Chugugi, Supyo, and Punggi: Meteorological instruments of the 15th century in Korea

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Introduction and Background

Meteorology in Korea in modern sense had its start in the 15th century when scientific devices were invented for the measurement of rainfall, flood levels, and wind direction. These inventions were part of the effort to control and understand nature's influence on agricultural production. This fact is described in detail in volume 93 and 96 of the *Sejong sillok* (Annals of King *Sejong*; CE 1418~1450). About 300 years later, another record in volume 114 of the *Yongjo sillok* (Annals of King *Yongjo*; CE 1724~1776) also supports this invention. The historical *sillok* were translated into the modern Korean language in 1994 and were subsequently digitized.[1] In this study, *sillok*, which is a veritable record, will be used together with secondary sources in order to explain the invention of the rain gauge in Korea and describe its background and purpose. Two other meteorological devices invented in Korea in the 15th century, the watermark and wind anemoscope, will also be introduced.

The earliest record that snow accumulated in the capital of *Goguryo* was in December, CE 77, when the depth was recorded as three *chok*. *Chok* is a traditional length unit corresponding to about 20 cm. Also recorded are flood level records of three to four *chok* for ten days in CE 350.[2]

The mention of rain measurement appears on May 3, 1423 in the *Sejong sillok*, when the depth of wet soil was measured as 1 *chon* (fig. 1). *Chon* was the length unit corresponding to about 2 cm today. The next record can be found in 1425 in the *Sejong sillok* (Vol. 28): 'Drought. Ordered the provinces and counties to measure the depth of moisture penetration on the soil and report'. This measurement was called '*Wootaek*' and had been a simple method to record rainfall in the whole country in Korea.

Fig. 1. Wet soil depth recorded in the *Sejong sillok* (vol. 20). The dotted box is translated here. It reads: "It rained tonight, penetrating earth to the depth of approximately one *chon* (about 2 cm) in CE 1423."

Chugugi (Rain gauge) and *Chugudae* (Stand)

According to the *Sejong sillok*, heavy rains and severe droughts alternated around the year 1441. Whether or not there was adequate rainfall at the appropriate time determined whether there was to be a bumper crop or a famine. However, the depth depended on the soil type, texture and dryness. It could not be compared with each other. The *Sejong sillok*, under the date of August 18, twenty-third year of the reign of King *Sejong* (CE 1441), mentions the epoch-making event in the history of agricultural meteorology as follows:

> The Minister of Taxation informed [the court] that according to reports from the provincial governors on the amount of rainfall, the conventional method of measurement was unable to distinguish between the differences in the depth of rainwater on the ground when it was parched and when it was soaked. Therefore, they recommended that the *Soungwan*[3] should be instructed to prepare a pedestal or a base and place thereon a vessel of iron 2 *chok* in depth and 8 *chon* in diameter to measure the amount of rainfall.

Prince *Munjong* designed the instrument in CE 1441 and named the rain gauge as *Chugugi* with 1.5 *chok* (30 cm) in depth and 7 *chon* (14 cm) in diameter. The depth of rainfall was measured by a ruler called *Chuchok*. A network of such gauges was soon established at every district office on the Korean peninsula. The scientists and officials of *Soungwan* engaged in the work of compiling meteorological information gathered data from outposts in the provinces, counties, and towns of the realm for more than 700 years, until the downfall of the *Joseon* dynasty at the beginning of the 20th century.

It is well documented that the *Chugugi* was invented in the 15th century in Korea.[4] The Japanese historian of science and technology Keiji Yamada recently wrote, "It must be taken into consideration that there is no Chinese record that defines clearly the standardized instrument to measure the rainfall amount. Apparently, there was a mathematical problem to calculate the rainfall amount in a round bowl in China. Neither artifacts nor records show that the ancient Chinese scientists invented such an instrument. The invention of a column shaped instrument with standard uniform size was done by *Joseon* scientists and was their own original idea."[5]

There are only three records (CE 1530, CE 1542, and CE 1586) to measure the rainfall in Seoul. That is because the rain gauges made during the reign of King *Sejong* were all destroyed or lost during the Japanese invasion (1592-1598). All rainfall records previous to 1770 are based on *Supyo* or watermark readings taken in the *Cheonggyecheon* stream following through the middle of Seoul (see below).

