American Meteorological Society
97th ANNUAL MEETING | SEATTLE

Korea Meteorological Administration

Statistical Review of Annual Precipitation at Seoul in 1778-2015

25 January 2017

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Statistical Review of Annual Precipitation
at Seoul in 1778-2015

C/O/N/T/E/N/T/S

OBJECTIVE

1 Dataset Understanding

- review two or three recorded Chukwookee (1778-1907) and modern (1908-2015) rain data of view point of historically and scientifically

2 Statistical Features

- check monthly and annual data using exploratory data analysis and graphics
- check statistical test among specific samplings for similarity and consistency

3 Variability and Trend

- investigate long-term period of annual precipitation
- evaluate the climate variation and apply socio-economic impacts in Seoul

HISTORICAL RECORDS

Chukwookee and Observing Network

- King Sejong invented Chukwookee (Korean rain-gauge) which is standardized as cylinder type rain-gauge in May
- commanded daily measurements through organized observation networks in September of 1441.
- Rain records of Royal Secrecariat (Seungjeongwon Ilgi) in 1770-1894 and Record of Daily Reflections (Ilseongnok) in 1785-1910.
- Unfortunately, rain measurement temporally quitted up on the invasion and restarted in 1770. With this reason precipitation recording data using Korean rain-gauge remains only between 1770-1907.

HISTORICAL RECORDS

Documents with Daily Weather Description

Joseon Wangjo Sillok (http://sillok.history.go.kr) [1392-1863]

- Joseon Dynasty Royal documents includes 28 Kings chronological daily records
- 1,893 books (Korea National Treasure 151, UNESCO in 1997)

Seungjeonwon Ilgi (http://sjw.history.go.kr) [1623-1907]

- The daily records written by royal secretariat of Joseon Dynasty
- 3,243 books (Korea National Treasure 303, UNESCO in 2001)

Ilseongnok (http://history.go.kr) [1752-1910]

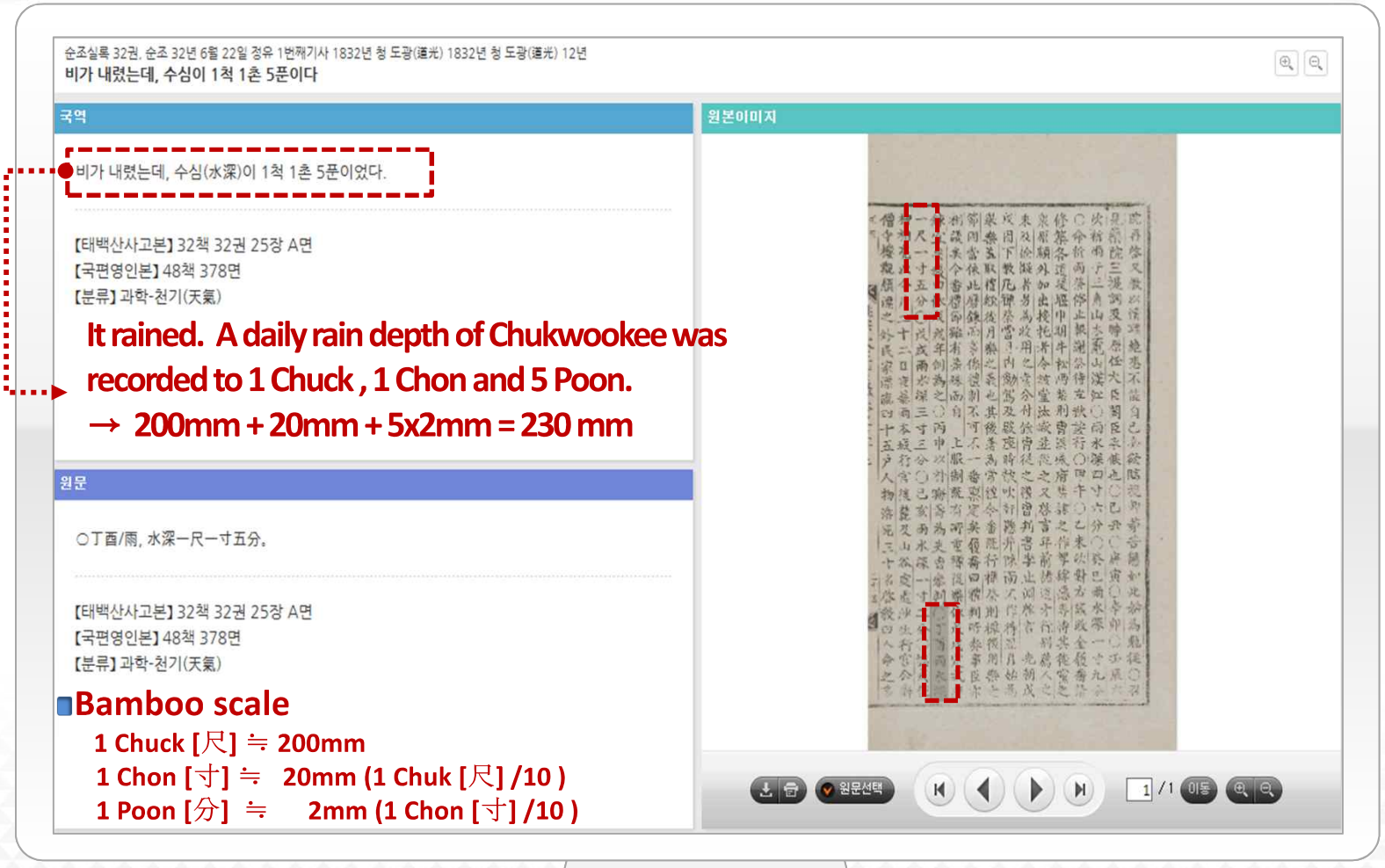
- The daily reflections from secretariats in Palace
- 2,329 books (Korea National Treasure 153, UNESCO in 2011)

Goongnaebu Ilgi [1894-1885]

- A part of Seungjeonwon Ilgi
- 5 books

HISTORICAL RECORDS

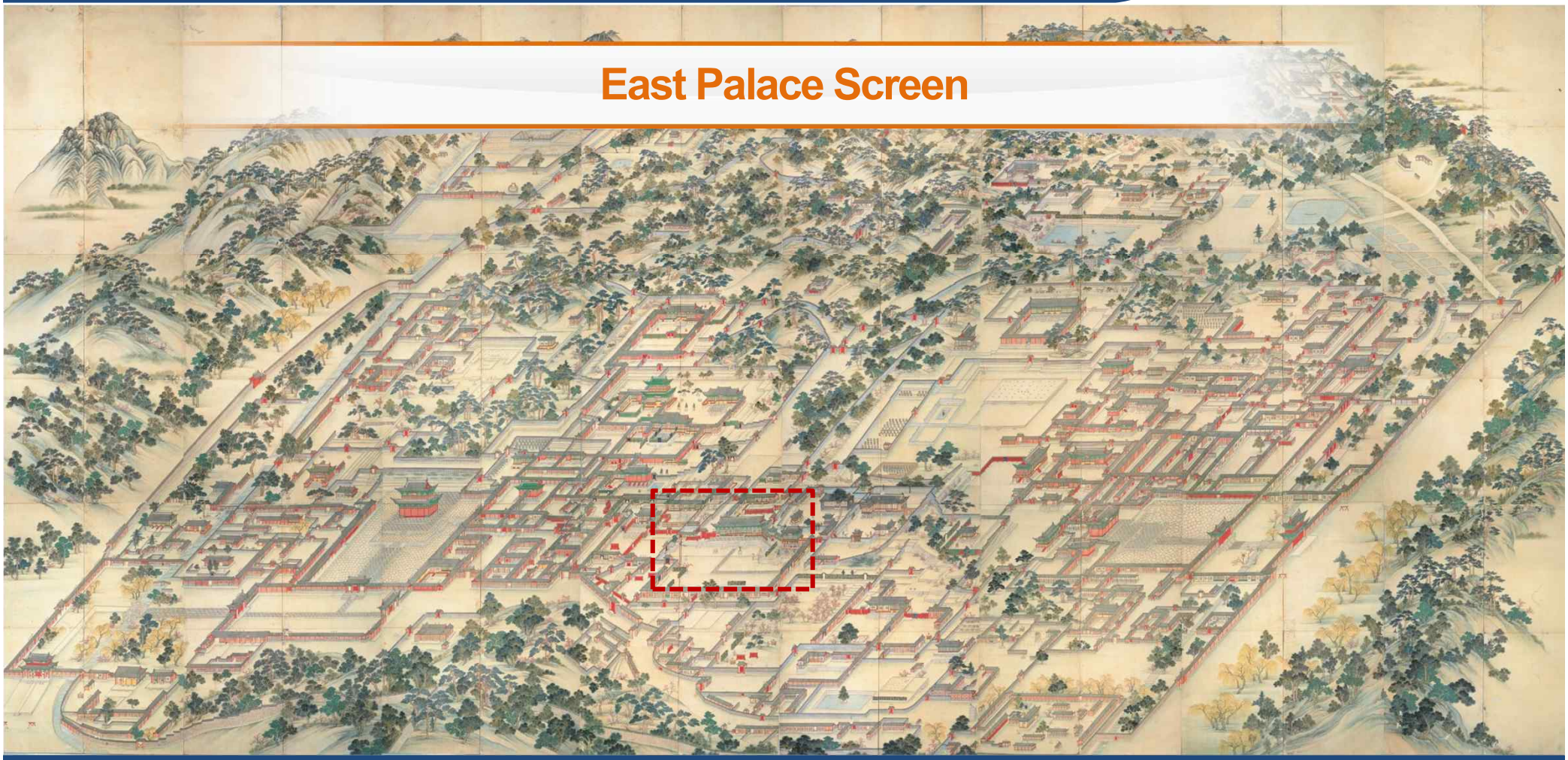
The National Institute of Korean History



