in Joseon dynasty compared with the previous ~500 years. In order to know the change of solar activity in detail, we examine Korean historical meteorological records which can indicate climate change. We analyze historical frost records and find that around 600 frost records during the last millennium shows sign of cooling down of temperature. This result is well in accord with that of historical sunspot records. We also find that one thousand year periodical change of temperature and ~250-year periodic solar activity.

I. Introduction

Korea has a long history and contains amount astronomical observations in chronicles such as Samguksagi(三國史記), Goryeosa(高麗史) and Joseonwangjosillok(朝鮮王朝實錄, hereafter, Sillok), and so forth. Korean chronicles contain various astronomical phenomena such as solar and lunar eclipses, sunspot, meteor and meteor shower, meteorite, comet, movement of planets, aurora, etc. (Park 2008; Yang 2012). In general, Korean historical observations can be classified into three groups. The first one is periodical phenomena such as sunspot, meteor shower, eclipses and so forth. These records are very useful in modern astronomy particularly in the analysis of long-term variations of each phenomenon. Yang et al (1998; 2005a) and Yang (2004) found that historical sunspot and meteor in chronicles are real phenomena and they show well-known periodic property. The second one is non-periodical phenomena such as comet, SN, meteorite, etc. In this case, epoch of the stellar explosion is essential information to understand the astrophysical characteristics of the object (Yang et al 2005b). The last one is the phenomena we can see all the times such as motion of planets, position of the moon, meteor, and so forth. These records can tell us the number distribution of historical observational records. Figure 1 shows the number distribution of astronomical observations during Goryeo dynasty (AD998-1392). During the Goryeo dynasty, the most observational phenomenon is motion of planets, and the next one is meteor record.

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[1] The draft is a tentative result of this study. Final document which include this draft will be published in any relevant journal.

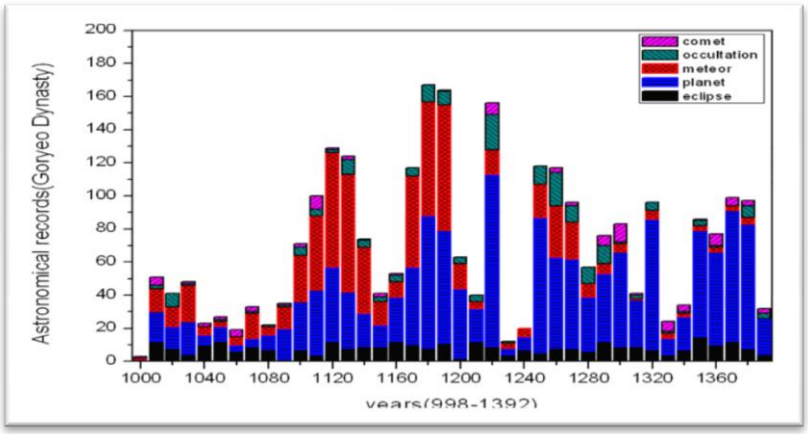

Figure 1. Number distribution of Korean observational records in Goryeosa (AD 998-1392)

If historical observational phenomena were recorded faithfully, the records could be useful data in modern astronomy. For instance, when we examine historical solar and lunar records, we could get astronomical knowledge such as delta T, nutation, and obliquity of the ecliptic, etc. When historical sunspot and aurora records give us the information of solar long-term variation, we might estimate the global climate change. There were several star explosion records in Korean chronicles. When we know epochs of the explosions and visual magnitude of the object then we can calculate physical parameters such as distance, brightness, condition of ISM, outburst model, and so forth. Historical comet and meter records let us know the evolution of periodic comet and remnants of the tail and environment of solar system, and so forth. So, historical astronomical records are very useful in modern astronomy. Historical observations also give us clues for understanding the long-term variation of nature such as global climate change. Furthermore, we could interpret ancient culture from historical astronomical records.

Korean chronicles contain amount and successive astronomical records around over 2,000 years. Therefore, historical records are highly valuable for study on the long-term variation of celestial bodies such as solar activity, evolution of periodic comets, and stellar evolution, and so forth. In this work, we examine solar long-term variation and its effects on global climate change past two thousand years using historical sunspot and meteorological records which can reflect solar activity.