King *Yongjo* (CE 1724-1776) finally determined to set up the network of *Chugugi* throughout the country and accordingly issued an edict to this effect. On May 1, 1770 in the 46th year of his reign, bronze rain gauges were made in accordance with the specifications established during the reign of King *Sejong*. The rain gauge stand was made from a stone block 46 x 37 x 37 cm and had a hole or basin 16 cm in diameter carved to the depth of 4.2 cm (fig. 2). Both on the front and rear sides of the stone stand was inscribed the name *Chugudae*, the stand for the *Chugugi*, while to the left on the rear side were inscribed the letters *Gollyung gyongsin Owol cho* (Manufactured in May, sexagenary year 57 in the reign of the *Chinglung* Emperor in China). At that time, the *Gollyung* was a generally used year name in Korea. The *Chugugi* and *Chugudae* placed at *Taegu* (southeastern city of Korea) were brought to the *Incheon* observatory in 1910 and then kept at the Korea Meteorological Administration (KMA) in Seoul until now, but the *Chugugi* disappeared during the Korean War (CE 1950-1953).

Fig. 2. The *Chugugi* (replica) and *Chugudae* (original) made in CE 1770, in accordance with the specifications established during the reign of King *Sejong* (CE 1418-1450).

In 1782, a rain gauge was installed in the courtyard of the *Changdeok* Palace during a severe drought that lasted from June to July. The marble stand on which the *Chugugi* was placed have detailed inscription explaining the significance of the rain-measuring device. The inscriptions read as follows:[6]

> In the twenty-fourth year of the reign of King *Sejong*, a rain gauge was made of copper [iron] to the size of 1 *chok* and 5 *chon* in height and 7 *chon* in diameter, one being installed in each province, county, and township to measure the depth of rainwater after each rain. In the forty-sixth year of the reign of the preceding King [*Yongjo*], copies of the old model were cast and installed in the *Changdeok* and *Gyonghui* Palaces and in the eight provinces. Although the vessels may be small in size, they are heavy in weight and import since they embody the efforts made under the two sacred eras to combat both floods and droughts. In the summer of the sixth year [of King *Jongjo*], a severe drought visited the whole 500 ri [distance unit] of *Gyounggi* Province and the paddies were parched and cracked. Thereupon, the King blamed his holy self and widely sought advice. Having had a cloth screen set upon the altar, His Majesty alit from the sedan chair to offer a prayer in person, until his royal attire was wet with evening dews. Also, convicts were amnestied, and the people and scholars, and women and children within the capital looked up in grateful wonder, and tearfully spoke in these words: "Since His Majesty has such great apprehension for the well-being of his subjects, rain is bound to come; even if no rain shall fall, his subjects should feel more grateful than if rain came." That night, there was a great rain, and the depth reached one *chon* and two *pun*. This was entirely due to His Majesty's virtue. His Majesty was worried that the rain was not sufficient; so he had a rain gauge installed in the courtyard of the *Changdeok* Palace and measurement taken, and it was found sufficient. Thereupon, His Majesty called upon his courtiers *Sim Yom-jo* and *Chong Chi-gom* to record his exceeding joy. They are his most loyal subjects. They know that when then there is no rain, the apprehension of His Majesty on behalf of his subjects can not measured by the same measure as the apprehension of the subjects, and that when there is rain, His Majesty's joy must far surpass that of his subjects. This rain gauge embodies such apprehension and such joy on the part of His Majesty. Respectfully, subject *Sim Yom-jo*, subject *Chong Chi-gom*.

Soungwan dealt with the astronomy, geography, calendar, fortune, weather, and time announcement. *Soungwanji*, a 328-page treatise by the Bureau of Astronomy and Meteorology published in 1818, records the procedures for measuring and recording meteorological phenomena such as hail, thunder, snow, dustfall and rainfall (fig. 3).