Web site http://www.history.go.kr

HISTORICAL RECORDS

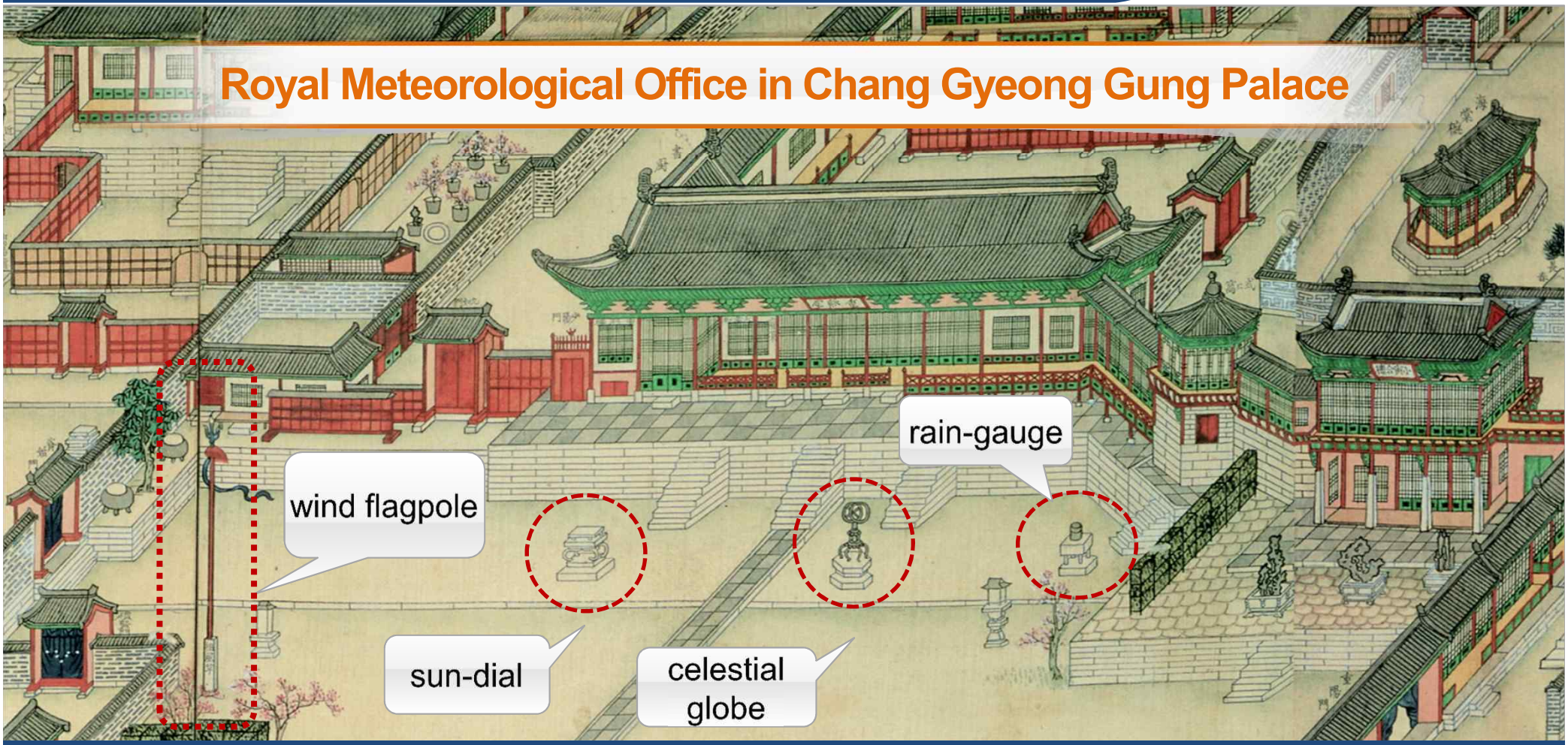
East Palace Screen



East Palace Screen (East of main Palaces [Chang Deok Gung Palace and Chang Gyeong Gung Palace], size of the screen is 567 cm × 273 cm , composed 16 pieces folding screen. It was painted by anonymous palace artists in 1824. Korean Government declared National Treasure No. 249 in 1989)

HISTORICAL RECORDS

Royal Meteorological Office in Chang Gyeong Gung Palace



Wind flagpole observed 24-directional wind direction and speed (invented in 1770). Korean Treasure No 846.
Sun-Dial observed time measurement (invented in 1434).
Celestial globe made from copper, observed celestial movement (invented in 1437). This one is portable type.
Rain-gauge is to observed rain amount in nationwide (invented in 1441).

DATASET

Wada's Version (1917)

- Constructed rain-gauge data (1770-1907) from Seungjungwon Ilgi and Ilseungnok
- Calendar system: solar (Gregorian) calendar instead of Lunar calendar
- Arakawa (1956) introduced the monthly dataset of Chukwookee

Hahn's Version (1996)

- Reanalyzed old Korean Official Document and Wada's version in 1996
- Complied Chukwookee data in eight provinces of Joseon Dynasty in 18 Century
- Calendar system: solar (Gregorian) calendar instead of Lunar calendar

Jhun's Version (1997)

- Recompiled Chukwookee dataset from Seungjungwon Ilgi and Ilseungnok
- Data Base : Converting solar calendar to luni-solar calendar and set up by daily unit

KAMC (Korean Academy of Meteorology and Climate, 2010)

- Daily precipitation data edited by the local government report of (1892-1907)
- Restoring continuous Chukwookee data for Gaksadeungnok

DATASET

Statistical data

- $Month = \sum \text{Daily Rainfall}$

$$Year = \sum_{i=1}^{n=12} \text{Month}$$

Dataset

- Period-I : Chukwookee (1770-1905)
- Period-II : Modern rain-gauge (1908-2015)

Monthly data Missing Rate

Table 1-1. Precipitation missing data and its percentage in Period-I

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Missing number	84	74	16	0	1	2	1	1	3	6	10	39
Available (%)	35.9	43.5	87.8	100.0	99.2	98.5	99.2	99.2	97.7	95.4	92.4	70.2

※ Winter : liquid water of snow is not recorded
※ First Sino-Japanese War(1894)

Table 1-2. Precipitation missing data and its percentage in Period-II

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Missing number	1	1	1	1	2	1	1	2	1	1	2	1
Available (%)	99.07	99.07	99.07	99.07	98.1	99.07	99.07	98.1	99.07	99.07	98.1	99.07

※ Missing number : Korean War

Quality Assurance

Old Korean Chukwookee (rain-gauge) data

- **Guideline to Qualifying Data**
  - WMO-No.100 regulation : collected ratio over 80% is available

- **Guideline to Detecting Outliers**
  - By exploratory data analysis (e.g., plotting boxplot)

Chk-Ⅰ $< Q_1 - 1.5(Q_3-Q_1)$ Chk-Ⅲ $< \mu - 2\sigma$

Chk-Ⅱ $> Q_3 + 1.5(Q_3-Q_1)$ Chk-Ⅳ $> \mu + 2\sigma$

※ to check extremely minimum and maximum values

Modern Rain-gauge Data

- **WMO-No. 100 regulation for data management**
- **Quality Control : range checks, temporal checks, internal consistency check etc.**
- **ISO 9001 guideline for data quality management**