II. Historical Sunspot and aurora records

In Korean history, there are a lot of sunspot records, especially in Goryeo dynasty (AD 918-1392). Sunspot phenomenon shows solar activity directly, thus it is a fundamental records to understanding the solar variations. Aurora phenomenon also shows solar activity. Yang et al (1998) have analyzed historical sunspot and aurora records using the Fourier transform methods and found that sunspot and aurora records in Goryeo dynasty show well-known periodical short-term solar activity of 11.3 year. Most aurora records in Korean chronicles were described as red-vapor(赤氣) because Korea is located in low latitude from magnetic pole. Goryeo people might see aurora phenomenon in Korean peninsula due to movement (; approach to Korean peninsula) of the magnetic pole. Figure 2 shows the distribution of sunspot and aurora records. The y-axis of the Fig. 2 indicates magnitude of observational phenomenon. Actually, historical sunspot was

described as big as black spot, plum, egg, peach and pear in Korean chronicles. The magnitude in the y-axis of sunspot in fig. 2 indicate the size of sunspot.

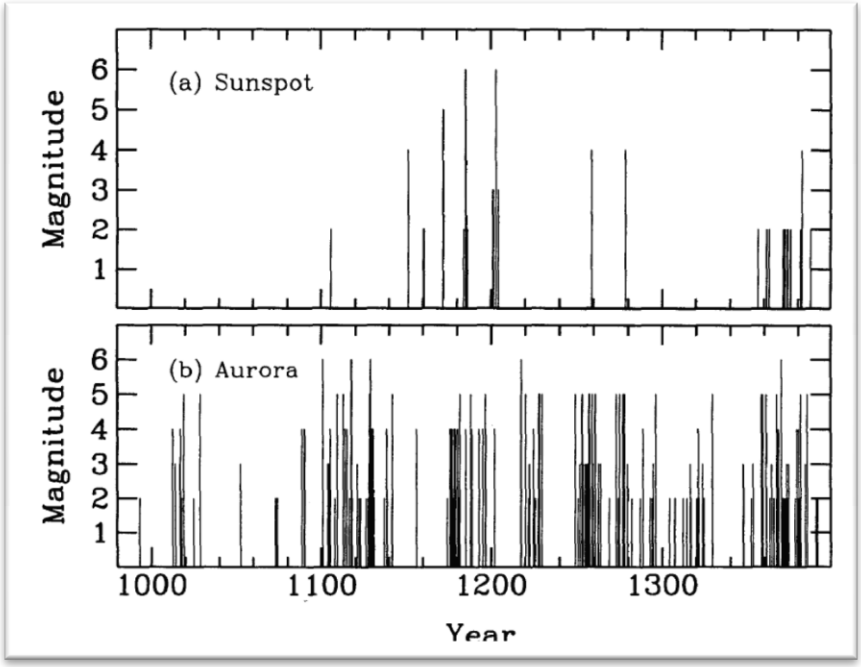

Figure 2. Number distribution of sunspot and aurora records in Goryeo dynasty (AD 918-1392, Yang et al 1998)