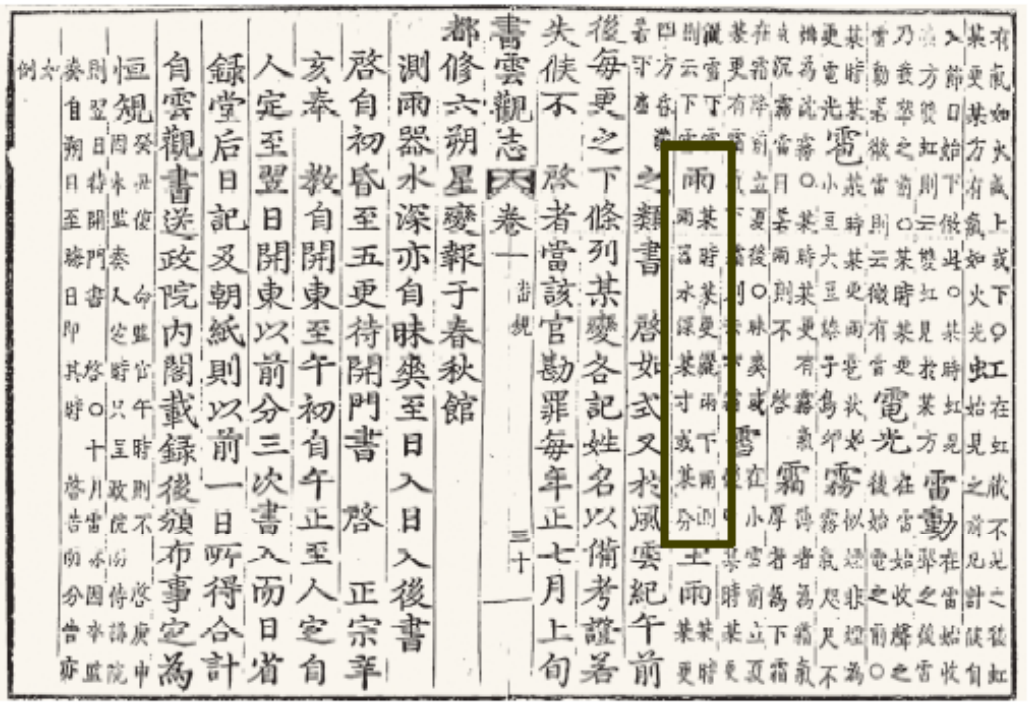

Fig. 3. The method of recording the rainfall amount written in *Soungwanji* (1818). The dotted box is translated here. It reads: Rainfall is recorded at the time, the date, and the water depth in the *Chugugi* in *chon* and *pun* (about 2 mm).

The only known surviving *Chugugi* was made in 1837 and bears the inscription: “made in the thirty-fourth sexagenary year of Tao-Kuang during King *Hunjong* (CE 1834-1849).” It was located in *Kongju* until 1910 when it was taken by the Japanese to Japan. The Japan Meteorological Agency returned it to Korea in 1971 as a result of efforts to restore Korean cultural assets, and it is presently kept at the Korean Meteorological Agency (KMA) in Seoul (fig. 4).

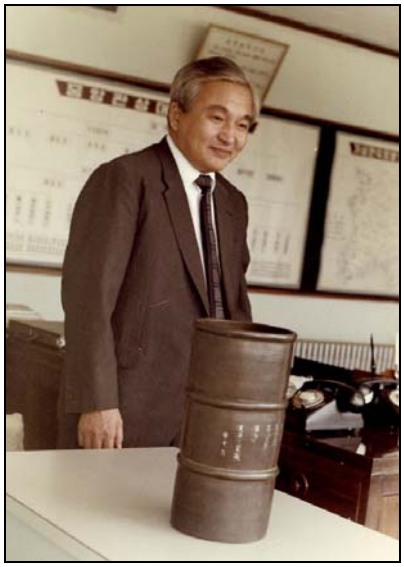

Fig. 4. The only genuine *Chugugi* in existence, made in 1837 and returned to Korea from Japan in 1971. This was designated as National treasure No. 561 in Korea. Dr. I.K. Yang, director general of the KMA (1968-80), is pictured.