Descriptive Statistics and Checking Outliers

Table 2-1. Summary of Summer precipitation statistic data and Outlier limit at Seoul

Month	Min	Q_1	Median	Mean	Q_3	MAX	SD(σ)	Chk- Ⅰ	Chk- Ⅱ	Chk- Ⅲ	Chk- Ⅳ
Period-I (Chukwookee)	156.0	508.0	660.0	741.4	879.5	2018.0	335.48	-49.25	**1436.7**	**70.4**	**1412.36**
Period-II (Rain gauge)	246.0	574.5	774.0	807.2	972.5	1784.0	292.97	-22.5	**1569.5**	**221.26**	**1393.14**
Period I+II	156.0	536.0	724.0	771.0	947.0	2018.0	318.03	-80.5	**1563.5**	**134.94**	**1407.06**

Table 2-2. Summary of annual precipitation statistic data and Outlier limit at Seoul

Year	Min	Q_1	Median	Mean	Q_3	MAX	SD(σ)	Chk- Ⅰ	Chk- Ⅱ	Chk- Ⅲ	Chk- Ⅳ
Period-I (Chukwookee)	374.0	882.0	1097.0	1150.0	1359.0	2566.0	393.5	**166.5**	**2074.5**	**363.0**	**1937.0**
Period-II (Rain gauge)	48.3	1085.0	1254.0	1320.0	1547.0	2355.0	370.4	**392.0**	**2240.0**	**579.2**	**2060.8**
Period I+II	48.3	963.0	1190.0	1228.0	1452.0	2566.0	391.7	**229.5**	**2185.5**	**444.6**	**2011.4**

① Chk- Ⅰ $< Q_1 - 1.5(Q_3 - Q_1)$ ② Chk- Ⅱ $> Q_3 + 1.5(Q_3 - Q_1)$ ③ Chk- Ⅲ $< \mu - 2\sigma$ ④ Chk- Ⅳ $> \mu + 2\sigma$

STATISTICAL ANALYSIS

Normalization

Z-scores and analysis

$$\mu = \sum_{i=1}^{n} \left(\frac{X_i}{N} \right)$$

$$\sigma = \sqrt{\sum_{i=1}^{n} (x_i - \mu)}$$

$$Z = \frac{X - \mu}{\sigma}$$

Z : Z –score μ : Mean σ : Standard deviation X : Data set

Dataset

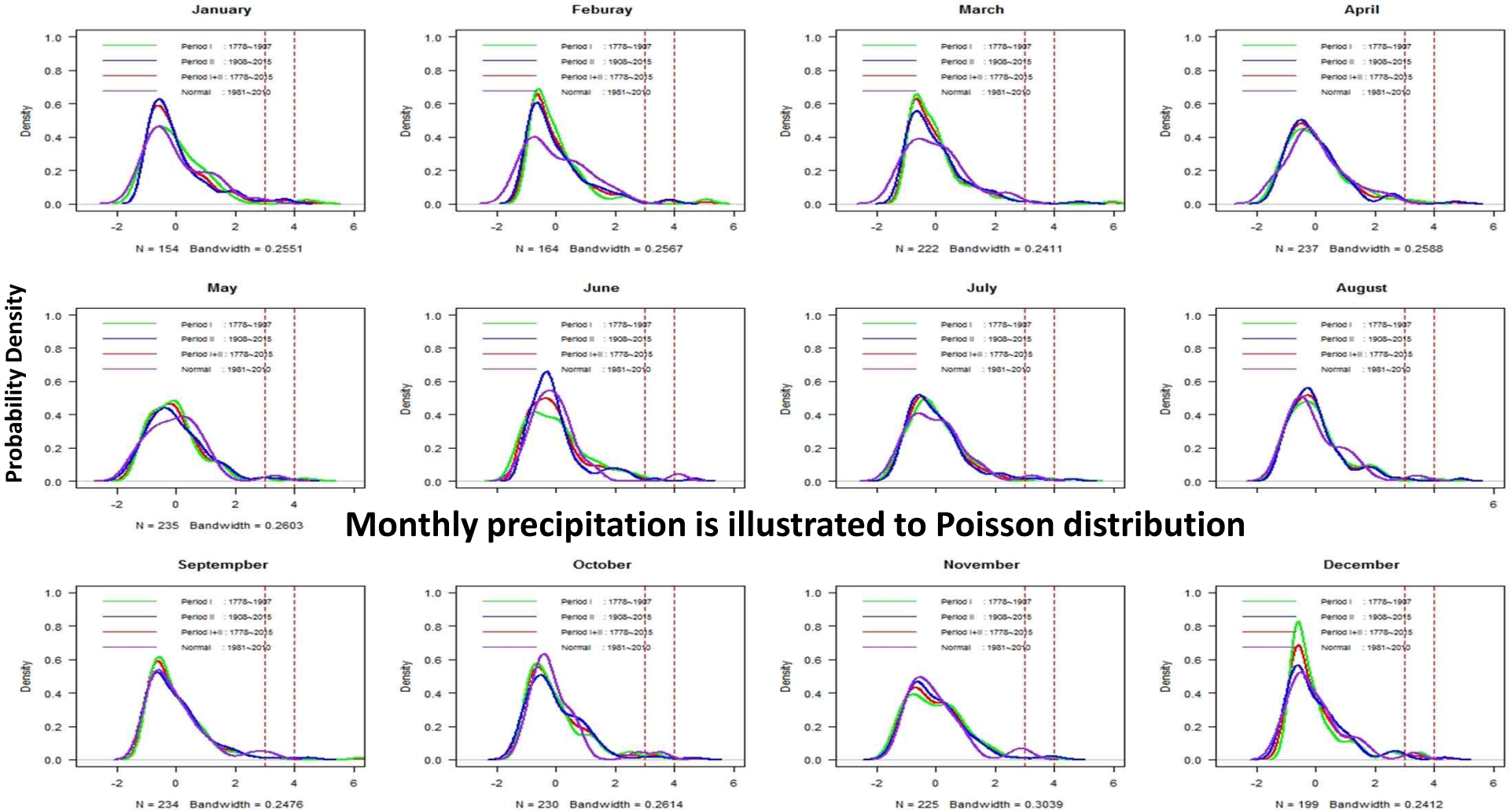
- Period I (1708-1907, Chukwookee)
- Period II (1908-2015, modern rain-gauge)
- Period III (1708-2015, Chukwookee + modern rain-gauge)
- Climate Normals (1981-2010)

Analysis

- Probability density function
- Box plot distribution

STATISTICAL ANALYSIS

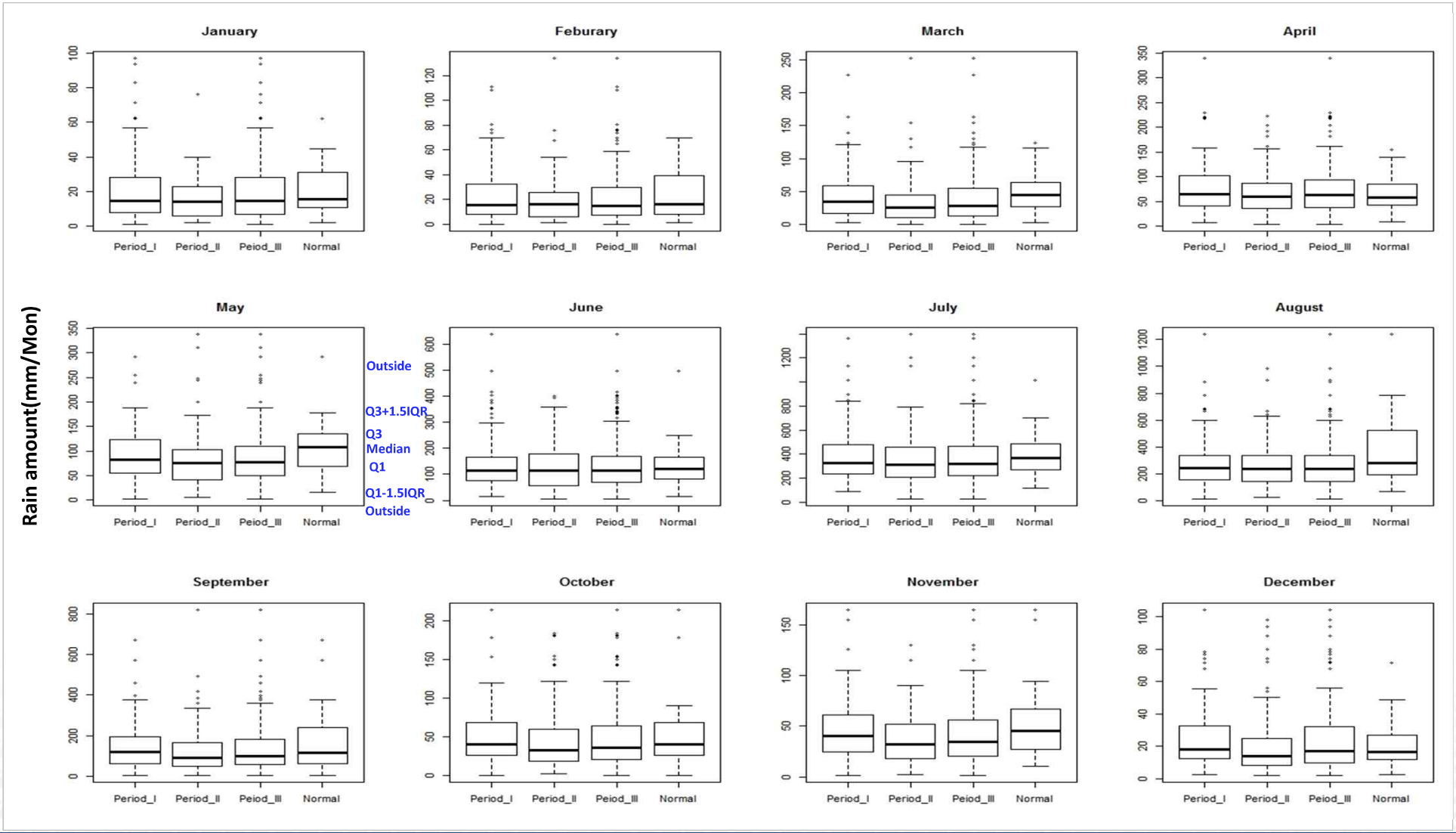
Distribution of Probability Density Function