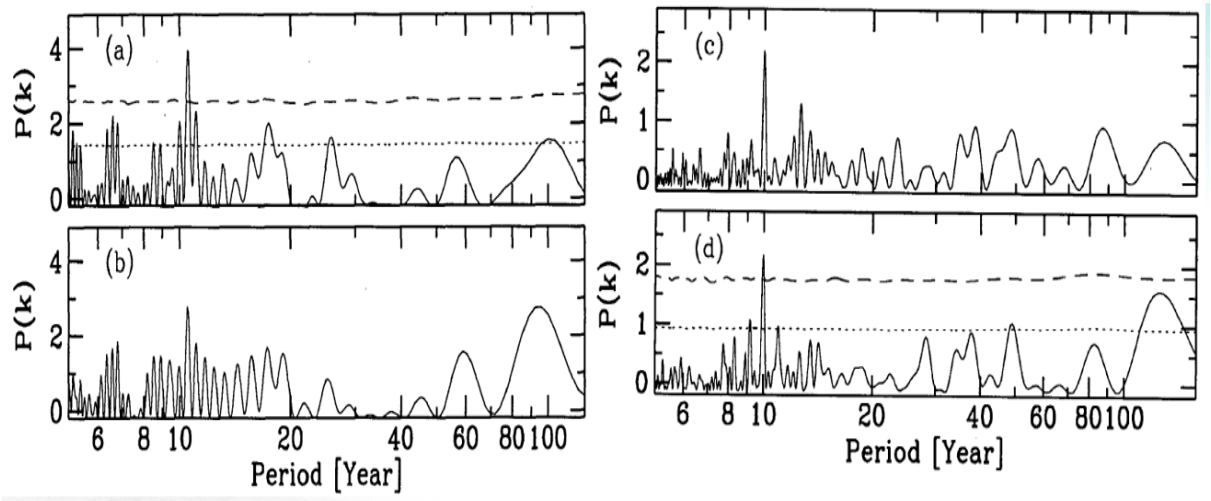

Figure 3. Power spectrum of Sunspot (a,b) and aurora (c,d) records during Goryeo dynasty (AD 918-1392, Yang et al 1998). (a) is the result including weight-value and mag. based on the size of sunspot, (b) is not including mag. of each record, (c) is result of 93 records for mag. >4, and (d) is the result of 45 records for mag. >5. Dashed and dotted lines in (a) and (d) indicate the confidence level of upper 0.14 and 2.30% in random generating using Monte-carlo simulation.

Figure 3 shows power spectrum of sunspot and aurora records during Goryeo dynasty (Yang et al 2008). Figure 3(a) and 3(d) show well-known short-term solar activity of ~11-year. And it means that sunspot and aurora records in Goryeosa are true observations. We also find a long-term solar activity in the power spectrum. In Fig. 3(a) and 3(d), we also guess a long-term activity of ~100-year.

In Korean history, Joseon dynasty (AD 1392-1910) is in succession to former dynasty, Goryeo. There are ~20,000 items in Joseon dynasty whereas around 5,000 items in Goryeo dynasty. However, sunspot records in Joseon dynasty is a few, so we cannot analyze the sunspot records in Joseon dynasty using the Fourier transform method. Figure 4 shows the number distribution of historical sunspot records in Goryeo and Joseon dynasties. As is well known, there were three solar minimum activities, and the minimum activities had caused the Little Ice Age (LIA) from the sixteenth to the nineteenth centuries (Michael 2003). Figure 4 shows the reason of lack of sunspot records during Joseon dynasty. Number distribution of historical sunspot is well match with the solar activity during around last one thousand years. It roughly shows that solar activity has decreased last one thousand years.

In order to know precise long-term solar activity, we need older historical observations. However, there are few sunspot observational records during the Three Kingdoms period (37BC~AD935), unfortunately. Meanwhile, Korea has also amount meteorological observations in chronicles. Thus, we examine historical meteorological records to know the long-term solar activity.