The rain data measured in *Kongju* province as well as other areas in the Korean peninsula were found in *Kaksa tungnok* (Records and Documents from Governmental Offices consisting of 91 volumes during the 19th century in Korea. Digitalization of *Kaksa tungnok* was done by Korean Institute of Korean History in 2002[7].

Rainfall data as measured by the *Chugugi* in Seoul were archived from June 1770 with gaps in the record for April, July, and September 1772 and August 1775. A 227-year record of annual precipitation amounts observed in Seoul from 1776 to 2003 is shown in figure 5. Precipitation data before 1907 were based on the *Chugugi* records, and after 1907 were measured by the KMA using a modern rain gauge.

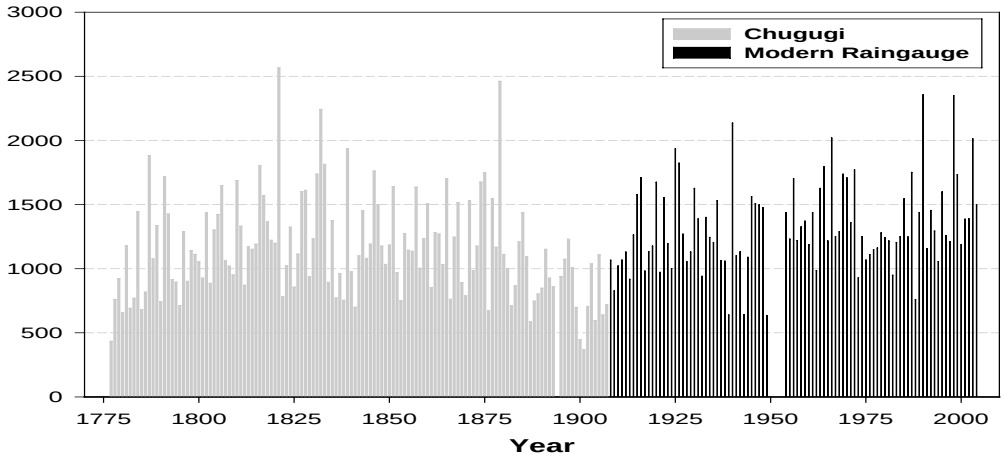

Fig. 5. The annual precipitation amounts observed in Seoul from 1776 to 2004.

At the beginning of the 20th century, there were five kinds of *Chugugi* made of iron and their eleven stands made of granite or marble[8]. However, at present, five stands and only one rain gauge remain in Korea as shown in Table 1.

Table 1. The *Chugugi* and *Chugudae* preserved in Korea

	Chugugi	*Chugudae*	Photograph	Original Location	Location (at present)
CE 15th century	Missing	Granite 61x92x58 cm (without inscription)		Seoul, Korea	KMA, Seoul, Korea
CE 1770	Missing	Granite 46x37x37 cm (inscription on two sides)		*Taegu*, Korea	KMA, Seoul, Korea
CE 1782	Missing	Marble 30.3x45.3x45.5cm (inscription on four sides)		Seoul, Korea	National Palace Museum of Korea, Seoul Korea
CE 1811	Missing	Granite 44x43.8x43.8 cm (inscription on one side)		*Tongyong*, Korea	Seoul Science Museum, Korea
CE 1828	Missing	Granite 60.5 x 28.5 cm (without inscription)		*Changdeok* Palace, Seoul, Korea	*Changdeok* Palace, Seoul, Korea
CE 1837	Bronze 32x15 cm 6.2 kg (inscription)	Missing		*Kongju*, Korea	KMA, Seoul, Korea

Supyo (Watermark) and *Supyo-gyo* (Bridge)

The watermark, *Supyo*, originally a wooden type column (2.5 m high), was invented in 1442 and erected west of the *Majon* Bridge on the *Han* River.[10]. Later in the era of King *Songjong* (CE 1469-1494), the watermark began to be made of stone, and this is the model that remains today. Figure 6 shows an example recorded in 1554 in which the water level of the *Han* River rose by 21 *chok* and 2 *chon* by the *Pobaek* scale. The *Pobaek* scale was used for measuring cloth while *Chuchok* was used mainly for determining the length of roads and for calibrating astronomical and meteorological instruments.