Monthly precipitation is illustrated to Poisson distribution

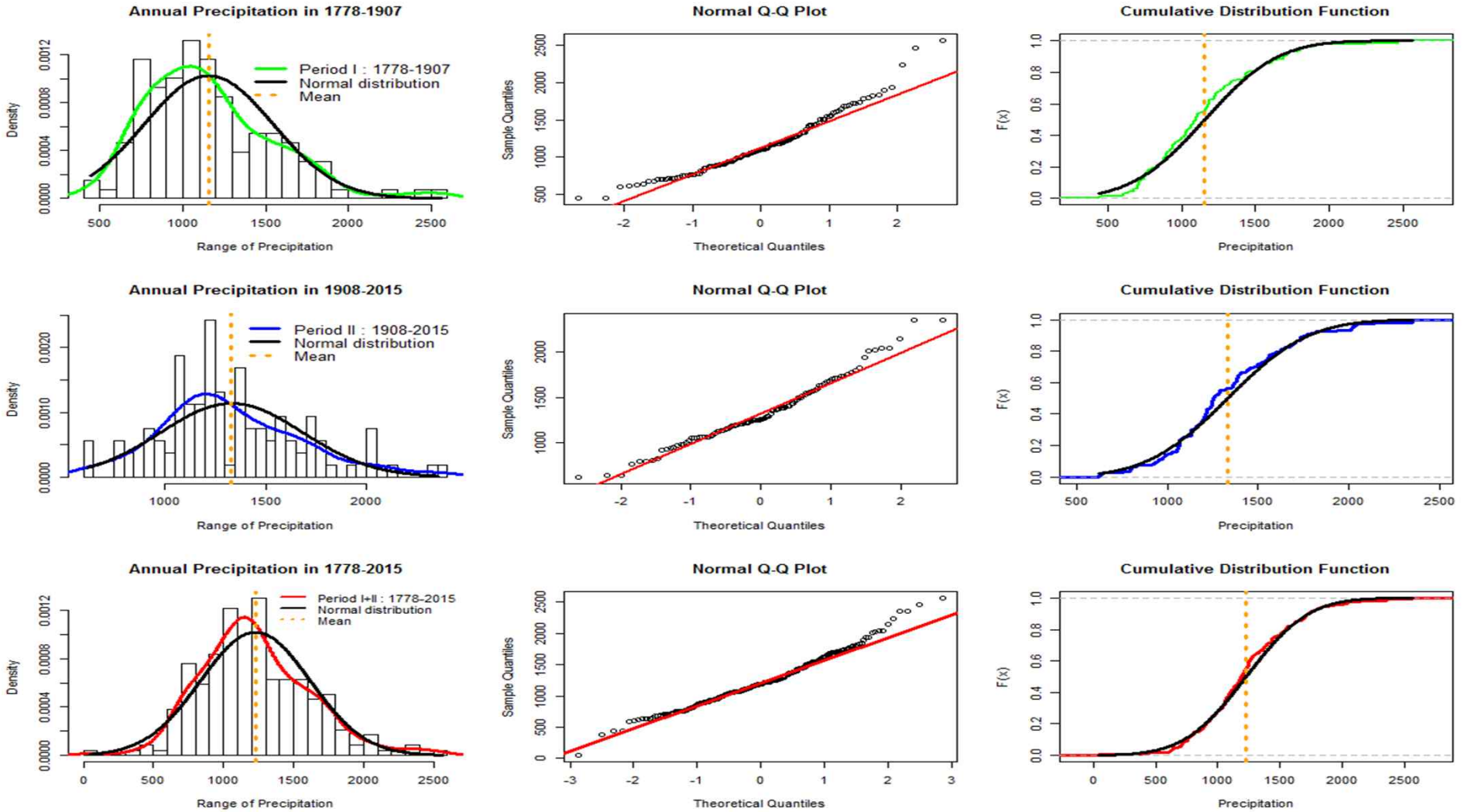
STATISTICAL ANALYSIS

Distribution of monthly precipitation



STATISTICAL ANALYSIS

ANALYSIS (histograms, Q-Q Plot, CDF)



STATISTICAL ANALYSIS

Hypothesis Testing

Hypothesis

$$H_O : \mu_{Hahn} = \mu_{Jhun} \qquad H_O : \mu_{Period-I} = \mu_{Period-II}$$
$$H_a : \mu_{Hahn} \neq \mu_{Jhun} \qquad H_a : \mu_{Period-I} \neq \mu_{Period-II}$$

Significance Level

$\alpha = 0.05$

if p - value $< \alpha\,(0.05)$ then H_o = reject

if p - value $\geq \alpha\,(0.05)$ then H_o can not reject

Test statistics

$$t^* = \frac{\overline{X}_{Period-I} - \overline{X}_{Period-II}}{\sigma(\overline{X}_{Period-I} - \overline{X}_{Period-II})} = \frac{\overline{X}_{Period-I} - \overline{X}_{Period-II}}{\sqrt{\left(\frac{S^2_{Period-I}}{\mu_{Period-I}}\right) + \left(\frac{S^2_{Period-II}}{\mu_{Period-II}}\right)}}$$