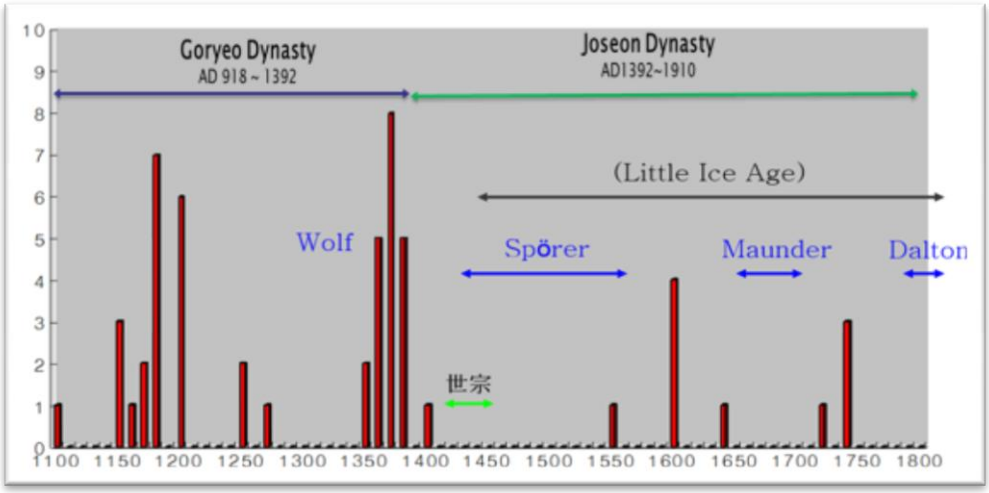

Figure 4. Number distribution of historical sunspot records (bar-histogram) during last ~1000 years and solar minimum activities. Wolf, Sporer, Maunder and Dalton are solar minimum activities.

III. Historical meteorological record and climate change

In Korean chronicles, there are amount and various meteorological records such as drought, frost, flood, rain, hail, snow, thunder, lightning, fog, storm, and so forth. Most meteorological records contain the information of observational site unlike astronomical records. Generally, meteorological phenomena have been recorded in the capital of dynasty, but some records were

observed in a specific region.

Korea has limited number of historical sunspot records, especially in 1st~7th centuries. In order to investigate solar long-term variations we examine the mechanism of each meteorological phenomenon in Korean chronicles. There are a lot of metrological records in the Three Kingdoms period in Korea (Fig. 5). Many meteoroidal phenomena show generally specific regional characteristics, while some phenomena could reflect global climate change. Therefore, we select the 'Frost' phenomena to investigate the solar long-term activities. As is well known, solar activity can affect the temperature of the Earth. And the frost record can reflect change of temperature. In order to know the correlation between the frost record and temperature, we analyze modern observation records for 20 years. Figure 6 shows the annual variation of last (spring) and first (autumnal) observational dates in two sites (Cheongju and Cheolwon) of Korea. Geographically, Cheolwon is located ~2° higher than Cheongju. Figure 6 shows that frost records could be a good temperature indicator.

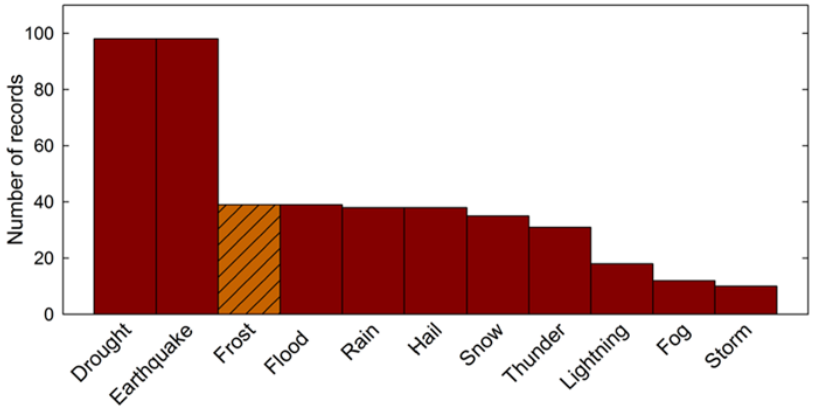

Figure 5. Number distribution of meteorological records in Samguksaki (57BC-AD935)

