JP2.5. CHANGES OF SEASONALITY AND PHENOLOGICAL CYCLES IN SOUTH KOREA

Gwangyong Choi*[1], Won-Tae Kwon[2], and David A. Robinson[1]

[1]Rutgers The State University of New Jersey, Piscataway, New Jersey
[2]Meteorological Research Institute, Korea Meteorological Administration, Seoul, Korea

1. INTRODUCTION

Global and regional temperature fluctuations over the past century have included, among others, decreasing diurnal temperature ranges, and seasonally increasing temperatures, particularly in meteorological winter (IPCC, 2001). So too has the timing of seasonal onset and ending changed in some locations. This has not only been recognized in terms of temperature but also with shifts of timing of fauna appearance (i.e. Roy et al, 2003) and floral blooming (i.e. Fitter et al, 2002). The purpose of this research is to examine whether there has been a significant change of seasonal timing in temperature and flora during the 20th century in South Korea.

2. DATA AND METHODS

Korea, located in the middle latitudes of northeast Asia, has four distinct seasons. Since the early 20th century, the Korea Meteorological Administration has documented climate conditions through measurement of temperature, precipitation and other atmospheric variables. So too have phenological data been collected. Our research focuses on data collected between 1920 and 1999 in major cities of Korea (Figure 1). : Gangneung (37°45′N, 128°54′E), Seoul (37°34′N, 126°58′E), Incheon (37°28′N, 126°38′E), Daegu (35°53′N, 128°37′E), Jeonju (35°49′N, 127°09′E), and Busan (35°06′N, 129°02′E). Daily maximum, minimum, and mean temperatures are analyzed to derive four seasons based on thresholds suggested by Lee (1973) (Table 1). Choi and Kwon (2002) report a significant warming trend during the study period, thus here, observations from the 1920s will be compared with those from the 1990s.

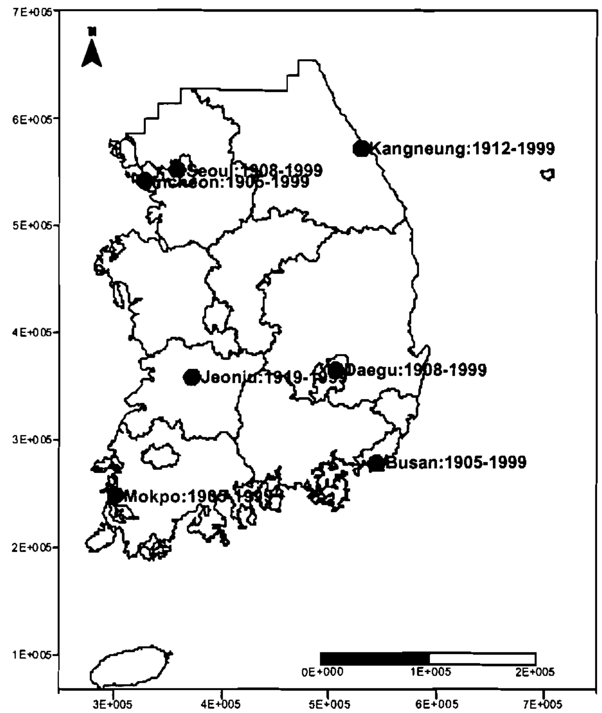

Figure 1 Location of weather stations and long-term data period used in this research

The flowering times for azalea, forsythia, and pear are compared with daily temperatures. The species of flowers analyzed are popular ones across Korea. Significant changes in flowering dates were observed in the 1990s compared to the pre 1990 interval, thus flora results will be discussed in terms of these intervals. In terms of climate components relevant to phenological cycles, temperatures in February and March are known to strongly impact the onset of phenophase for forsythia and azalea. Additionally, sunshine and rainfall also influence the determination of flowering time(http://www.weekend21.com/season/spring/2003 flower.hwp). Here we explore the development of a flowering prediction model by using the trends of daily maximum, minimum and