μ : mean

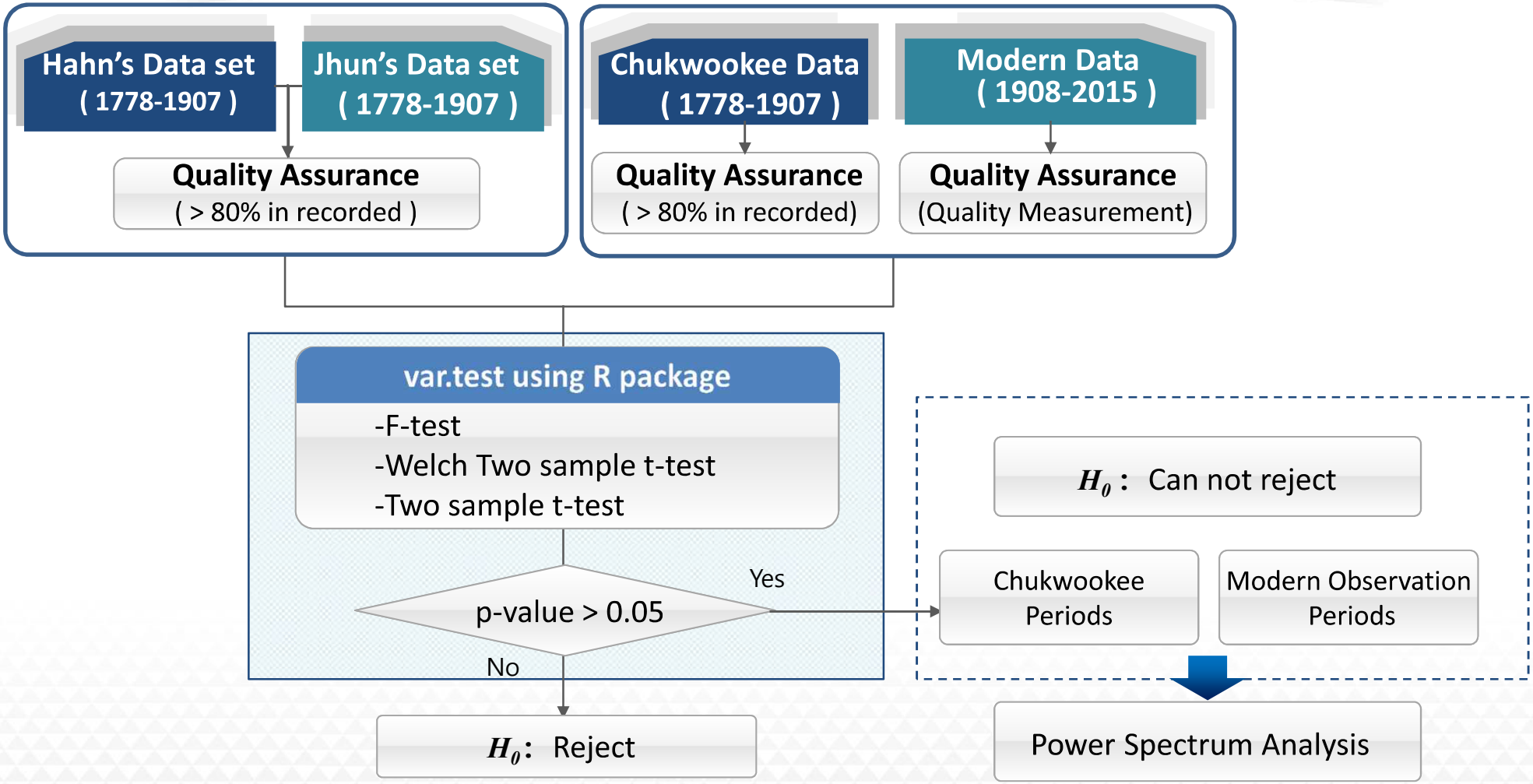
σ : standard deviation

$\overline{X}_{\text{Period-I}}$: mean of Chukwookee precipitation (1778 - 1907), Seoul

$\overline{X}_{\text{Period-II}}$: mean of modern precipitation (1908 - 2015), Seoul station

STATISTICAL ANALYSIS

Statistical Procedure



Hypothesis Testing

Table 3-1. t-test results between Hahn and Jhun dataset at Seoul

Classification	Winter(DJF)	Spring(MAM)	Summer(JJA)	Fall(SON)
T-statistic	7.020	3.4015	1.1449	-0.14113
Degree of freedom	243.89	257.96	257.53	255.95
P-value	2.187e-11	0.000776	0.2575	0.8879

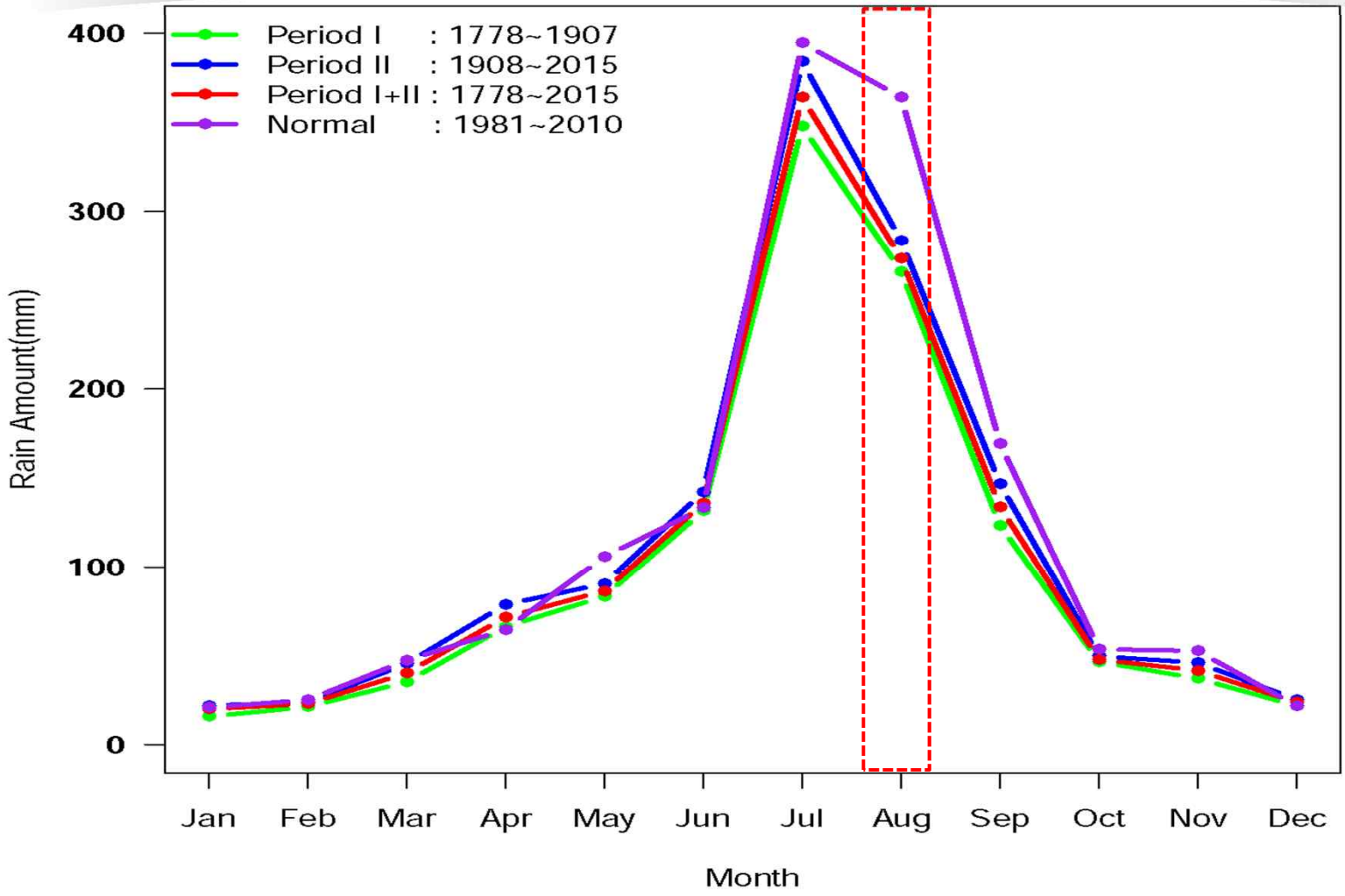
Table 3-2. t-test results between Period-Ⅰ and Period-Ⅱ dataset at Seoul

Classification	Winter(DJF)	Spring(MAM)	Summer(JJA)	Fall(SON)
T-statistic	8.4702	2.9417	1.611	2.407
Degree of freedom	214.58	229.35	234.16	226.890
P-value	3.894e-15	0.0035	0.1085	0.016

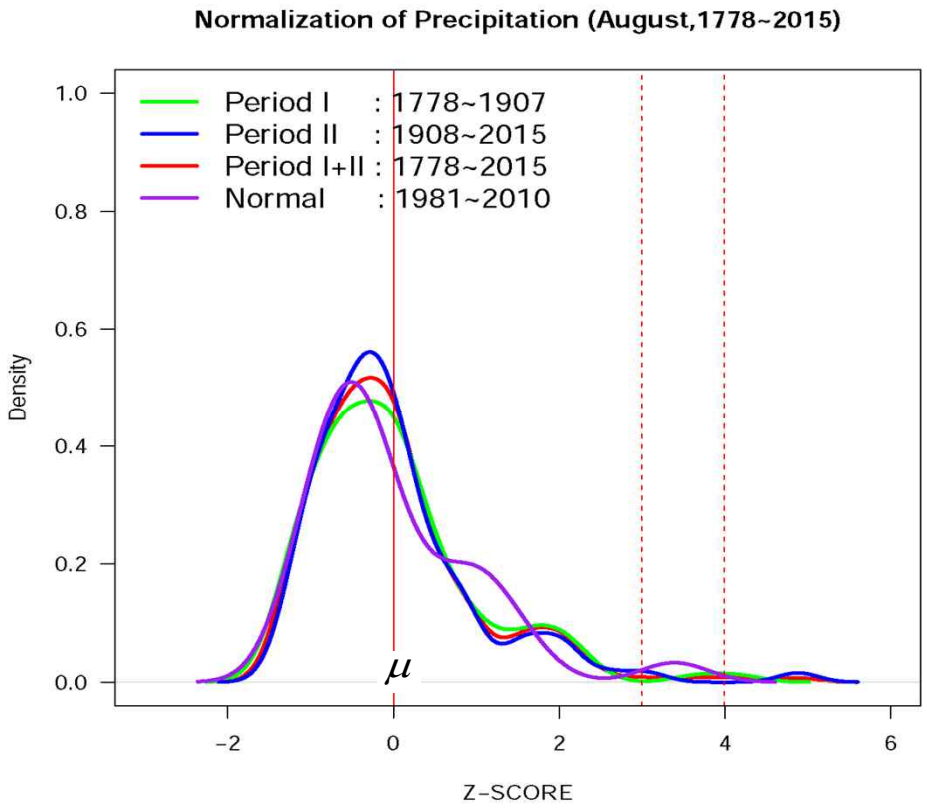
※ Sampling of summer show large p-value , statistically the two samples are similar