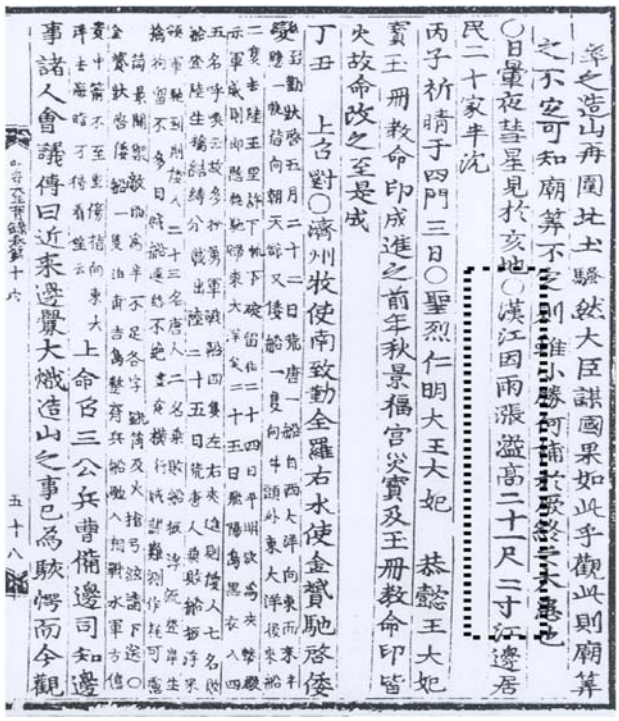

Fig. 6. The water level of the *Han* River was increased up to 21 *chok* and 2 *chon* (by the *Pobaek* scale) by flood in 1554.

All records previous to 1770 are based on watermark readings, and there appears in the *Injo sillok* (Annals of King *Injo*; CE 1623~1649) in 1648 an entry indicating that the report on the watermark reading for the heavy rains of the previous day had not been filed. The entry of May 18, 1743 states: “Heavy rain, Measurement made by the watermark. It appears also that during the era of King *Injo*, watermarks were set up at two places in Seoul, the *Injo sillok* mentioned a ‘central watermark’ and ‘southern watermark’ together with the water mark readings in the *Han* River. The detailed flood level records were investigated during the period from 1400 to 1821[11].

The wooden watermark was improved using the granite type column which has a scale of 1 *chok* (about 20 cm) to 10 *chok* (about 2 m), and also has special marks indicating the drought, normal, and flood levels. The six-sided granite type column is 3 m high and is shaped like a fish swimming upstream in order to reduce the stream

friction (fig. 7). It was possible to read the water level on the bridge called *Supyo-gyo*.

Fig. 7. The *Supyo-gyo* (bridge) and the *Supyo* (watermark) in *Cheonggyecheon* in the early 1900s.

When the *Cheonggyecheon* was covered up in a road expansion project, the original granite type watermark and the *Supyo-gyo* were moved to the *Jangchungdan* in Seoul, and afterwards the watermark only was removed to the *Sejong* Memorial Hall in Seoul (fig. 8).

Fig. 8. The *Supyo-gyo* in *Jangchungdan* (left) and the *Supyo* (watermark) preserved at the *Sejong* Memorial Hall (right) in Seoul at present.

Punggi (Anemoscope) and *Punggidae* (Stand)

A third meteorological instrument, the *Punggi*, or anemoscope, was erected in the era of King *Sejong* to record the direction and approximate speed of the wind. It consisted of a streamer attached to a long pole inserted into a *Punggidae*, or solid stand. The entire assembly was approximately 8 m high. It is not clear when systematic observations of wind direction actually commenced, but the anemoscope aided investigations of the influence of the wind on crops and shipping. Two existing bases, eight-sided granite columns (2.25 m) made in 1770, are now preserved in Seoul at the *Gyeongbok* Palace and the *Changgeong* Palace (fig. 9).