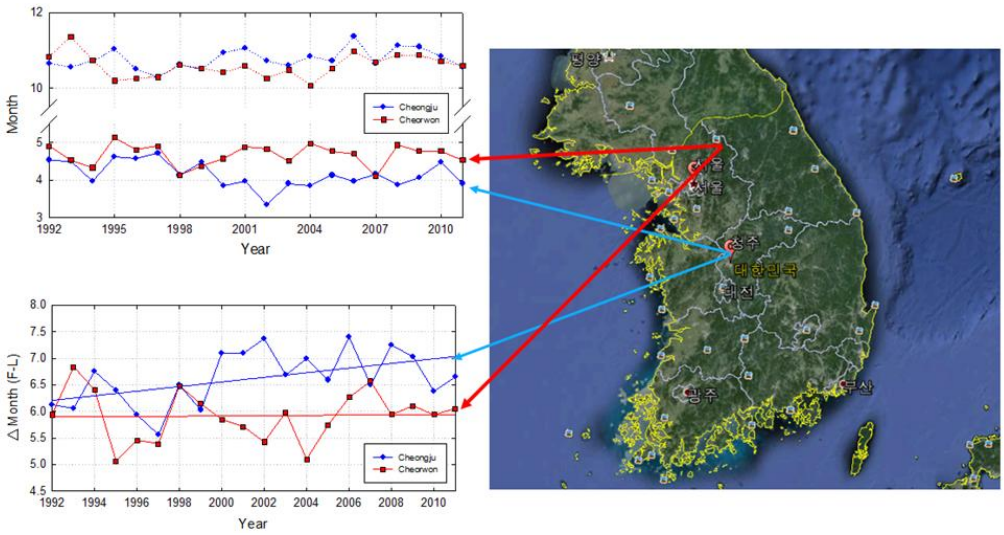

Figure 6. Annual variations of first and last frost observations in Cheongju(blue) and Cheolwon(red) in 1992-2011. Data from KMA.

Over the past few decades, many people very interested in the climate change. Climate is a long term phenomenon, and it appears on the wide area. It is known that climate change affected by Solar radiation, volcanic activity, Topography, Earth's orbital variation, CO_2 and so forth. Climate change can be assessed across short, medium and long timescales. Short-term (recent) climate change is on a timescale of decades, and the medium-term (historical) timescale covers changes over the last few thousand years. And long-term climate change has occurred on geological timescales, over hundreds of thousands to millions of years. Korean historical meteorological records can be a useful information to understand the climate change of the historical timescale.

For the historical time scale, variation of solar activity and volcanic activity are known as the main causes of the climate change. In general, solar activity can be the major cause of climate change in the historical timescale because volcanic phenomenon is the occasional event and consequently it affect in influence of a short period. In this work, we focused on the historical timescale of the climate change.

The Korean chronicles, Samguksagi, Goryeosa, and Sillok contain 38, 48, and 667 frost records, respectively. Historical frost record could be a useful data to understand the long-term variation of temperature. We examine historical frost records and find that high latitude has longer observation duration rather than lower latitude (Fig. 7). It means that historical frost reflect temperature climate, and also we might estimate solar activity based on the historical frost. Frost records in Goryeosa and Sillok roughly indicate that temperature gradually changes cooling down during last one thousand years (AD918-1910), and this result is well match with that of Korean historical sunspot records.

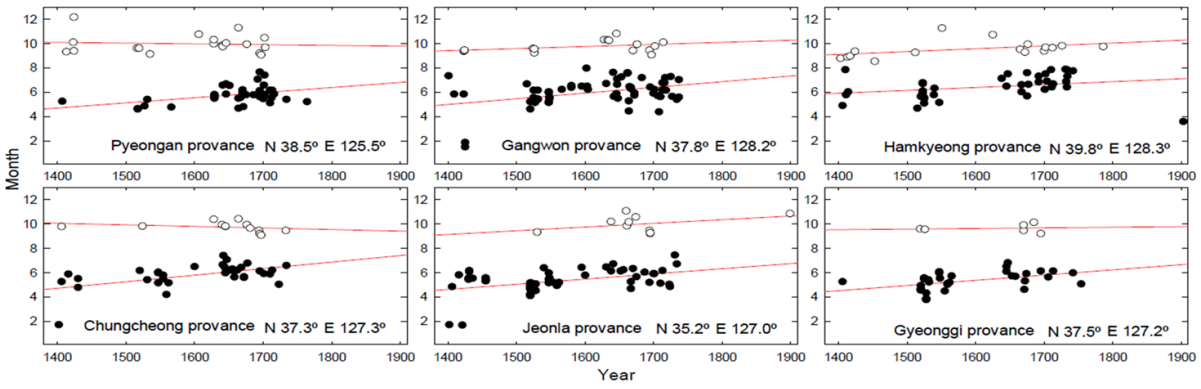

Figure 7. Variation of the first and last frost records in 6 areas during Joseon dynasty (1392-1910)

Zhu(1973) analyze Chinese metrological records during BC2000-AD1950 and compare the variation of Chinese temperature with that of Greenlandic Ice-core data. Figure 8 shows the result of temperature variation of China and Greenland from meteorological records and Ice-core data, respectively. Dansgaard(1969) already has analyzed climate change during one thousand years using Greenlandic Ice-core (shown in the fig. 8.) The results of Chinese and Greenlandic temperature variations roughly show that during the recent 500-year is cooler than the before 500-year. Moreover, the result is well match with that of Korean historical sunspot and frost records.