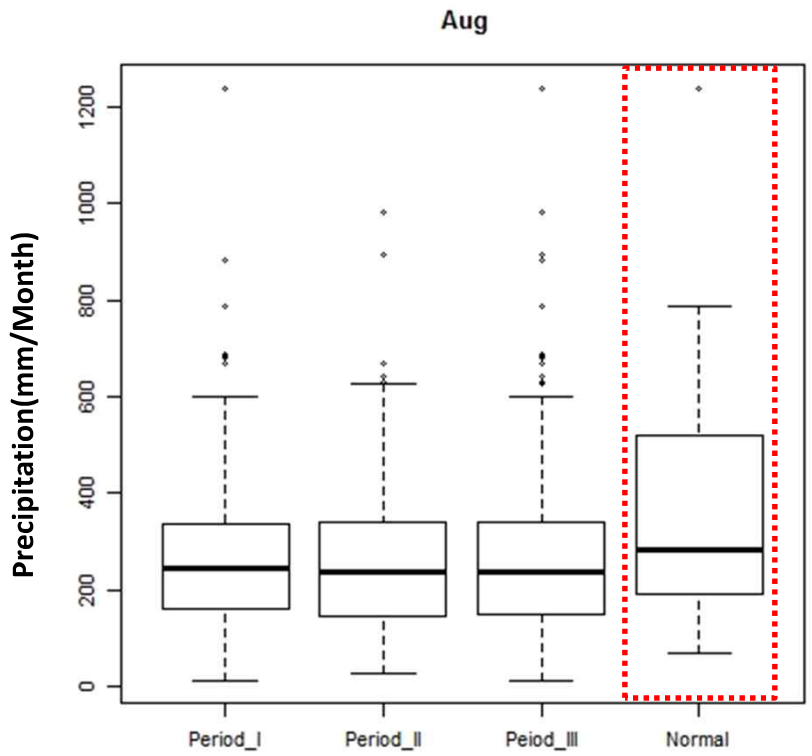
STATISTICAL ANALYSIS

Monthly Mean Precipitation Amount at Seoul



STATISTICAL ANALYSIS

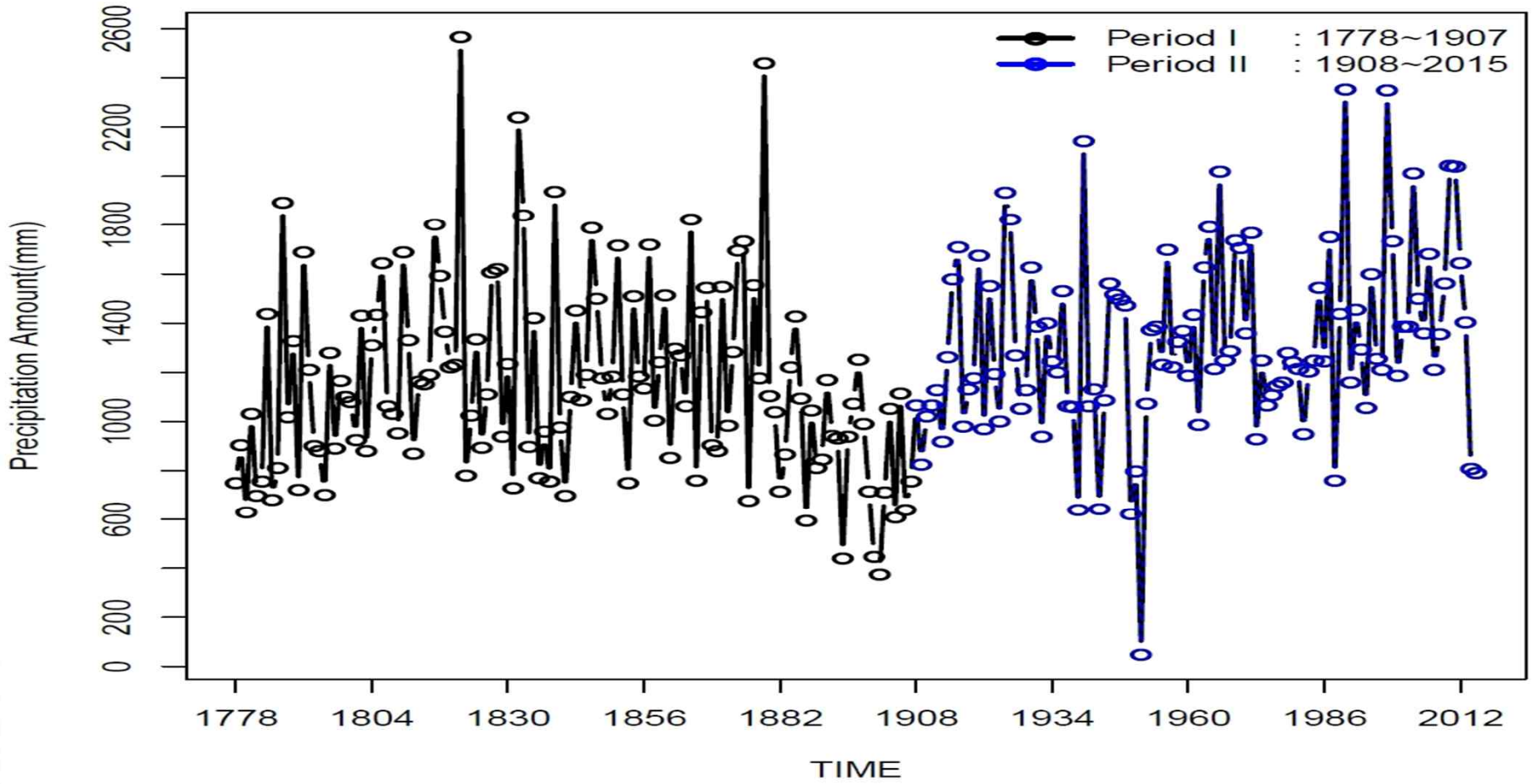




Classification	Min	Q_1	Median	Mean	Q_3	Max	SD
Climate normal (1981-2010)	68.2	194.4	284.2	364.2	501.1	1238.0	257.4
Period - II (1908-2015)	13.4	159.3	243.3	283.4	336.7	1238.0	195.4
Period - I (1778-1907)	26.0	147.3	238.0	265.2	336.6	982.0	171.6