Fig. 9. Eight-sided granite *Punggidae*, made in 1770 for wind streamer, preserved in Seoul at the *Gyeongbok* Palace (left) and the *Changgeong* Palace (right).

An eighteenth-century painting on display at Seoul University Museum depicts *Punggi*, *Punggidae*, *Chugugi*, and *Chugudae* in one of the courtyards of the *Changdeok* Palace (fig. 10).

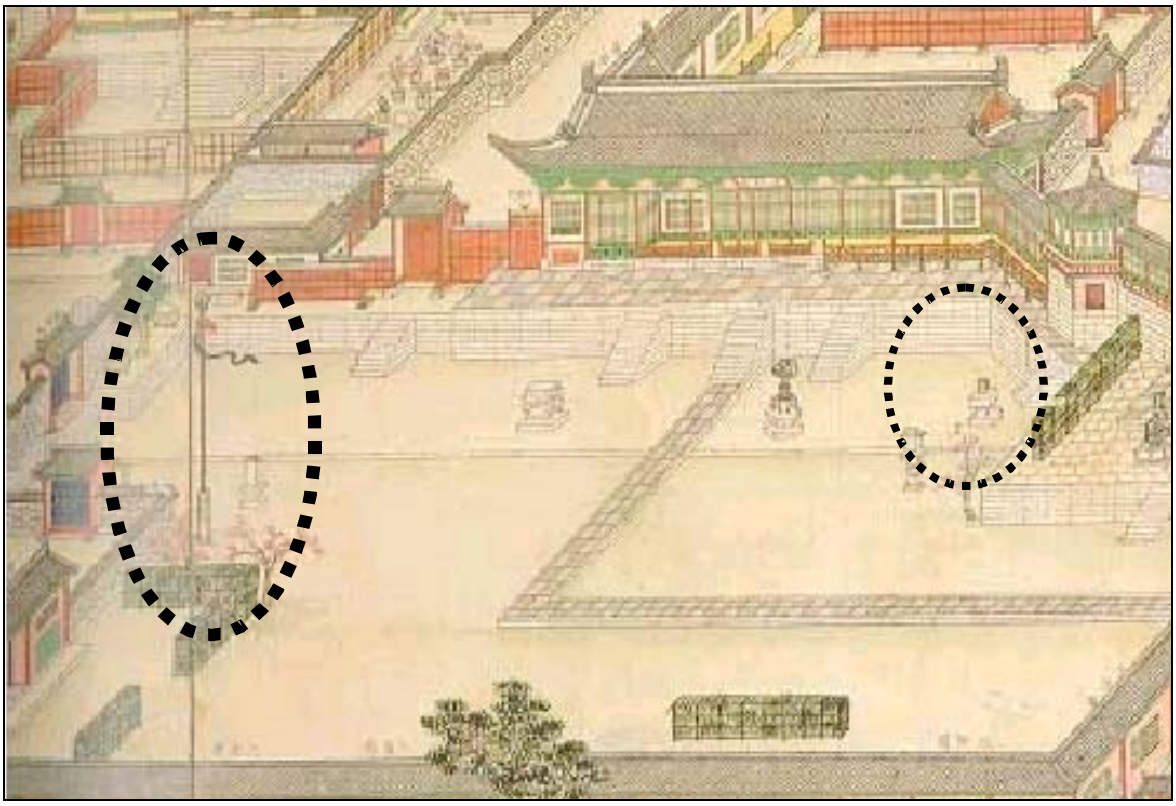

Fig. 10. *Pungi*, *Punggidae*, *Chugugi* and *Chugudae* in a part of the *Changdeok* Palace painted in the 18th century.