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* *Corresponding author address*: Gwangyong Choi, Rutgers The State University of New Jersey, Geography Department, Piscataway, NJ, 08854; e-mail:tribute@eden.rutgers.edu

Table 1. Standards used to divide the seasons in South Korea (Lee, 1973)

Seasonal Change	Component	Threshold
From Winter to Spring or from Fall to Winter	Daily Mean Temperature	5°C
	Daily Minimum Temperature	0°C
From Spring to Summer or from Summer to Fall	Daily Mean Temperature	20°C
	Daily Maximum Temperature	25°C

mean, temperatures in these and the adjoining months of January and April. Frequencies of frost days (daily minimum temperature below freezing) and ice days (daily maximum temperature below freezing) prior to flowering are used as independent variables in linear models to predict the flowering timing of a dependent variable.

3. CHANGES OF SEASONALITY

According to the analysis of daily temperatures based on thresholds of seasonality, compared to the 1920s, in the 1990s spring and summer started earlier in the year by 16-23 days and 7-13 days respectively, while autumn finished later by 6-26 days (Figure 2a). Except for Busan, which is affected by the warm ocean, spring in the 1920s started on March 18-23 in the southern and central region of the Korean Peninsula, while vernal onset in the 1990s began on February 28-March 6. The onset date of summer also changed from June 9-17 in the 1920s to May 30-June 9 in the 1990s. On the other hand, autumn started on September 7-11 in the 1920s compared with a later onset on September 9-18 in the 1990s. In addition, winter onset was also delayed, moving from November 10-24 in the 1920s to November 19-December 5 in the 1990s. As a result, the period of winter in the 1990s was 22-49 days shorter than in the 1920s, while spring and summer became longer by 6 – 16 days (Figure2b).

(a) (b)

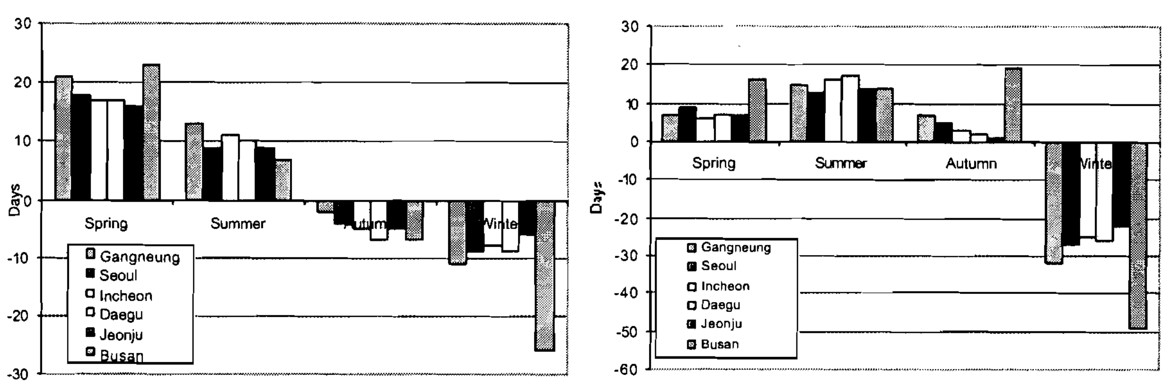

Figure 2. Changes in (a) onset date and (b) length of each season between the 1920s and the 1990s in South Korea

4. CHANGES OF PHENOLOGICAL CYCLES

Time series of forsythia flowering dates since the 1920s in six regions of South Korea are shown in figure 3. In these time series, a change pattern of roughly a clockwise spiral shape is detected, meaning the initial flowering has become earlier in recent decades. Forsythia flowering dates in the 1990s were 6 days earlier than the 1920-89 average (Table 2). Prior to the 1990s, initial forsythia flowering was on approximately March 30, while in the 1990s, flowering could be detected around March 24. Azalea also flowered earlier by 8 days in the 1990s than for the pre-1990 period. Azalea flowering occurred roughly on April 3 earlier in the 20^{th} century, but on March 26 in the 1990s. Pears flowered 4 days earlier in the 1990s, changing from April 12 to April 8. Thus it appears that early bloomers show the greatest change.