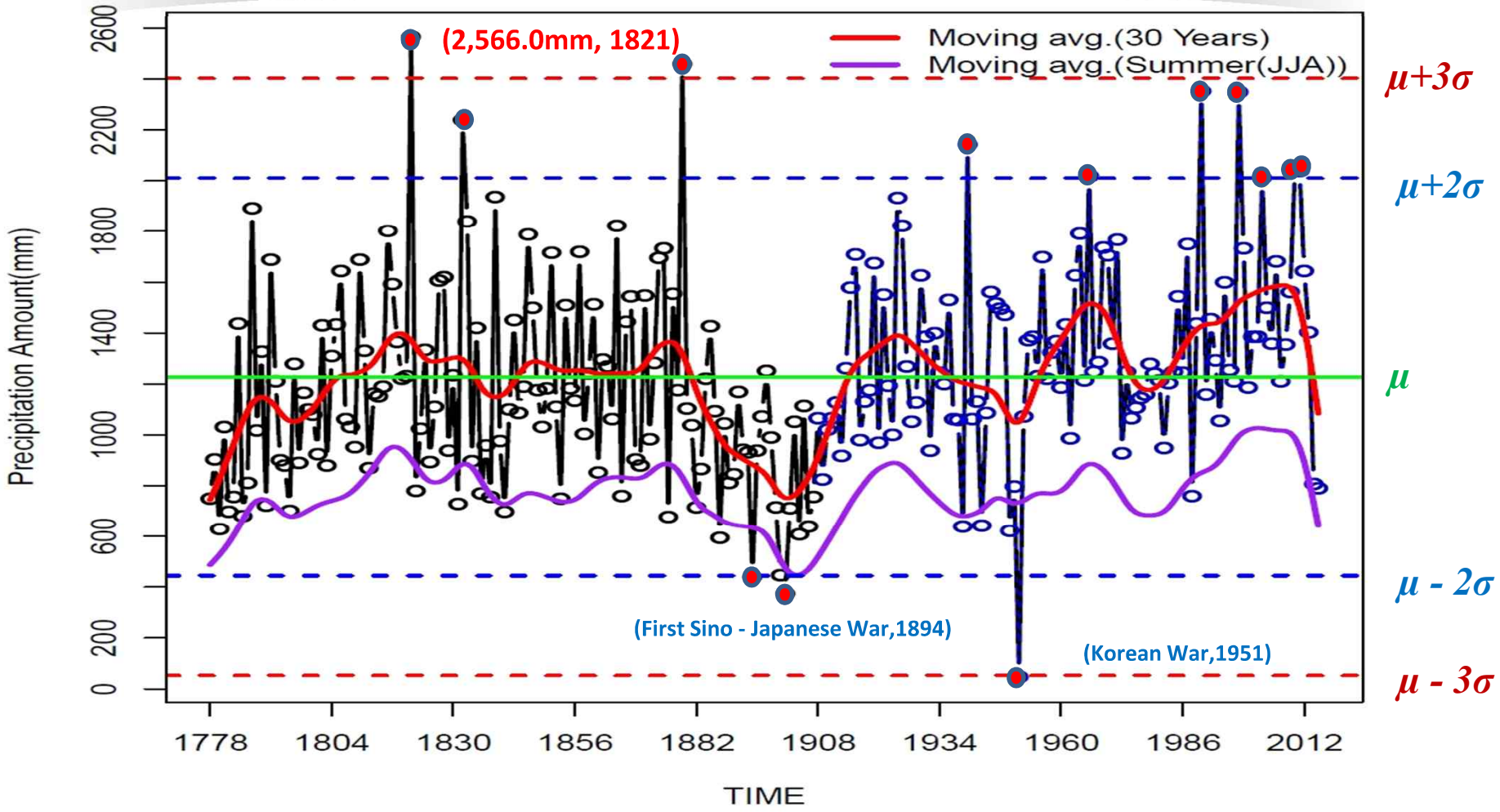
STATISTICAL ANALYSIS

Annual Precipitation Amount for 1778-2015



STATISTICAL ANALYSIS

Annual Precipitation Amount for 1778-2015



STATISTICAL ANALYSIS

Extremely Maximum and Minimum Annual Rainfall in Top 10 for 1778-2015

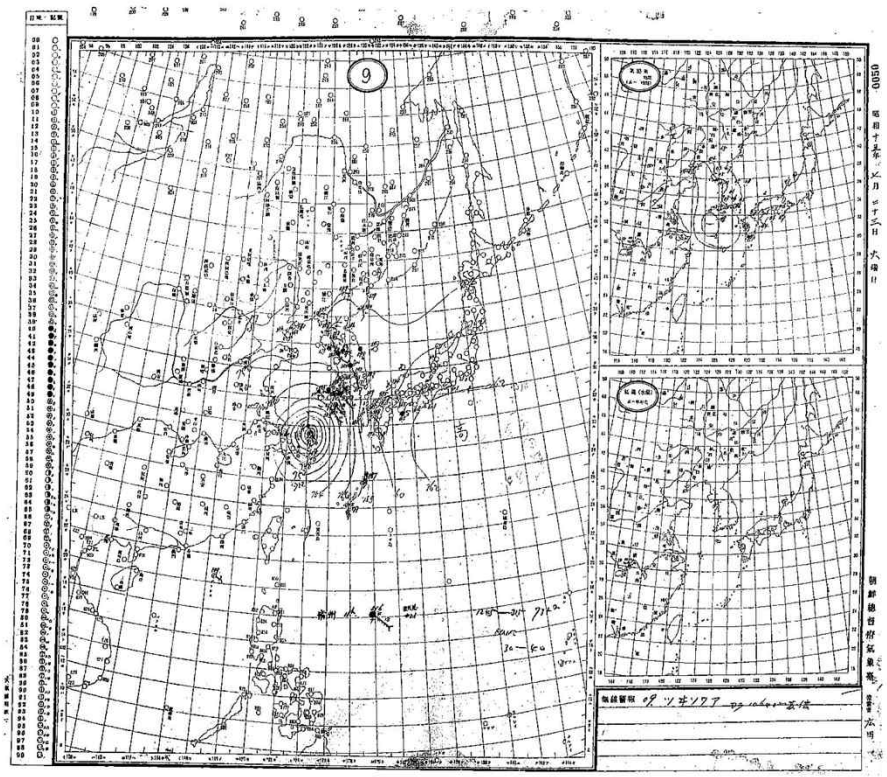
Rank	Above Mean + 2*Sigma (>= 2011.4 mm)	Below Mean - 2*Sigma (<= 461.8 mm)
1st	2,566.0 (1821) : flooded houses(5,805), drowned person(251)	48.3 (1951, Korean War)
2nd	2,462.0 (1879) : flooded houses(2,351), farmland, Korea	374.0 (1901)
3rd	2355.5 (1990)	442.0 (1894, First Sino - Japanese War)
4th	2349.1 (1998)	446.0 (1900)
5th	2242.0 (1832) : flooded houses(10,837), drowned person(357)	594.0 (1887)
6th	2145.1 (1940)	608.0 (1904)
7th	2043.5 (2011)	623.5 (1949)
8th	2039.3 (2012)	630.0 (1780)
9th	2018.9 (1966)	638.7 (1939)
10th	2012.0 (2003)	640.0 (1906)

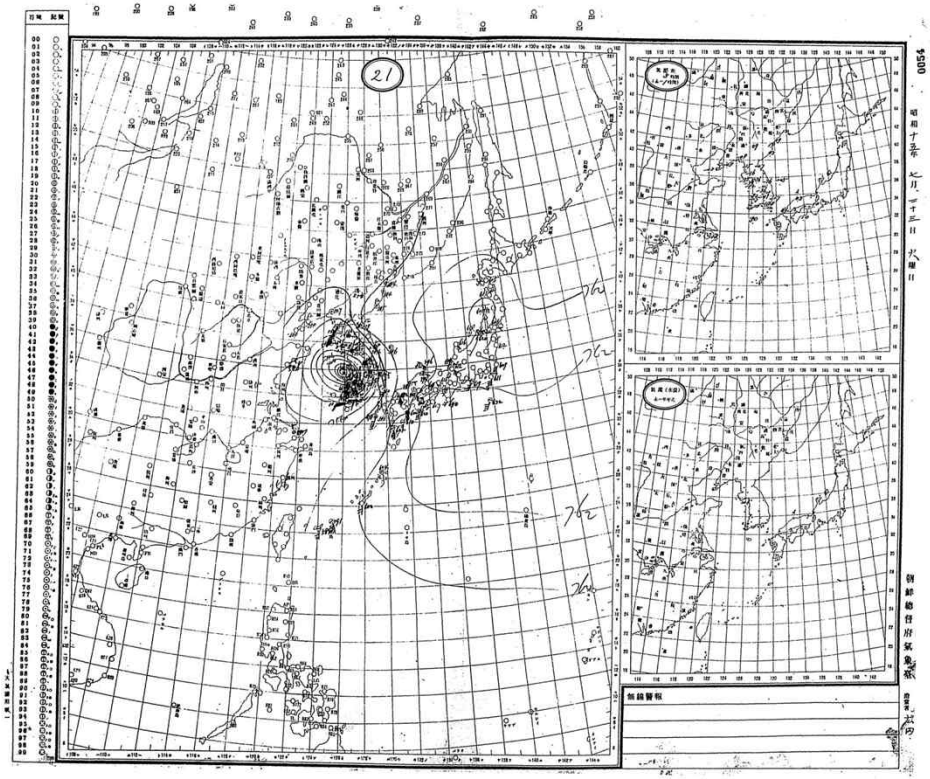
Classification of Extreme Rainfall Events

Classification	Direct TC	Indirect TS, TD	Chang-ma front	Stationary front	Meso-cyclone	Reference
June	1		6		4	
July	4		7		3	
August	2	2		2	5	
September	2	2			3	
Total	9	4	13	2	15	