Conclusion

The *Chugugi* (rain gauge) was meteorological instruments used[12] and also invented in the 15th century in Korea. The instruments including *Supyo* (watermark) and *Punggi* (anemoscope) were also devised from the need to understand and measure the meteorological conditions scientifically. Although there are some missing data of those observations during the periods of foreign invasion, the remaining records and instruments implied that there was a systematic network for the rain in the Korean peninsula during the 15th century.

Although there are gaps in the observational record during periods of foreign invasion, the surviving data and instruments imply that standardized instruments and a systematic network for rain measurements existed in the Korean peninsula during the 15th century.

Acknowledgements

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Endnotes

[1] The *annals of Joseon Dynasty* are the annual records of the *Joseon* Dynasty (CE 1392-1910), and were written from 1413 (year 13 of the reign of *Taejong*) to 1865 (year 2 of the reign of *Gojong*). The annals comprise 1,893 volumes. The *Annals of Joseon Dynasty* are the most important primary source for studying the history of *Joseon*, with very high credibility-each king was even forbidden to read the record of his own reign, for the purpose of maintaining its independence. *Joseon* established four separate repositories to store copies of the *Annals*: *Chunchugwan* (in Seoul), *Chungju* county, *Jeonju* county and *Seongju* county. All three except the repository in *Jeonju* were burned down in the Japanese invasion (CE 1592-1598). *Joseon* printed five more copies after that war and stored them in *Chunchugwan* and the mountains *Myohang-san*, *Taebak-san*, *Odae-san*, and *Mari-san*. The *Chunchugwan* copy was lost in 1624, due to the treason of *Yi Gwal*. Part of the *Mari-san* copy was lost during the *Manchu* invasion 1638, and the surviving volumes moved to *Jeongjok-san* in 1633. The copies of the *Annals* were preserved to the end of *Joseon* Dynasty. In Japanese Colonial Period (CE 1910-1945), the Japanese moved the *Odae-san* copy to Tokyo University, but the copy was soon lost in the Great Kanto earthquake of 1923. The *Annals* written in classical Chinese were translated into modern Korean language and were digitized.

[2] The *Samguk-sagi* (History of the Three Kingdoms; BCE 57-CE 918).

[3] The *Soungwan* was the Bureau of Astronomy and Meteorology.

[4] Yuji Wada, *Scientific Memoirs of the Korean Meteorological Observatory* 1 (Chemulpo, Korea, 1910): 26-31 (In Japanese and French); Sang-woon Jeon, "On the Scientific Measuring Methods of the Rainfall Depth in the Yi-Dynasty of Korea," *J. Hist. Sci.*, Japan, 66 (1963): 49-58 (In Japanese); Sang-woon Jeon, *Science and Technology in Korea* (Cambridge, Mass.: MIT Press, 1974), 112-19; Sung-sam Kim, "Comments on the Chinese claim for the invention of rain gauges," *Korea J.* (July 1990): 22-32.

[5] Keiji Yamada, *Kankoku kagakusa* (Tokyo: Nippon Hyoron Sha Co., LTD, 2005), 483-4 (In Japanese).

[6] Sang-woon Jeon, *A History of Science in Korea* (Seoul, Korea: Jimoondang Publishing Company, 1998), 149.

[7] Sang-won Kim, "The Findings of Gongju Chugugi Data in Joseon Dynasty," *Bull. Korea Meteorol. Admin.* (Nov. 2004): 28-29 (In Korean).

[8] Wada Yuji, *Joseon Ancient observation records survey and report*, (Incheon: Joseonchongdokbu, 1917), 52-64 (In Japanese).

[9] Central Meteorological Office, 1961: *Monthly Precipitation Records (1770-1960)*. 1-15; Hyun-sook Jung, G.H. Lim, and J.H. Oh, "Interpretation of the Transient variations in the time Series of Precipitation Amounts in Seoul, Korea," *Journal of Climate* 14 (2001): 2989-3004.

[10] Wada, *Joseon Ancient observation records,* 26-27.

[11] Ibid., 51-64.

[12] John F. Griffiths, "A Chronology of Items of Meteorological Interest," *Bull. Amer. Meteorol. Soc.* 58 (1977): 1059.