A multiple regression model was constructed to predict the flowering date by using the number of Ice days (ID) and Frost days (FD) occurring since January 1 and before flowering. Resulting equations include:

$$\text{Forsythia day} = 63.63 + 0.36\ ID + 0.26\ FD$$
(R-square: 0.72)

$$\text{Azalea day} = 65.13 + 0.41\ ID + 0.15\ FD$$
(R- square: 0.71)

$$\text{Pear day} = 79.49 + 0.28\ ID + 0.48\ FD$$
(R-square: 0.73)

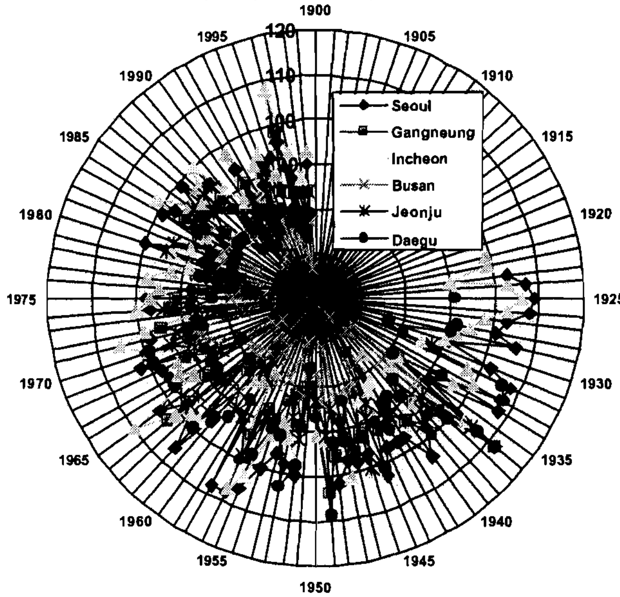

Figure 3. Forsythia flowering in South Korea (1920-1999). Data are plotted as days past January 1

Table 2. Flowering dates before and after 1990. Average values are days since January 1, standard deviations (SD) and differences in days

Species	Region	Pre-1990		Post-1990		Difference
		Average	SD	Average	SD	
Forsythia	Gangneung	88	8	86	6	-2
	Seoul	98	8	88	7	-10
	Incheon	94	7	93	7	-1
	Daegu	89	9	78	4	-11
	Jeonju	89	8	85	6	-4
	Busan	78	6	74	4	-4
	Korea	89	10	84	8	-6
Azalea	Gangneung	91	9	88	7	-3
	Seoul	99	9	85	8	-14
	Incheon	98	6	93	7	-4
	Daegu	92	9	85	6	-6
	Jeonju	93	7	87	6	-6
	Busan	86	9	77	7	-9
	Korea	93	9	86	8	-8
Pear	Gangneung	101	7	98	6	-3
	Seoul	110	5	104	7	-6
	Incheon	111	5	109	5	-3
	Daegu	98	6	92	6	-6
	Jeonju	103	5	100	6	-3
	Busan	90	6	87	4	-3
	Korea	102	9	98	9	-4

5. CONCLUSOIN

Twentieth century fluctuations of seasonal onset and ending dates as defined by temperature, and initial spring flowering of forsythia, azalea and pear were examined over South Korea. Results can be summarized as follows:

1) The onset of spring in the 1990s was 6-23 days earlier than in the 1920s. As result of this and a later onset of winter, the period of winter in the 1990s was 22-49 days shorter than in the 1920s.

2) Spring flowering for all flora species was earlier in the 1990s than in previous decades by 4 to 8 days.

Using prediction models should prove beneficial to decision makers scheduling flower festivals, to those forecasting domestic fruit production, and to those interested in the timing of allergen releases. Future studies will be geared toward enhancing these models and to determining the impact of 20th century urbanization on the results found in this study.

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