STATISTICAL ANALYSIS

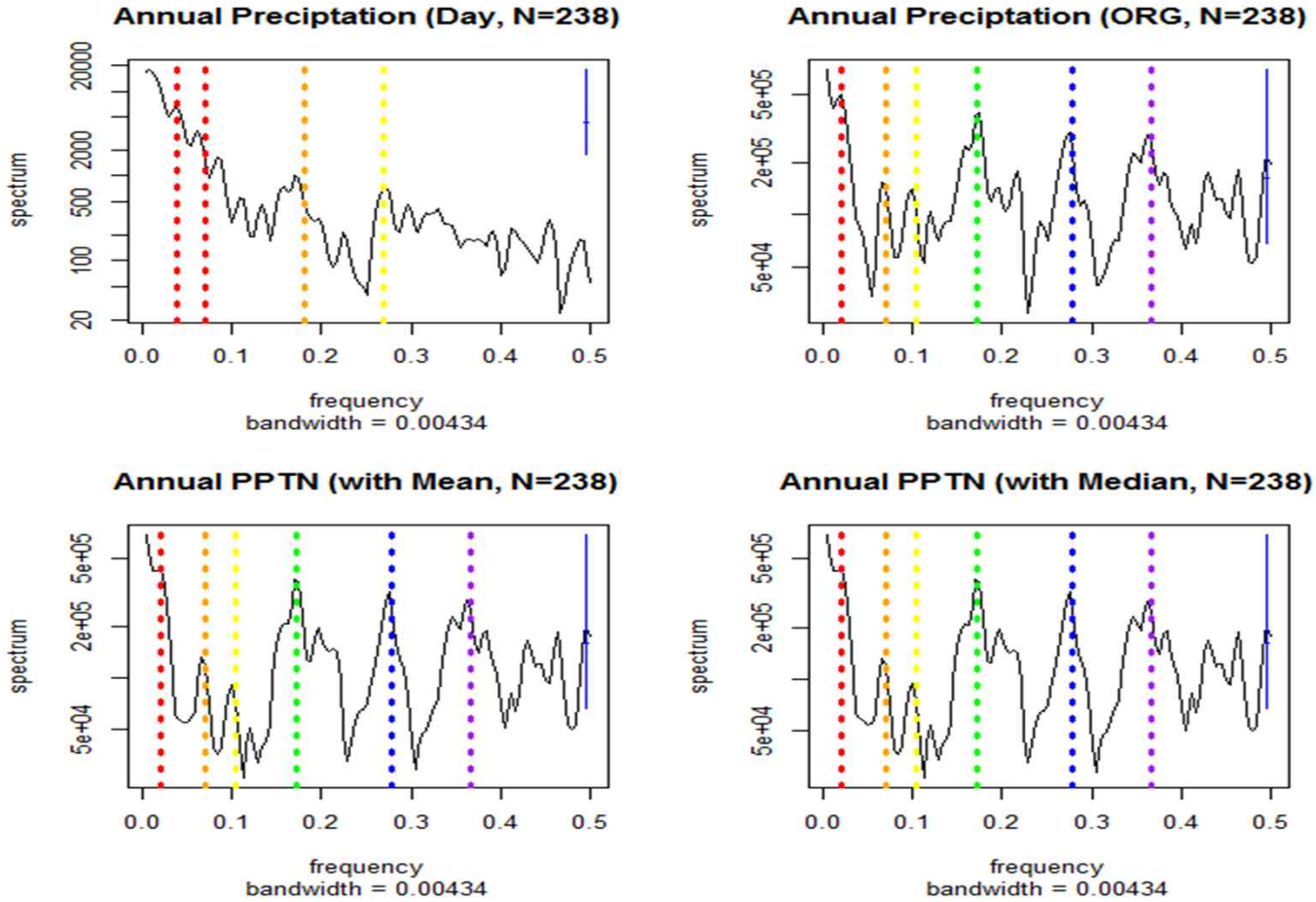
Surface Weather Chart (1940.07.23.00UTC-12UTC)





STATISTICAL ANALYSIS

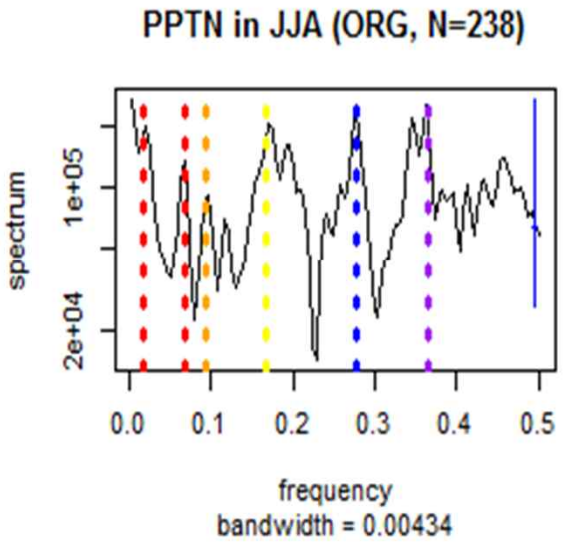
Power Spectrum Analysis of Annual Precipitation at Seoul for 1778-2015

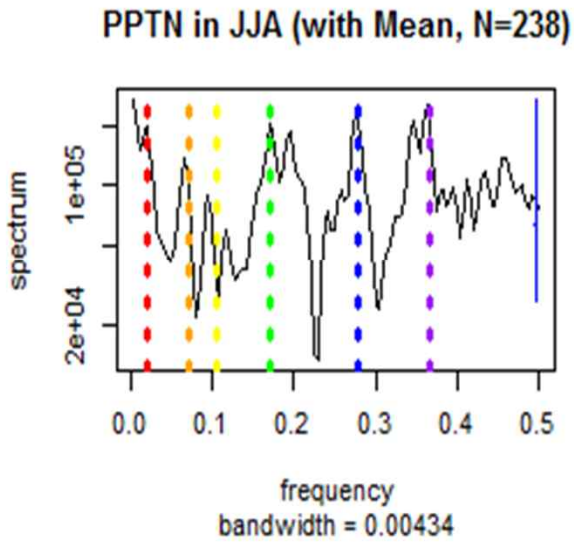


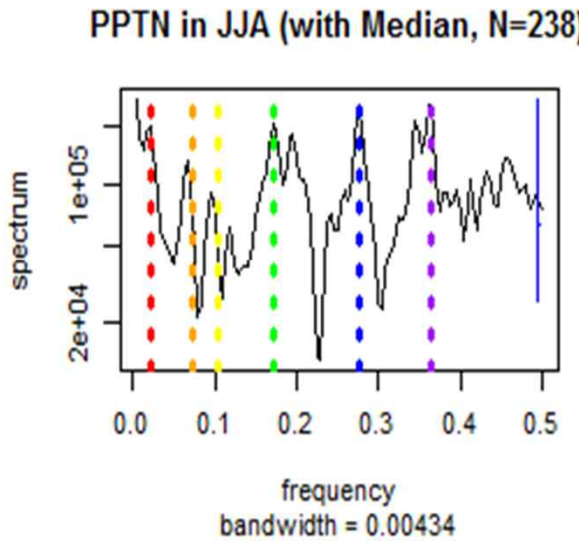
5-year (red), 17-year (orange), 25-year (yellow), 41-year (green), 66-year (blue) and 87-year (purple) cycles

STATISTICAL ANALYSIS

Power Spectrum Analysis of Summer (JJA) Precipitation of Seoul for 1778-2015







※ Using Mean and Median during Korean War(1951)

Periods are analyzed with 5-year, 17-year, 25-year, 41-year, 66-year and 87-year cycles
These set of periods are approximately similar with annual ones

CONCLUSION

Summary and Future Plan

I Summary

- shown to annual and seasonal precipitation in near-normal distribution of, while monthly precipitation in poisson distribution.
- extracted long-term periods by annual base of rain in more than 230 years long ex) about 5-year, 17-year, 25-year, 41-year, 66-year and 87-year cycles
- analyzed extreme value cases associated with chang-ma, meso-cyclone, and tropical cyclone events
- investigated five events of top 10 cases (more than 2 sigma) and larger standard deviation value after 1980's

2 Future Plan

- using proxy data (e.g., tree-ring data) for compensation of missing data treatments and previous (before 1770's) data estimations

Rain Observing in Royal Meteorological Office in Joseon Dynasty

Korea Meteorological Administration

Statistical Review of Annual Precipitation at Seoul in 1778-2015

Thank You