In the fig. 8, 18 century is the coldest period during past two thousand years in China and Greenland. Korea also has the similar tendency of temperature climate. Bae(2004) reported that 18C of Koran peninsula has unusual low temperature based on the meteorological records.

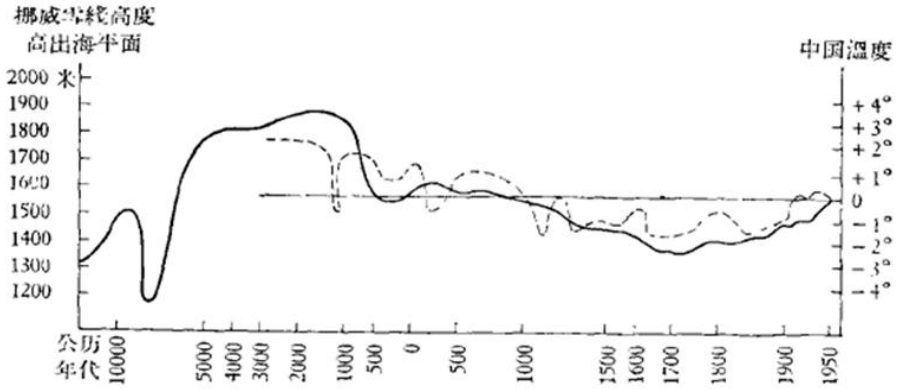

Figure 8. Temperature variation of China(solid line) and Greenland(dotted line) from the historical meteorological observations and Ice-core data, respectively.

IV. Discussions

Korean history has been recorded in successive chronicles which cover around two thousand years from the three Kingdoms period to Joseon dynasty. Historical chronicles contain various historical events and natural phenomenon, and these records are important property to understand Korean history. In particularly, the astronomical and meteorological records are very useful to examine climate change.

There are a lot of historical sunspot records from Goryeo to Joseon dynasties dating AD 918-1910, and the historical records indicate that solar activity decrease during the last one thousand years. Actually, 43 sunspot records in Goryeo dynasty show well-known short term periodical activity of 11.3-year and also show possible periodical long term activity. However, there are few sunspot records in Joseon dynasty thus, it is difficult to find solar activity quantitatively using astrophysical calculations.

In order to know the long-term variation of solar activity, we examine historical meteorological records. Periodical solar activity certainly affect global climate change, thus we select "Frost record", which could show temperature climate, to investigate the long term solar activity. We examine the correlation between duration of frost observation and temperature climate, and find a good direct correlation between them. We analyze historical frost records and find that the temperature roughly falls down slowly during past one thousand years. Like sunspot records, there is few frost records in the Three Kingdoms period (37BC~AD935) thus, we exclude those in this work.

Meanwhile, Chinese and Greenlandic temperature roughly had been changed cooling down during the past two thousand years (Fig. 8) However, Greenlandic Ice core data shows small fluctuations even cooling down. In fact, Korean historical frost records also show possible fluctuation in temperature variation. We examine solar activity in detail using Korean and Chinese historical sunspot records, and find around 250-year periodical solar activity. The new long-term solar activity of ~250-year is a good possibility. Moreover, the 250-year solar cycle has a good match with Korean historical frost records. Historical sunspot records have maximum periods in AD1150, 1400, and 1650, and climate temperature shows transient cooling down at the same periods. We guess that there are two major components in the climate change during past two thousand years. The one is cooling down slowly past two thousand years and the other is the 250-yr solar cycle. More studies are necessary to understand the solar activity and climate change.

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